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Seasonal monitoring of soil erosion at regional scale: An application of the G2 model in Crete focusing on agricultural land uses

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ABSTRACT

A new soil erosion model, namely G2, was applied in the island of Crete with a focus on agricultural land uses, including potential grazing lands. The G2 model was developed within the Geoland2 project as an agro-environmental service in the framework of the Global Monitoring for Environment and Security (GMES, now Copernicus) initiative. The G2 model takes advantage of the empirical background of the Universal Soil Loss Equation (USLE) and the Gavrilovic model, together with readily available time series of vegetation layers and 10-min rainfall intensity data to produce monthly time-step erosion risk maps at 300 m cell size. The innovations of the G2 model include the implementation of land-use influence parameters based on empirical data and the introduction of a corrective term in the estimation of the topographic influence factor. The mean annual erosion rate in Crete was found to be 8.123 t ha^{-1}. The season from October to January (the rainy season in Crete) was found to be the most critical, accounting for 80% of the annual erosion in the island. Seasonal erosion figures proved to be crucial for the identification of erosion hotspots and of risky land uses. In Crete, high annual erosion figures were detected in natural grasslands and shrublands (14.023 t ha^{-1}), mainly due to the intensification of livestock grazing during the past decades. The G2 model allows for the integrated spatio-temporal monitoring of soil erosion per land-use type based on moderate data input requirements and existing datasets.

1. Introduction

Soil erosion caused by water has been addressed globally as one of the most critical soil degradation hazards. It has been found that almost 12% of the European territory (115×10^6 ha) is subject to erosion. The European Union has identified soil erosion as a key priority for the protection of soils (EC, 2006) and has estimated its financial cost as being several billion Euros per year. The risk of erosion is particularly high in Mediterranean areas, especially in areas that are subject to inappropriate agricultural management, land abandonment, intense road construction, or wild fires (Cerdà et al., 2010). Any of the above drivers, alone or in combination, assisted by a dry climate, can trigger or seriously accelerate soil erosion.

Of all the factors influencing erosion, rainfall erosivity and vegetation cover are considered to be the most dynamic. Therefore, capturing detailed temporal rainfall and vegetation characteristics could prove crucial to making realistic and accurate erosion assessments. Based on experience gained in the previous decades, the new G2 model attempts to provide the necessary temporal detail for soil loss assessments at local to regional scales (Karydas et al., 2012). The G2 model uses the empirical formulas of the Universal Soil Loss Equation (USLE), while using rainfall erosivity data and time series of biophysical parameters derived from satellite data on a monthly basis (Panagos et al., 2012a). The importance of monthly rainfall erosivity maps for soil erosion risk assessments has been also suggested by Renard et al. (1997). In addition to rainfall erosivity and vegetation cover, inputs to the G2 model include soil erodibility, topographic influence and slope intercept. The G2 model was developed within the Geoland2 project as an agro-environmental tool in the framework of Global Monitoring for Environment and Security (GMES, now Copernicus) initiative. To date, the G2 model has been applied to the Strymonas (or Struma) river basin (Panagos et al., 2012a) and the Ishmi-Erzeni watershed in Albania, with encouraging results. The G2 model has been further developed in the current study.

The objective of this research study was to make seasonal erosion assessments in Mediterranean agricultural areas using the G2 model. More specifically, the study aimed to:

- Improve the G2 model taking into account land-use data.
- Identify hotspots (spatial dimension) and seasons at high risk of soil erosion (temporal dimension).
- Identify critical land uses and the impact of vegetation cover in agricultural land uses.

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2. Materials and methods

2.1. Study area

The Greek National Committee for Combating Desertification considers Crete to be a high-risk area for desertification due to large-scale deforestation of sloping lands, intensive cultivation and overgrazing, which results in accelerated soil erosion and the formation of badlands. Croke et al. (2000) also consider Crete to be a high-risk area for desertification due to a combination of inappropriate land uses and high spatio-temporal variation of climatic factors.

Crete is located in the Eastern Mediterranean basin (35:20:27 N, 25:07:46 E). With a population of 623,065, it is the largest island of Greece (8336 km^2) (Fig. 1). According to the Nomenclature of Territorial Units for Statistics (NUTS) used for administrative purposes in the European Union, Crete is one of the 13 Greek NUTS2 regions and has four regional units at NUTS3 level (Panagos et al., 2013): Chania, Rethymnon, Heracleion, and Lassithi (from west to east). It is mostly a mountainous area with a mean elevation of 482 m and the highest peak at 2456 m (Mount Psiloritis). The topography of the island is quite undulating due to its carstic geology, with an average slope of 28% (or 15°). Crete has a dry sub-humid Mediterranean climate (humid mild winters; dry warm summers). The mean annual precipitation is 730 mm with a standard deviation of 230 mm. Significant rainfall differences are recorded between the western (wetter) and eastern (drier) parts of the island during the autumn and winter seasons. Rainfall during the spring season is very low, and is negligible during the summer season. The mean annual temperature ranges between 15 and 20 °C.

Soils in Crete are generally poorly developed and shallow. According to the European Soil Database, Leptosols occupy about 56% of the island surface, while Regosols cover another 25% (European Soil Portal, 2013). The presence of these soils is generally attributed to historical human activity, in particular to deforestation and overgrazing. Some Luvisols (about 10%) can be also found in the upper parts of some small fluvial plains.

Crete is mostly covered by natural grasslands and shrubs (46%) and permanent crops (olives 23%, vines 2.6%, and citrus 0.7%). A significant part of the land is covered by heterogeneous agricultural areas or fields mixed with natural vegetation (15.2%), whereas a small share (0.5%) is covered by greenhouses, arable land (irrigated or not) and pastures. Forest coverage is less than 4% of the total area (CLC, 2000). The main land uses in Crete have not changed significantly over the past 50 years, but in some cases the intensity of land use has changed. A large share of vineyards was replaced by new olive plantations, especially during the 1990s and 2000s (Karydas et al., 2008). Moreover, the number of livestock units (LSU) (goats and sheep) grazing the island has increased more than five times (from 1.4 to 6.8 LSU ha^{-1} in the period 1960–2010) due to agricultural policy incentives (Nikolaidis et al., 2013).

2.2. Data

A time series of precipitation data for 11 years (1969–1979) with 10-min resolution was available for four weather stations in Crete (Emprosneros, Nithafri, Archanes, Kalamavka) (Hydroscope, 2012). In addition, a set of 24 weather stations was used from SoilTrEC project (Banwart et al., 2011) with average monthly precipitation records for the same time period (1969–1979). Rainfall data is the main input to the G2 model for estimating rainfall erosivity.

A set of 31 soil samples from the pan-European LUCAS topsoil dataset (Toth et al., 2013; Panagos et al., 2013) and an additional set of 60 soil samples of the SoilTrEC project (Banwart et al., 2011), mainly from the western part of the island, were made available for the study. The samples included soil organic carbon and texture data used in the soil erodibility equation of the USLE, which is adopted by the G2 model.

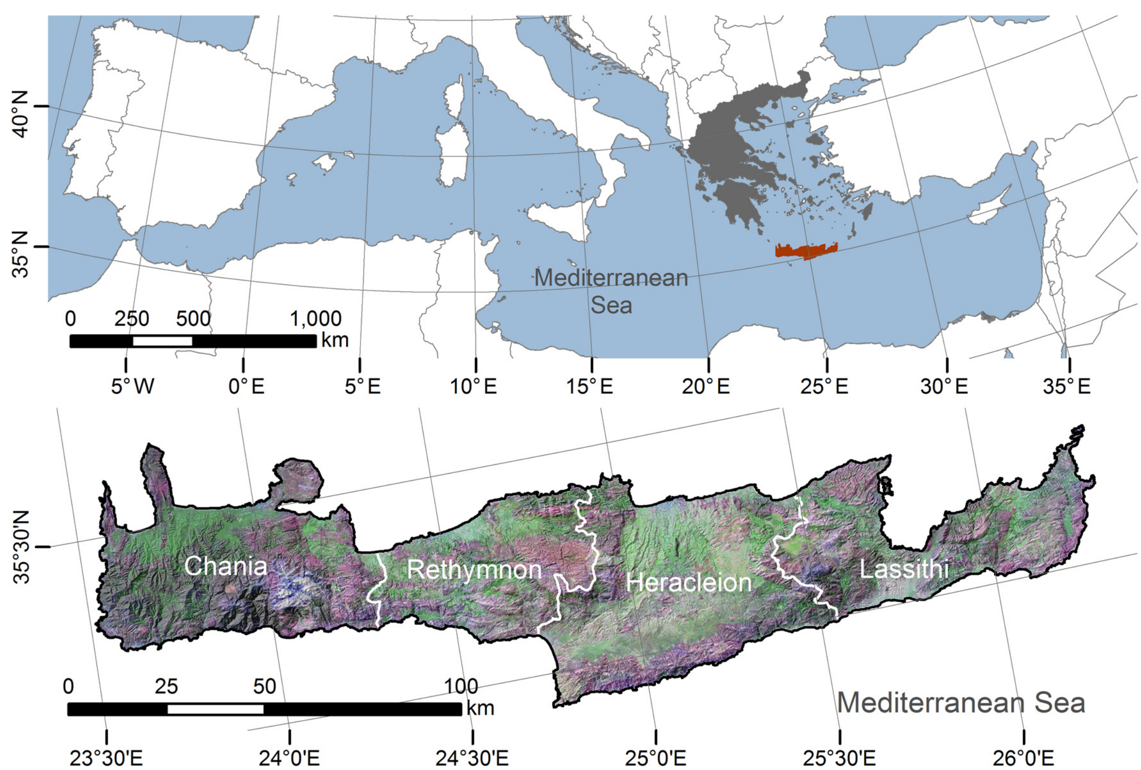

Fig. 1. The Island of Crete. Upper panel: location of Greece (grey) and Crete island (red). Lower panel: false-colour composite of high resolution satellite image mosaic (source: JRC). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)