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Brief communication
"Does climatic change in precipitation drive erosion in Naxos Island, Greece?"

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Abstract. In this paper we examined whether the recorded precipitation changes cause erosion in Naxos Island, Greece using precipitation indices derived from daily precipitation totals, during the period 1955–2007, in order to develop an erosion risk model. Although the mean annual precipitation appear to be low (∼360.0 mm), the erosion processes of the area are very intense, because of the intensive character of precipitation, the high slope relief, the differential lithology and the absence of important land cover The results of the analysis showed that the climatic changes in precipitation and the changes in land cover and land use are the main drivers for the erosion. This is why the 2nd (1971–1985) and 3rd (1986–2007) studied sub-periods may be called of high erosion risk, and especially the second one mainly because of the increased frequency of extreme precipitation events.

1 Introduction

According to the Intergovernmental Panel on Climate Change (IPCC, 2007), the frequency of heavy precipitation events has been increased over most land areas, consistent with warming and observed increases of atmospheric water vapor. Besides, more intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics. Recently, Nastos and Zerefos (2008) found that increased observed variance and scale parameter of the fitted Gamma distributions on the precipitation datasets of Greece occur/take in the western and southern-eastern regions, especially during the last decade 1991–2000, indicating the incidence of extreme daily precipitation. Besides, Nastos and Zerefos (2009) studying the spatial and temporal variability of consecutive dry (CDD) and wet days (CWD) in Greece concluded that CDD appear maxima in the Cycladic archipelago area and the south-eastern Aegean Sea, while the longest CWD are observed in western Greece and western part of Crete Island.

Various papers have been published on the topic of erosion risk applying different methodologies, based on several parameters, such as morphometric variables (Jozefaciuk and Jozefaciuk, 1993; Gournelos et al., 2004), rainfall erosion indexes (Stocking and Elwell, 1976; Chávez, 2006) or mathematically based erosion risk self-organising maps (Bartkowiak et al., 2002).

The purpose of this study is to present and analyze the run off erosion regime in Naxos Island, Greece and attempt to interpret the climatic role of the precipitation indexes in the erosion process.

2 Data and analysis

Naxos Island is part of the Cycladic archipelago area in the central Aegean Sea, Greece. The climate, according to Köppen/Geiger climate classification, is of Mediterranean type with long dry summers and mild winters, while strong winds appear during the whole year (Theoharatos, 1978). In this study the factors resulting in erosion of Naxos Island are examining. The meteorological data, with respect to daily precipitation totals, were acquired from Naxos meteorological station of the Hellenic Meteorological Service, for the

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period 1955–2007. The used precipitation time series were examined for homogeneity by applying the non papametric Swed-Eisenhart Runs Test (Mitchell et al., 1966) and the relative homogeneity Alexandersson Test (1986). The precipitation time series are considered reliable according to the performed specific control tests, while the few missing daily values for the years 2004 and 2005 are responsible for not estimating the relative climatic indices in these two years. The precipitation indices estimated were: the largest number of consecutive days with daily precipitation amount below 1 mm (CDD), the largest number of consecutive days with daily precipitate on amount above 1 mm (CWD), the number of days with precipitation greater than 20 mm (R20) or 30 mm (R30) and the simple daily intensity index (SDII). The SDII is defined as follows: let RR_{wj} be the daily precipitation total for the wet days w ($RR \geq 1$ mm) in period j. If W is the number of the wet days within the period j, then:

$$\mathrm{SDII}_j = \frac{\sum_{w=1}^{W} \mathrm{RR}_{wj}}{W}, \quad \text{(mm/day)}$$

Assuming that the period j concerns the year, then the SDII is defined as the annual precipitation total/number of rain days ≥ 1 mm/day. All the aforementioned definitions are according to/based on the joint CCl/CLIVAR/JCOMM Expert Team (ET) on Climate Change Detection and Indices (ETCCDI), (Peterson, 2005).

Moreover, photo-interpretation of aerial photos and satellite image was carried out, along with detailed field work, in order to map the different parameters used for the extraction of the erosion risk index. Geographical Information System (GIS) was used for the insertion, handling and process of the collected data, for the development of secondary information layers, as well as for the development of the erosion risk model. Erosion risk model was developed in MapInfo Professional environment with the use of MapBasic Programming language.

The principal variables used for the estimation of Naxos' erosion risk model, rock's susceptibility to erosion, manmade characteristics and the climatic conditions, were calculated for each pixel. Each of the above variables includes many sub-parameters, calculated and weighted accordingly, in order to extract the final one: the erosion risk index for different time periods.

3 Results and discussion

In order to calculate the rock's susceptibility to erosion variable we took into account the lithology, the existence of tectonical structures and discontinuities and finally the geomorphological status (Evelpidou, 2001). The geomorphological status is also based on sub-parameters; a) the morphological slope, which stands for the morphological slope gradient, the form of the slope and the aspect, b) the drainage density, which is highly related to water's runoff quantity and the substratum's permeability, and c) the main geomorphological characteristics of the study area.

The second main variable, the anthropogenic interference, stands mainly for the protective mechanisms land useland cover and terraces. In the case of Naxos Island the anthropogenic factor had a positive impact on run off erosion processes. For the needs of this study, we assumed that from the aforementioned parameters, vulnerability is stable during the study time period, while the other two parameters (anthropogenic interference and climatic regime) have changed. Three different scenarios were taken into account: a) period 1955–1970, b) period 1971–1985, and c) 1986–2007, weighted accordingly by the climatic condition one. Empirical logical rules (if…then) were constructed and followed in the model developed in GIS environment used MapBasic programming language, in order to extract how the different climatic parameters interfere with the climatic index. All sub-parameters affected the final one, but in different way and in a different weight.

Finally, all aforementioned variables were used in a Boolean logic model in order to extract the erosion risk index for the three different time periods. Logical rules used in order to extract the erosion risk index are also empirical. All sub-parameters are affecting the final one, but in a different way and with a different weight. These empirical rules, take into account all final parameters (each of it may include many sub parameters calculated in the previous steps as described before) in order to extract the final one, the erosion risk index.

Concerning climatic change in precipitation, the analysis showed that significant positive trends (C.L. 95%) for extreme precipitation events (number of days with rain >20 mm) appear, while episodes with high daily intensity are more frequent and hazardous in the recent years.

The climatic conditions, concerning the studied precipitation variables, during the 1st studied period (1955–1970) seem to be milder than the respective ones within the other sub-periods. The low mean values within the 1st sub-period, especially for the indices of extreme events (R20, R30 and SDII), has resulted in small runoff. Erosion risk during this period (Fig. 1a) appears to be low for the largest part of the island (89%) and very low at the central north part of the island (11%), which is covered by migmatite formation. This pattern changes radically within the 2nd studied period (1971–1985). During this period (Fig. 1b), the climatic conditions change and especially high mean values of the indices of the extreme events appear, along with high variability. Therefore, this has driven in high erosion risk for the largest part of the island (79%) and only a small percent appears to be of medium (20%) and low (1%) erosion risk. The central north part, covered by migmatite formation, appears to be of low to medium erosion risk. The rock's susceptibility is critical under this climatic regime. Finally, during the 3rd studied

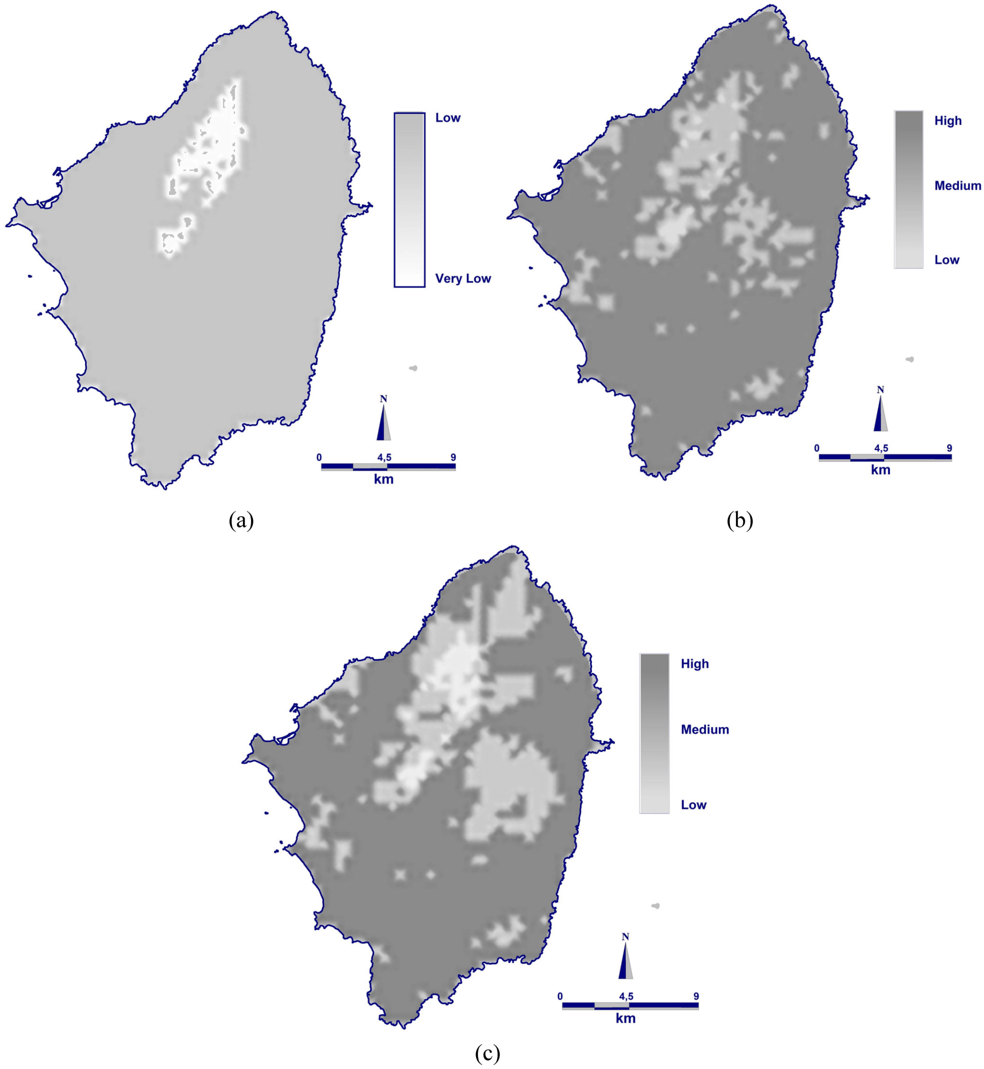

Fig. 1. Erosion risk map of Naxos island for the three different time periods **(a)** period 1955–1970 (upper left map), **(b)** period 1971–1985 (upper right map), and **(c)** 1986–2007 (lower map).

period (1986–2007) the climatic regime turns to milder conditions compared to the second period, but the mean values of the examined climatic indices are still high. This period could also be characterized by high erosion risk (Fig. 1c) but lower compared to the 2nd studied period. The 70% of the island is of high erosion risk, the 27% of medium erosion risk and the 3% of low erosion risk. During this period the protective mechanism is almost eliminated because of the terraces abandonment and the lack of vegetation due to the turn of anthropogenic activities mainly to touristic ones.

4 Conclusions

The development of an erosion risk model was carried out in Naxos Island, Greece. Taking into consideration that the vulnerability is stable during the studied periods, while the other two parameters have been changed, three erosion risk plots were constructed for three consecutive sub-periods, in order to interpret the evolution of the erosion process. The results of the analysis showed that the climatic changes in precipitation, concerning significant positive trends for the extreme precipitation events (number of days with rain >20 mm) during the study period, resulted in intense run off. This factor in combination with the rock's susceptibility to erosion and the changes in land cover and land use are the main drivers for the erosion and therefore the desertification in the Island of Naxos. For these reasons, the 2nd (1971–1985) and 3rd (1986–2007) studied sub-periods could be characterized by high erosion risk, and especially the second sub-period, mainly because of the frequent extreme events, which are projected to be more hazardous in the future (IPCC, 2007).

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