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Searching for a downward spiral? Soil erosion risk, agro-forest landscape and socioeconomic conditions in Italian local communities

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ABSTRACT

Soil erosion is a common form of land degradation in Europe concentrating on sloping rural areas. Consequences of soil erosion include the alteration of the long-term balance between ecosystem functioning and socio-ecological systems. Although it was hypothesized that rural areas with specific environmental (soil, climate, vegetation) and territorial attributes (economic marginality and poor accessibility) are more exposed to soil erosion risk, less information are available on the spatial link with various socio-spatial, productive, cultural and political attributes of local communities, spanning from unemployment to subsidence agriculture, from quality of life to water management, from poverty to economic backwardness. Taken together, these factors may trigger a downward spiral leading to land degradation. The present study explores, on a municipal scale in Italy, the spatial relationship between an index of soil erosion risk and 133 indicators describing six research domains. Exploratory data analysis based on non-parametric inference, principal components analysis and hierarchical clustering was carried out with the aim to profile municipalities exposed to high risk of soil erosion and to identify a restricted number of factors possibly determining a downward spiral towards soil erosion and land degradation. Results indicate that the socioeconomic profile of risky areas in Italy is characterized by specific rural development attributes and defined productive structure and socio-spatial characteristics representing a possible target for mitigation policies. Multi-factor studies investigating the influence of the local socioeconomic context on soil erosion may contribute to improve the effectiveness of national soil conservation strategies.

Introduction

The soil plays a key role in the process of desertification in dry and semi-arid land, especially in cases where soil depth, necessary to sustain plant roots and to store water and the nutrient elements, is too small (Rubio and Bochet, 1998; Basso et al., 2000; Geist, 2005). While soil erosion is a natural process essential for soil formation, most concerns are related to accelerated erosion, where the natural rate has been increased mostly by human activity (Almansa et al., 2012). Soil erosion by water is a widespread problem throughout Europe and involves detachment of material by raindrop impact and flow traction (Panagos et al., 2012a). Runoff is the most important driver of severe soil erosion and therefore processes that influence runoff play an important role in any analysis of erosion intensity (Panagos et al., 2014a). By removing the most fertile topsoil, erosion reduces soil productivity and, where soils are shallow, may lead to an irreversible loss of natural farmland. Even where soil depth is good, loss of the topsoil is often not conspicuous but nevertheless potentially damaging (Montanarella, 2007). Severe erosion is also associated with the development of temporary or permanently eroded channels or gullies (Costantini and Dazzi, 2013). The soil removed by runoff, for example during a large storm, accumulates below the eroded area possibly causing damages to buildings and infrastructures (Volk et al., 2010).

The main causes of soil erosion are inappropriate agricultural practices, deforestation, overgrazing, forest fires and construction activities. Erosion rate is very sensitive to climate, land-use and conservation practices at farm level (Montanarella, 2007). The Mediterranean region is prone to soil erosion because it is subject to long dry periods followed by erosive rain falling on generally steep slopes with fragile soils (Conacher and Sala, 1998). Changes in climate regimes and landscape transformations observed in the area

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since World War II exacerbated this process (Salvati et al., 2013). This contrasts with other European regions, such as North-Western and central Europe, where soil erosion is locally less severe because rain falling on mainly gentle slopes is evenly distributed throughout the year and, consequently, the area affected by erosion is restricted to sensitive soils (Volk et al., 2010). In parts of the Mediterranean region, erosion has reached a stage of irreversibility and in some places erosion has practically ceased because there is no more soil left. With a very slow rate of soil formation, any soil loss of more than 1 t ha^{-1} $year^{-1}$ can be considered as irreversible within a time span of 50–100 years (Millennium Ecosystem Assessment, 2005).

Despite soil erosion is regarded as a major cause of desertification and a serious form of soil degradation in Europe and primarily in the Mediterranean region (Montanarella, 2007; Helldén and Tottrup, 2008; Imeson, 2012), the latent relationship between rural development, local communities and the territorial context was explored in relation to the degree of soil erosion only in specific cases and especially on a local scale using indirect approaches (Kok et al., 2004; Iosifides and Politidis, 2005; Wilson and Juntti, 2005; Patel et al., 2007). By assessing the role of factors shaping the risk of desertification at the global scale, Kosmas et al. (2014a) identified some socio-demographic and institutional variables influencing the risk of soil erosion in a non-linear way. Moreover, Kosmas et al. (2014a,b) indicated specific drivers of land abandonment possibly linked with soil erosion at the continental scale. By developing an in-depth local-scale analysis, Corbelle-Rico et al. (2012) corroborated Kosmas and co-workers' results. However, all these studies have dealt with specific territorial contexts and the description of the socioeconomic conditions supposed to influence soil erosion was based on a restricted set of indicators. Boardman et al. (2003) reviewed the main socioeconomic factors involved in soil erosion at the European scale and Imeson (2012) debated on the effect of selected drivers on land degradation providing evidence in line with what found by Kosmas et al. (2014a). Almansa et al. (2012) introduced an original approach to estimate the potential costs of soil erosion in the Mediterranean region. Finally, Volk et al. (2010) and Barbayiannis et al. (2011) proposed operational frameworks informing soil conservation policies with special focus on erosion risk.

In a period of rapid variations in climate, soil, vegetation and land-use due to global change, revised agricultural policies and changing international market forces (Lambin and Meyfroidt, 2010; Romm, 2011; Abu Hammad and Tumeizi, 2012; Salvati and Carlucci, 2013), it is also important to assess the state of soil erosion at both continental and regional level, using objective methodologies. Candidate approaches must allow the assessment of erosion to be repeated as conditions change, or to explore the broad scale implications of prospective global or European-wide changes in land-use (Meusburger et al., 2012). The results of applying such a methodology can also provide estimates of the overall costs attributable to erosion under present and changed conditions (Almansa et al., 2012), and objectively identify areas where more detailed study is needed and the application of remedial action is imperative (Volk et al., 2010). Different modelling approaches were introduced in the last two decades to assess actual soil erosion rate and erosion risk in Europe including USLE, PESERA, MESALES and G2, among others (Le Bissonnais et al., 2002; Kirkby et al., 2013; Karydas et al., 2014; Panagos et al., 2014b). Moreover, data for soil erodibility are available at European level (Panagos et al., 2012b). In Italy, a national soil erosion map was prepared by the Joint Research Centre (Ispra) and the European Soil Bureau and provides detailed spatial data for the evaluation of soil erosion. The study is based on the Universal Soil Loss Equation (USLE) deriving the various factors involved in the model from elementary data provided by various national sources (Grimm et al., 2003).

Based on these premises, the present study proposes an exploratory spatial analysis of the soil erosion index provided by Grimm et al. (2003) coupled with 133 indicators illustrating territorial, socioeconomic, cultural and political attributes available at the municipal scale in Italy, a Mediterranean country experiencing a high risk of soil erosion in specific areas (Perini et al., 2008). Following Salvati (2014), municipalities were considered a spatial domain suitable to investigate the socioeconomic characteristics of rural communities using statistical indicators derived from official data sources, including censuses of agriculture, industry and population. Local communities represent, possibly better than other spatial domains, the complexity of the territorial context in southern Europe which is reflected in the millenary interactions between nature and humans (Conacher and Sala, 1998). An exploratory data analysis applied to the selected indicators was developed with the aim to identify the socioeconomic profile of the local municipalities exposed to soil erosion risk.

Methodology

The investigated area

The area examined in this study includes the whole Italian territory covering 301,330 km^2 of which the 23% are flat, the 42% are hilly and the 35% are mountainous (Salvati and Carlucci, 2011). Italy is characterized by a traditional north-south divide in both environmental (climate regimes, landscapes, vegetation, soils and cropping systems) and socioeconomic variables (income and wealth, labour market and demography). Italian land is administered by 20 regions and more than 8000 local municipalities. The administrative asset of 2001 was chosen in this study as the reference spatial unit (8101 local municipalities) to enable an effective matching between environmental and socioeconomic data (Istat, 2006). The local governance system changed only moderately in 2013 with 8094 municipalities administering the Italian territory.

Italy is considered a hotspot for land degradation and desertification in the Mediterranean region (Costantini and Dazzi, 2013) and erosion constitutes an important cause of soil degradation in the area (Salvati and Bajocco, 2011). A large part of the country is subject to the risk of accelerated erosion because of the relief, high soil erodibility and unsustainable agricultural practices (Grimm et al., 2003). Erosion risk locally increased in recent decades, partly because of the growing rainfall erosivity counterbalancing, at least in part, the slow decline of erosion rate due to natural forestation following the abandonment of farming in less favoured areas (Costantini et al., 2009).

Soil erosion risk index

The European Soil Bureau of the Joint Research Centre, Ispra (JRC) assessed soil erosion in Italy based on the determination of potential risk according to the parameters defined by the Universal Soil Loss Equation (USLE). This model uses empirical factors of vulnerability that combines soil (climate erosivity, erodibility, topography) and related information on the influence of human activities (e.g. farming activities, soil conservation practices). The study used the following data sources all provided by JRC (Grimm et al., 2003): (i) Mars Meteorological database for climate data, (ii) Soil Geographical Database of Europe (scaled 1:1,000,000) for information related to the textural classes of the soils used to develop the *K* index, (iii) CORINE Land Cover database integrated with NOAA Advanced Very High Resolution Radiometer images to derive *C* index and (iv) a Digital Elevation Model with a resolution of 250 m for the data regarding *L* and *S* factors. Estimated soil loss (*A*) was considered proportional to a parameter, the so-called Rainfall