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Land-use and land degradation processes affecting soil resources: Evidence from a traditional Mediterranean cropland (Greece)

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ABSTRACT

Land degradation is a complex process resulting from the permanent interaction between physical and human factors. The effect of changes in land-use and land management on soil erosion and desertification risk has been studied in Messara Valley (Crete, Greece) over the last six decades (1950–2010). Vegetation cover and land-use have been analyzed using representative aerial photographs and ortho-photomaps for representative dates. Soil attributes have been described in a semi-detailed survey in 2010. Soil erosion rates and desertification risk have been assessed for each period using the PESERA and TERON models and the MEDALUS methodology, respectively. Based on distinct socio-ecological characteristics of the area three major time intervals have been identified. Cereals extensively cultivated during the first time interval were progressively replaced by olive plantations and vineyards in the following periods. Soil erosion due to water runoff was important especially in the olive transition period, declining in the olive subsidy period. However, tillage erosion became an important degradation process especially in the olive subsidy period due to mechanization of the agriculture determining soil losses ranging from 0.5 to 30 cm in sloping areas. Desertification risk due to soil erosion and land characteristics has significantly increased during the olive subsidy period.

1. Introduction

Awareness due to the increased environmental stress on natural resources, imposed by the growing human demands, urges the scientific community to define the origins of the problem and to propose practical solutions to restore ecosystem or to mitigate environmental degradation (Millennium Ecosystem Assessment, 2005). The drastic changes in the use of land and the shift of cropland management towards more intense practices, observed at global scale over the last decades, are considered the main driving forces of land degradation (Foley et al., 2005). The intensification of agriculture and unsustainable landscape transformations negatively impacted soil quality in the Mediterranean region (EEA, 2000; Yassoglou and Kosmas, 2001; López-Garrido et al., 2014). Soil erosion and land desertification are recognized as the most common land degradation processes in this region (Kosmas et al., 2000, 2002, 2006; Gordon et al., 2008; Cerdà et al., 2010). These processes are closely interrelated, whereas the human interventions by the appropriate land-use and land management practices can be critical for rehabilitation (Kosmas et al., 1997, 1999a,b; Tsara et al., 2001; EC, 2006; Cerdan et al., 2010).

Soil erosion is a natural process causing limitations to soil productivity, contributing to water quality problems under specific environmental conditions (Gobin et al., 2004; Kirkby et al., 2008). The accelerated erosion rates, due to the synergic action of biophysical and socioeconomic factors, alarmed scholars and politicians in recent decades. As a consequence, a great deal of methodologies and indicators have been developed for the assessment of soil erosion (Gobin et al., 2004; Kapalanga, 2008). Among the most widely used soil erosion models, the PESERA model was developed to provide an explicit assessment of the long-term soil water erosion rate depending on vegetation cover, climate and management characteristics (Kirkby et al., 2008). Furthermore, a wide range of studies focus on tillage erosion, acknowledging the growing human impact on land (Van Oost et al., 2006). The empirical methodology developed by EU TERON project is a useful tool for estimating soil relocation in hilly agricultural areas, where tillage induces higher erosion rates than water or wind (Govers et al., 1994; 1996 Gerontidis et al., 2001). The combination of both water erosion and tillage erosion can provide information about the overall erosion rates affecting hilly agricultural areas.

Similar with soil erosion, land desertification which is considered as a type of advance degradation in the Mediterranean region, affects semi-arid and dry regions where lack of water is the main limiting factor

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for the soil productivity (Lal, 1927; Kosmas et al., 2003). Desertification is a land degradation process triggered by excessive human activity in areas with unfavorable natural characteristics (Kosmas et al., 1999a,b; Yassoglou and Kosmas, 2001). The Environmentally Sensitive Areas (ESAs) to desertification scheme, originally developed within the MEDALUS project (Kosmas et al., 1999a,b), produced a flexible indicator system for identifying potentially threatened areas.

Research on land degradation, considered as the reduced potential of the land to provide ecosystem services, has highlighted four main pillars, the role of which has undergone significant debate: (i) climate, (ii) vegetation, (iii) social processes and (iv) economic and political processes (Hermann and Hutchinson, 2005). Vegetation and land-use affected by social and economic changes over time are of paramount importance in controlling land degradation due to soil erosion and land desertification (David et al., 2014; Kaplan et al., 2014; Kurothe et al., 2014). Interestingly, agricultural intensification (mechanization, extensive use of agro-chemicals and irrigation) was identified as one of the most relevant processes determining changes in the current use of land in rural areas of the southern Europe. A comprehensive knowledge of transformations in the use of land and in the prevailing land management practice transformations coupled with an in-depth monitoring of the evolution of the main land degradation processes at the local scale contributes to elaborate sustainable land management practices targeting the preservation of soil resources (Zalidis et al., 2002; Novara et al., 2011; Quaranta and Salvia, 2014).

Based on these premises, the objectives of our study are (i) to estimate the effect of land use and land management changes on key land degradation processes, (ii) to describe the evolution of land degradation processes over time coupled with changes in the socioeconomic context at the local scale, and (iii) to assess land degradation processes under alternative land management practices. Based on these premises, the present study has been focused on the evolution of land-use and land management practices in Messara Valley, Crete, and their impact on land degradation processes. The study period refers to the last 60 years (1950–2010) encompassing relevant transformations in the socioeconomic structure of the area together with important changes in cropping systems. Messara Valley is intended here as a paradigmatic case to understand the intimate relationship between environmental, agronomic and socioeconomic factors in rural Mediterranean dry areas experiencing a shift towards crop intensification.

2. Materials and methods

2.1. Study area

The Messara Valley is located in the central-southern part of Crete, about 50 km south of the city of Heraklion (Fig. 1), covering an area of 72,059 ha. The climate of the study area is dry sub-humid, with mild-wet winters and dry-hot summers. The average annual rainfall increases from west to east ranging from 493 mm to 737 mm (three meteorological stations with time period of data 1948–2004). Similarly, average air temperature ranged from 19.1 °C in the western part to 16.6 °C in the eastern part of the valley. The main materials of the upper geological layer are alluvial deposits (mainly in the lower/western part of the valley), marls (mainly in the hilly areas), limestone, flysch (in few hilly areas) and conglomerates. The area is characterized mainly as gently to moderately sloping (areas with slope gradient lower than 12% cover about 47% of the area). In the majority of the study area, elevation is 400 m above sea level. The soils of Messara Valley are mainly moderately deep to deep (soil depth greater than 60 cm characterizes 70% of the study area). In the lower part of the valley recent alluvial soils, classified as Fluvisols, rich in carbonates (15–30%) with clay loam dominant textural class and moderate fertility, were found (Yassoglou et al., 1971). The soils formed on hilly areas are characterized by their advanced degree of erosion with the parent material (mainly marls) exposed to the soil surfaces, classified mainly as Cambisols.

2.2. Changes in the cropping systems of Messara Valley

Messara Valley is one of the most important agricultural regions of Crete undergoing considerable socio-ecological transformations during

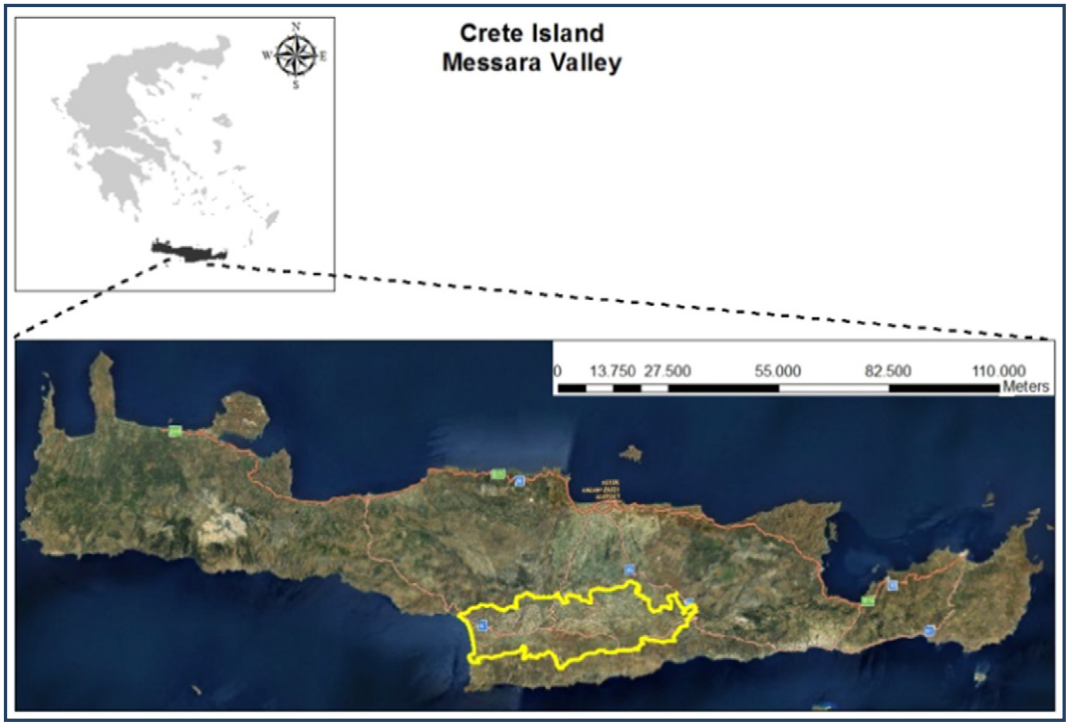

Fig. 1. Location of the Messara study area in Crete, Greece.
Source: Google Earth, elaborated by authors.