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The impact of mediterranean land degradation on agricultural income: A short-term scenario

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ABSTRACT

The present study estimates the potential costs of land degradation (LD) in agriculture at the national scale in Italy during 2000–2006 and provides a medium-term scenario for 2015 based on changes in climate conditions and human pressure. According to the user cost approach, a depletion factor (S) to agricultural income has been derived from the observed changes in a composite index of land sensitivity to degradation. Based on S figures, the investigated area has been classified into five risk categories from 'negligible' to 'high'. Surface land classified as 'high LD risk' increased slightly from 1.1 per cent in 2000 to 4.4 per cent in 2006 ranging from 2.9 to 8.6 per cent in 2015. Eleven indicators have been used to identify the socioeconomic conditions which possibly discriminate districts in 'high' and 'low' LD risk in agriculture. The gap in LD risk observed in 2000 between developed and disadvantaged regions in Italy reduced significantly in 2006. This suggests that agriculture is sensitive to LD in both economically marginal and affluent areas where climate and soil conditions are turning towards the worse. These results support strategies improving sustainable agriculture–environment relationships and protecting the soil resource base at the local scale.

Introduction

It was demonstrated that the decreasing stock of natural capital lowers the (sustainable) flow of resource inputs and ecosystem services (Daly, 1999; Mukherjee and Kathuria, 2006; Tan, 2006). While this problem is traditionally viewed as more urgent in natural resource-dependent countries, the seriousness of some environmental processes, like for instance climate changes, has broadened the concept of natural resource depletion to fields relevant for developed countries, too. In Mediterranean-like ecosystems, the decline in land quality known as land degradation (LD) leads to decreased productive capacity of agricultural and natural systems (Conacher and Sala, 1998; Ibanez et al., 2008) and is an important cause of income loss in rural populations suffering poverty and economic marginalization (Lorent et al., 2008).

Basically, three factors contribute to LD in this region: climate change, unsustainable land management, and increasing human pressure (Kosmas et al., 2003; Helldén and Tottrup, 2008). In particular, human pressure has grown enormously during the last century causing habitat fragmentation, deforestation, biodiversity loss, water shortage, soil erosion and salinization, and decline in soil organic matter (Montanarella, 2007). As an example, Salvati and Bajocco (2011) estimated that the surface area of sensitive land to degradation increased in Italy by more than 30 per cent during 1960–2008.

In developed countries the assessment of LD trends and its impacts on agriculture is complicated by the multiple relationships observed between ecological variables and human factors (Tanrivermis, 2003; Gisladottir and Stocking, 2005; Atis, 2006). Only few studies showed attempts to quantify costs of all major processes of LD (Requier-Desjardins et al., 2011). Some of them establish a framework for the analysis of LD costs providing a preliminary assessment through the use of the environmental function approach (de Groot et al., 2002; Atis, 2006; Requier-Desjardins, 2006). This approach needs structured input data hard to find even in many developed countries (Hein, 2007).

Many reasons thus suggest the use of indirect approaches when only poor-quality data are available (Salvati et al., 2011). Among such procedures, the user cost approach has been proposed as a way of taking properly into account the degradation of land resources, since it avoids the difficulty of putting a value on the stock of the resource itself (Ahmad et al., 1989). This approach relies instead on the estimation of current extraction rate of the available stock measured in physical terms (El Serafy, 1997). Salvati and Carlucci (2010) proposed a simplified, field-validated procedure aimed at estimating diachronically the potential costs of LD for specific target

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activities (e.g. agriculture) that can be adapted to different spatial scales according to the availability of data on land resources (Bojo, 1996).

Through the user cost approach, the present study estimates in 2000 and 2006 a depletion factor to agricultural income which takes into account the possible deterioration of soil resources due to LD in Italy, a country with a complex spatial pattern of land resources distribution and rural development (Salvati and Zitti, 2009). This objective was achieved by considering together environmental variables quantifying LD sensitivity with information about *per-capita* gross income, the agricultural value added, and the total workers employed in the primary sector at district scale. The procedure illustrated by Salvati and Carlucci (2010) was used in the present study to classify the investigated area into different levels of LD risk and was supplemented with a scenario analysis quantifying short-term trends (2007–2015) in the same variable. Here, as time flows at rather different speeds for environmental processes than for economic ones, we name a short-term horizon a length span of eight years, which represents a rather long-term period for economics. An additional objective of this paper was to explore the territorial disparities in the potential costs of LD for the Italian agriculture with the aim of deriving effective policy prescriptions against LD.

Methods

Study area

Italy covers a surface area of 301,330 km^2 and its latitudinal extension, mountainous topography, and proximity to the sea account for a marked deal of variation in climate, soil, vegetation, and rural landscape. Average annual precipitation ranges from 350 mm in Sicily to 1500 mm in north-eastern Italy. A large number of soil types and vegetation associations occurred throughout the country. Italy is divided into twenty administrative regions, more than one hundred prefectures and almost 8100 municipalities. The Italian Statistical Office identified 686 districts suited to study local labour markets, economic specialization, industrial districts, social conditions, urban concentration, and agriculture. On average, each district includes 12 municipalities and covers 440 km^2 with resident population amounting to nearly 83,000 inhabitants (Istat, 2006). Italian districts reflect the regional differentiation in both socioeconomic development and natural resource distribution (Salvati et al., 2011). Moreover, they represent the most disaggregated spatial unit suited to compare environmental and national economic accounts variables collected from official statistical sources in Italy (Salvati and Carlucci, 2010).

Environmental variables and indicators

The level of LD sensibility in Italy was assessed by way of the environmental sensitivity areas (ESA) scheme (Basso et al., 2000). The ESA scheme integrates several climate, soil, and land cover variables into a composite index of LD (hereafter 'ESAI'). The ESAI should be regarded as an 'early warning' indicator of LD (Salvati and Bajocco, 2011). Results of this procedure have been validated in several sampling sites across southern Europe (e.g. Lavado Contador et al., 2009).

Climate quality has been described by considering the average annual rainfall rate, the aridity index (defined as the ratio between rainfall and reference evapotranspiration, both measured over a thirty years period), and aspect (Basso et al., 2000). These indicators have been calculated using basic information available in the National Agro-meteorological Database of the Italian Ministry of Agriculture (Salvati and Carlucci, 2010). The database relates to data collected from nearly 3000 gauging stations since 1951. To ensure the homogeneous territorial coverage, the meteorological data were spatially interpolated through kriging or co-kriging procedures (with elevation, latitude, and distance to the sea as ancillary variables) in order to create a grid of 544 points with daily data of temperature, precipitation, humidity, solar radiation, and wind. Three analysis periods were selected: 1961–1990, 1971–2000, and 1978–2007. The reference evapotranspiration rate was calculated using the Penman–Monteith formula (Salvati and Zitti, 2009).

Soil data were obtained from the soil quality map produced in the framework of DISMED project and derived from the European Soil Database at a 1 km^2 pixel resolution (Joint Research Centre, JRC). An Italian database of soil characteristics ('Map of the water capacity in agricultural soils'), generated by the Ministry of Agriculture and based on nearly 18,000 soil samples, thematic cartographies (land system map, ecopedological map, and geological map of Italy, respectively obtained from the National Centre of Pedological Cartography, JRC-Ispra, and the Italian Geological Service), and a Digital Elevation Model provided by the Ministry of the Environment with 70 m resolution were used as ancillary information (Salvati and Carlucci, 2010). These datasets can be considered as the standard soil information available at regional level and are presented for use at 1:500,000 scale. This resolution is adequate for the level of analysis adopted in this paper. Soil texture, depth, slope, and parent material, regarded as proxies for additional soil structure influencing factors (e.g. organic matter, compaction), were selected as input variables (Lavado Contador et al., 2009). These variables have been considered as static during the investigated time period since they change slowly or rarely and by their nature are infrequently measured or mapped.

Land cover changes and LD have been quantified through four standard ESA variables: fire risk, vegetation protection against soil erosion, vegetation resistance to drought, and vegetation cover (Basso et al., 2000). Such indicators were obtained from the CORINE (COoRdinate INformation on the Environment) cartography in 1990, 2000, and 2006. The Corine Land Cover (CLC) project was co-ordinated by the European Environment Agency (EEA) and provided diachronic, pan-European land cover maps (Salvati and Bajocco, 2011) obtained from the analysis of satellite images. The choice of scale (1:100,000), minimum mapping unit (MMU) (25 ha) and minimum width of linear elements (100 m) for CLC mapping represents a trade-off between production costs and land cover information details. The standard CLC nomenclature includes 44 land cover classes. These are grouped in a three-level hierarchy. The five main (level-one) categories are: (i) urban areas, (ii) agricultural areas, (iii) forests and semi-natural areas, (iv) wetlands, and (v) water bodies. According to Kosmas et al., a weight was attributed to each category in order to obtain a land classification based on the different sensitivity level of its vegetation.

Three indicators, quantifying the environmental quality in terms of climate (climate quality index, CQI), soil (soil quality index, SQI), and vegetation (vegetation quality index, VQI), were estimated as the geometric mean of the different scores for each considered variable. The scores of each thematic indicator ranges from 1 (the lowest contribution to land sensitivity to degradation) to 2 (the highest contribution to sensitivity to degradation). The ESAI was thus estimated in each *i*-th spatial unit (an elementary pixel of 1 km^2) and *j*-th year (1990, 2000, and 2006) as the geometric mean of the three partial indicators. Theoretically, the ESAI scores range from 1 to 2. Lower scores indicate low levels of land sensitivity, while higher scores indicate 'fragile' or 'critical' environmental conditions leading to high land sensitivity. According to Lavado Contador et al. (2009), the investigated area was classified as 'non affected' by LD (ESAI < 1.175), 'potentially affected' (1.175 < ESAI < 1.225), 'fragile' (1.225 < ESAI < 1.375), and 'critical'