CLASSIFICATION OF DRAINAGE BASINS FOR ENVIRONMENTAL PURPOSES IN GIS PLATFORM USING SOFT COMPUTING APPROACH

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ABSTRACT

The drainage basin development reflects the dominant erosional processes and its internal rock structure. Many variables control the drainage basin evolution: lithology, topography, geology and climatic conditions.

The purpose of this paper is to propose different classification mechanisms of the drainage basins, based on the above controlling variables. These classification schemes can be divided in two categories: the Boolean model and the Fuzzy model, depending of the boundary vagueness of the initial data.

Such classification of drainage basins can become very useful for developing environmental protection strategies. Some examples are given from the Greek drainage system.

KEYWORDS: Erosion Risk, Classification methods, GIS, Geomorphology, Thera

INTRODUCTION

The geomorphological processes are being controlled by many variables. Firstly weathering of the rocks occurring by mechanical or chemical factors, which disintegrate or decomposes chemically the rocks. Next erosional processes are taking place. This depends on various factors such as the lithology, the slope gradient, the vegetation cover, the climatic conditions, the structure of the rocks and the erosivity of the erosion agent. The denudation of the existing landforms is mainly achieved by river or channel systems. Thus the drainage basin is considered a fundamental unit for studying such geomorphological process.

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METHODOLOGY

The classification of drainage basins or sub-basins evaluating erosion risk of soil or rocks involves a multi-step procedure. Firstly input data from topographical, geological, and land use maps, aerial photos interpretation and field observations are introduced in a GIS system. The scale of the input data depends on the needed detail of the derived data. The necessary input variables from the above data, sources are contour lines, geomorphological characteristics such us drainage system, geological formations and land use / land cover. Processing the above data secondary variables can be produced such as morphological slopes, drainage density and vulnerability of the rocks.

Following, a first set of logical rules is applied to the main drainage basins achieving a first level classification. These rules are usually of a fuzzy nature (Zadeh, L.A., 1965, Zadeh, L.A., 1987) because of the relative imprecision of the involved variables such as rocks erodibility, slope gradient, drainage density, etc.

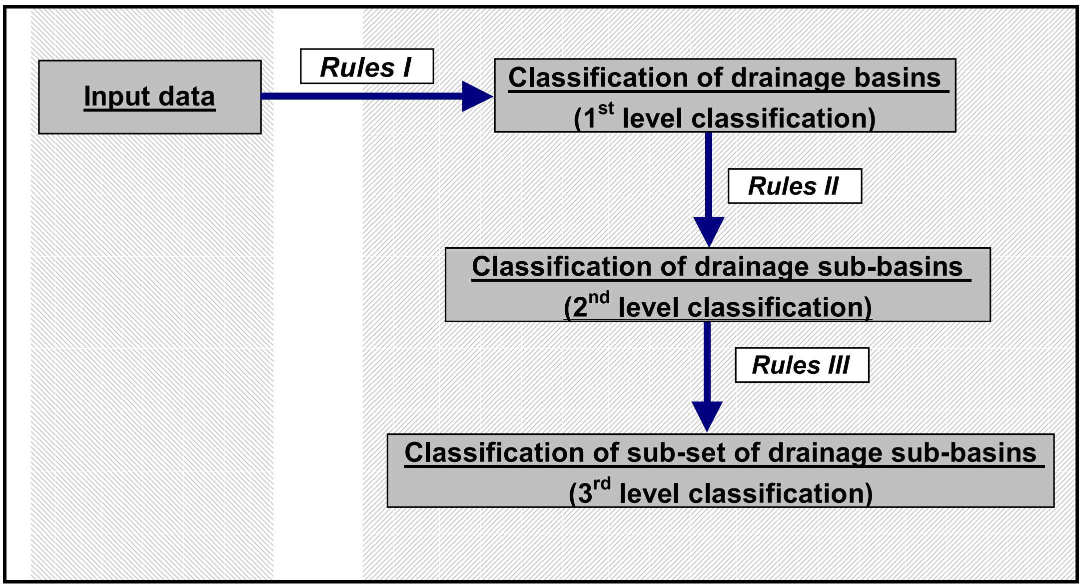

Fig. 1: Flow diagram of the multistep procedure for the estimation and classification of erosion risk.

After the first classification an output map is created in GIS, showing the spatial distribution of basins with different degrees of erosion risk. The drainage basins which present high or very high degrees of erosion risk are further decomposed using a new set of logical rules, and thus a second level of classification of drainage sub-basins is achieved. Finally the same procedure is repeated to arrive in the third level of classification of drainage sub-set of sub-basins (Fig. 1).

CASE STUDY: THE ISLAND OF THERA

The island of Thera is chosen for applying the above methodology (Fig. 2), for several reasons. Firstly the geological evolution of this island and the nature of surface sediments render Thera very susceptible to geomorphological processes. Secondly an extensive work has been done the previous years (Gournelos et al, 1995, Gournelos et al, 1999) by the authors, concerning the geomorphology of the island.

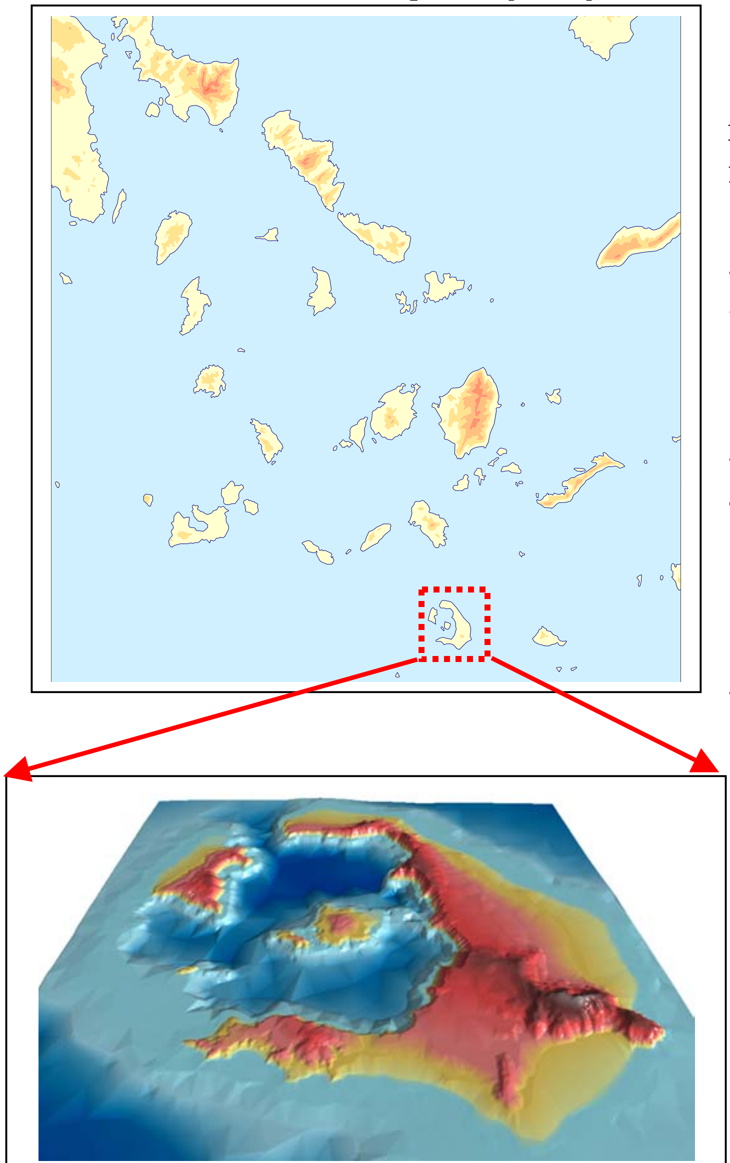
Fig. 2: The location of Thera island and a view of its morphology.

This island consists of a substratum of recrystallized limestones and metamorphosed rocks and a sequence of volcanic formations (Papastamatiou, 1958, Tataris, 1964, Fytikas et al, 1984, Friedrich and Velitzelos 1986, Skarpelis and Liati, 1987, Astaras et al, 2001). This volcanic activity started about 1,6 m.y. and its last phase was dominated by the Minoan explosion (Galanopoulos, 1958, Seward et al, 1980, Pichler and Kussnaul, 1980, Druit et al, 1989). Thus the Minoan eruption is responsible for the present landforms of the islands and the surface's rocks (Upper-Pumice series).

The input data that were used in this case study, were the contours with interval of 50m, deriving from the digitization of topographical maps scale 1:50.000 (HAGS, 1970, Topographical map, Thera Sheet, scale 1:50.00), the geological formations and tectonical structure from geological maps scale 1:50.000 (IGME, 1980, Geological map, Thera

Sheet, scale 1:50.000), the land use from different kind of land use maps (Ministry of Agriculture, 1986, Astaras, Th., et al, 1998) and from interpretation of aerial photos, scale 1:30.000 (HAGS, 1988, scale 1:30.000). Figure 3 shows some of the input data from which secondary information such as morphological slopes, drainage density and frequency have been derived.

The estimation of the rock's vulnerability was based on Selby's (1987) proposal, which considers the rock mass strength classification and rating, to

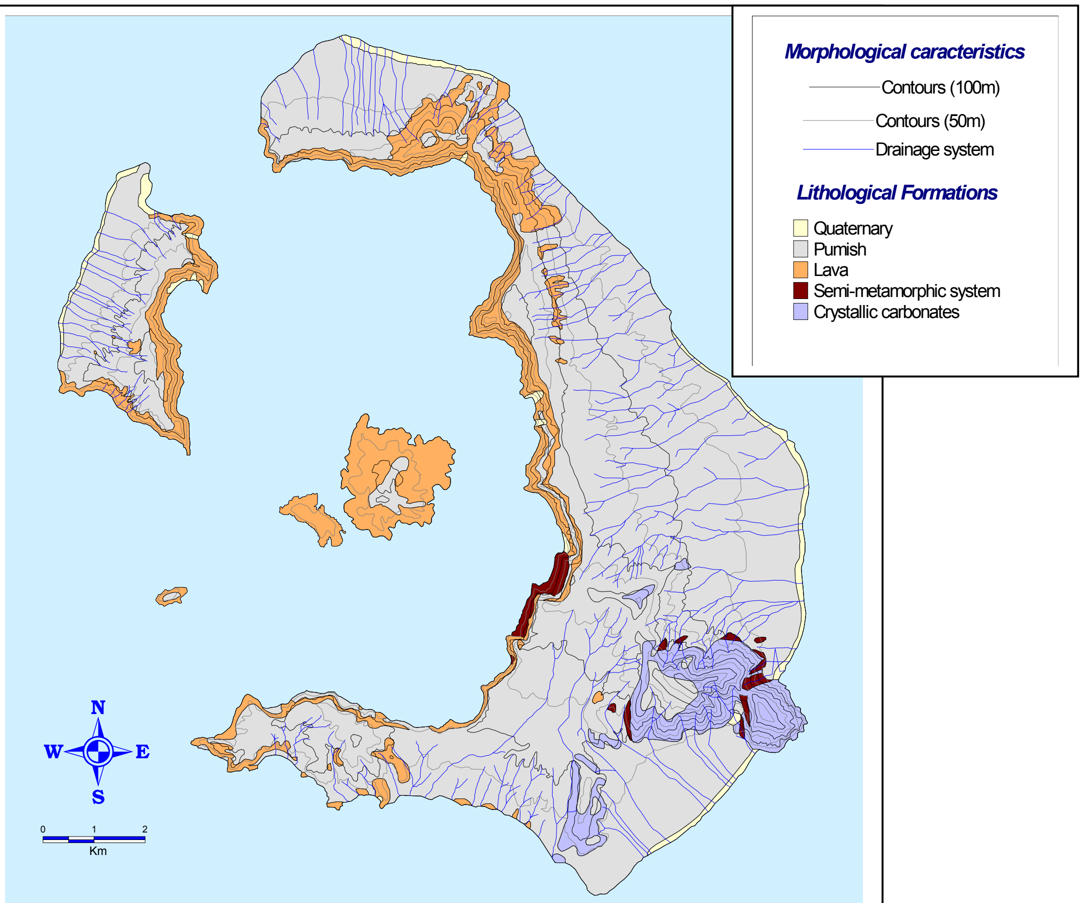

Fig. 3: Some of the input data: lithological formations derived from grouped geological formations, contours and drainage system.

express the resistance to erosion. Using this kind of classification limestones are more resistant to erosion than schists. The first attempt to assign erodibility values on different rock types was made by Jensen and Painter, (1974).

The classifications procedure for the Thera island is shown in figure 4 and is as follows:

- From the input data (geological, lithological formations, tectonical structures, topographical and morphological characteristics) the rocks erodibility was estimated. The erodibility of the rocks was the only variable, used in the first

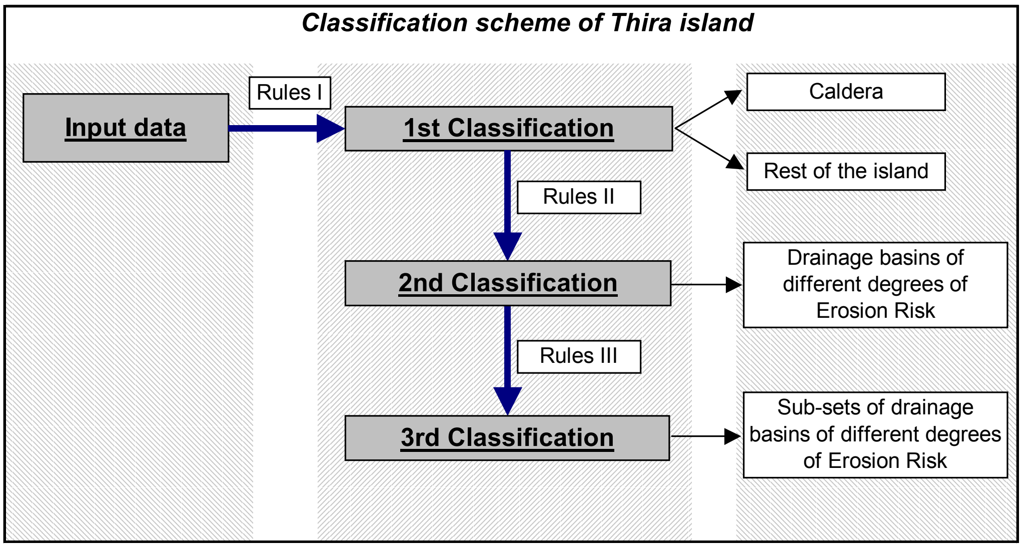

Fig. 4: Classification flow diagram that used in Thera case study.

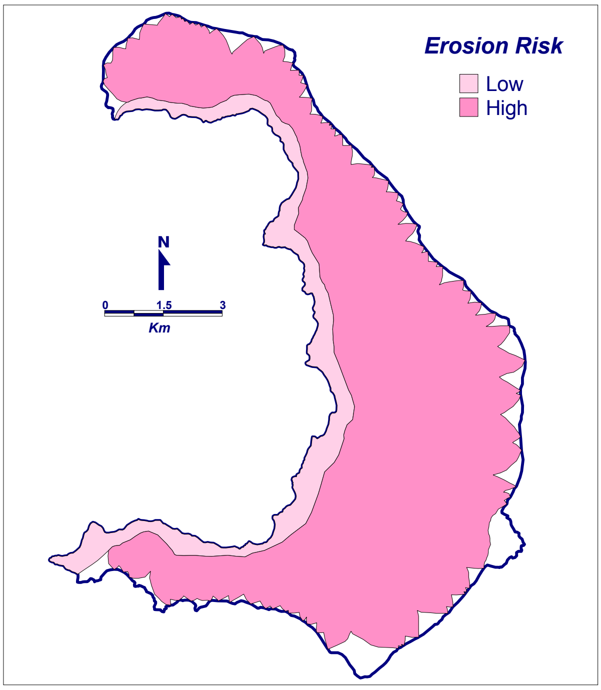

Fig. 5: First classification level, showing that the whole island except the 'caldera' area is considered as high erosion risk.

classification. The main geomorphological units are the caldera with a series of lavas and pumice deposits and the rest of the island, which was dominated by the Minoan pumice series. Figure 5 presents the first classification of Thera island. As shown the first classification concluded that the whole island except the caldera part is characterized of high erosion risk. The area outside of the drainage basins has not been calculated.

- The rest of the 'caldera' part, island, which has been indicated by the first classification as of high erosion risk, is further classified applying logical rules such as:

"If the erodibility of the rocks is High and slope gradient is High then Erosion risk is Very High".

The results of the second classification are shown in the figure 6. As shown in the legend of this figure, 42 drainage basins are of high erosion risk, meaning that the 53,16% of the studied drainage basins are of high erosion risk, while only the 5,06% and 16,45% are of low and very low erosion risk correspondingly.

- Following, the drainage basins of high and very high erosion risk indicated by the second classification have been chosen for the third level classification. The third level classification is achieved using the same logical rules as those in the second level classification. The results of the third classification are shown in Figure 7.

CONCLUSIONS

In this paper different schemes are proposed for classification of drainage basins or subsets of drainage basins. The most useful model is the fuzzy one, because relative imprecision of distribution values characterizes the involved variables. We applied this methodology in the case study of the Thera island and a series of output maps is produced. These maps show spatial distribution of the erosion risk degree of the areas of Thera in different scales and can be used in local planning for environmental management.

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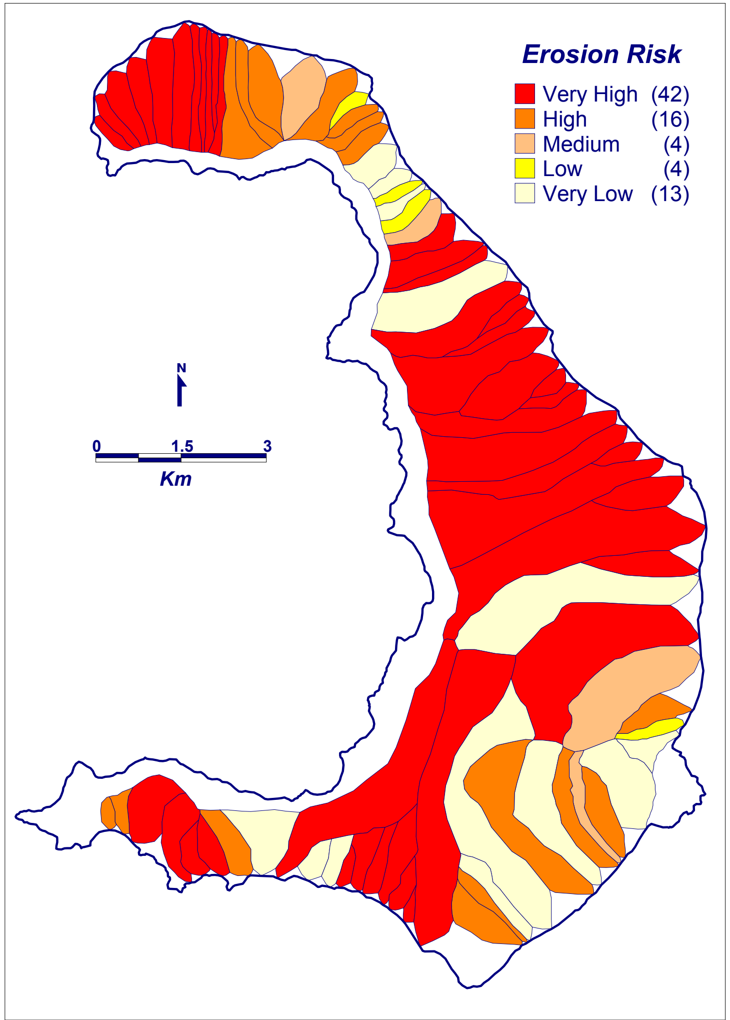

Fig.6: Erosion risk map of 2nd level drainage basins classification.

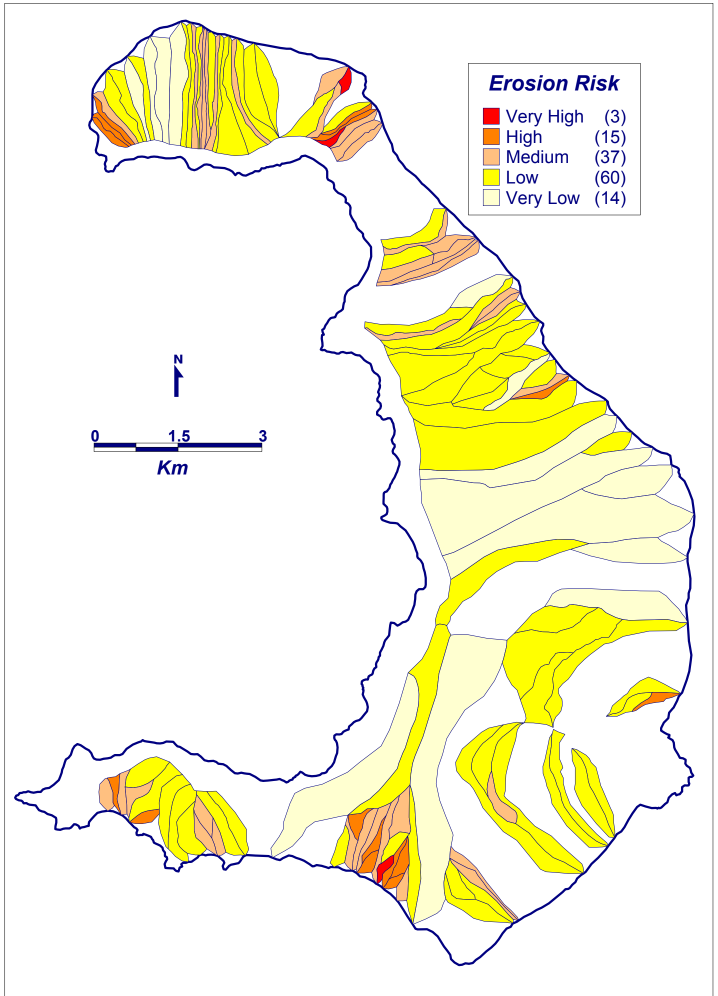

Fig.7: Erosion risk map of 3rd level drainage sub-basins classification.