Examples of erosion risk maps using Boolean and fuzzy logical rules in G.I.S.- web platforms

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Abstract

This study is dealing with two different transformation rules for creating erosion risk thematic maps. The first rule, based on Boolean logic, is a well known theory used for composing maps and demanding crisp sets as input data. The second one is the fuzzy logic theory, appropriate for handling fuzzy sets. In this context we present a case study from the Greek territory of Korinth. It concerns the hydrological basin where recently a catastrophic flood event has occurred. As input data we have used field measurements, aerial photos, satellite images, topographic and geological maps.

These data sets were georeferrenced, digitised and introduced to a G.I.S. – web platform. The G.I.S. – web technology permits easy data and map updates. Our software tools were the MapInfo G.I.S., the MapXtreme web interface and the MatLab. The aim of this paper is to emphasise on the utility of erosion risk maps for environmental protection and agricultural uses.

Introduction

The process of erosion is a complex phenomenon and there are many variables involved such as the topography, the geological substratum and the surface rocks, the drainage development and the rainfall distribution. One tool to deal with the erosion – related natural hazards is to construct erosion risk maps. These maps classify areas of similar erosion risk values. The development of these maps are based on the use of different input variables such as rainfall erosion distribution (Fournier, F. 1960, Hundson, N.W., 1981), sediment yield data (Diaconu, C., 1969) and morphotectonic variables (Morgan, R.P.C., 1974, Jozefaciuk, C., Jozefaciuk, A., 1993).

Finally different kinds of soil erosion model have been proposed (Giordano, A., 1986, Kirkby, M.J., 1995, Thornes, J.B., et al, 1996).

Methodology

A multistep methodology has been used to obtain the final output map. Similar papers concerning erosional problems have been published by Brundsen, D., et al 1975, Carrara, A., et al, 1977, Ives, J.D., Messerli, B., 1981, Binagli, E., et al, 1998.

The basic structure of this model is input variables through transforming rules which give the output variables.

The transforming rules can be described by two categories (Fig.1)· the Boolean transforming rules based on classical set theory (grid cell is the elementary unit), while the alternative approach is the fuzzy logic (drainage sub-basins is the elementary unit) where no-crisp sets can be processed (Zadeh, L.A., 1965, Mamdani, E.H., Assilian, S., 1975, Dubois, D., Prade, H., 1980, Yager, R.R., et al, 1987, Zadeh, L.A., 1987, Zimmerman, H.J., 1991).

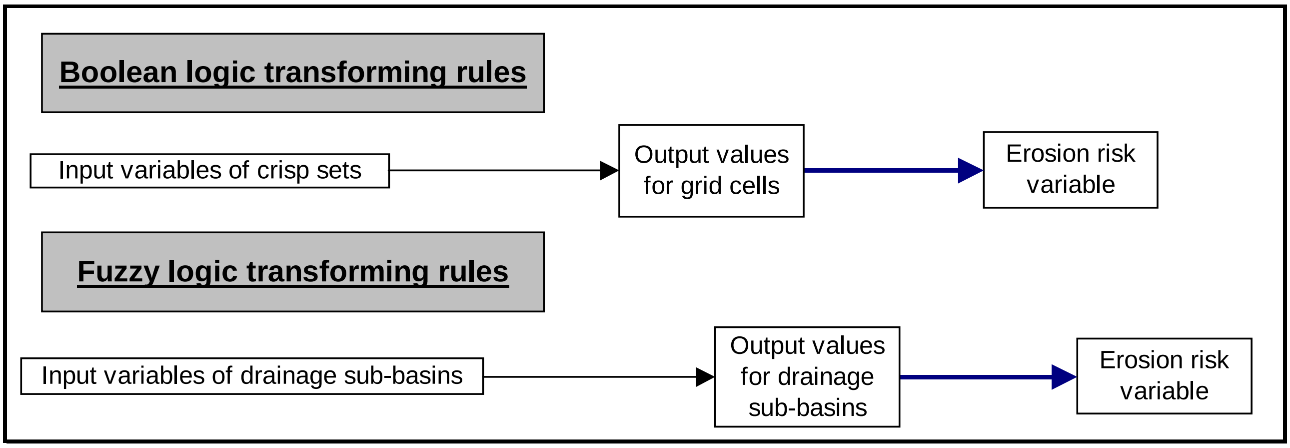

Fig.1: Boolean & Fuzzy logic transforming rules

Case study: The drainage basin of Korinth

The drainage basin of Korinthos is located in the north – eastern part of Peloponnese. A low coastal area in the northern part and a hilly and semi-mountainous area in the south (Fig.2) characterize the topography of this area. The main geological rocks of the basins (IGME, 1978, Nikolaou, N., et al, 1997) are quaternary and neogene formations in the northern part and alpine rocks in the southern part (Fig.3).

The principal input variables used in the study of both models (Boolean and fuzzy) were the erodibility of the rocks, the slope of topography and the drainage density (Fig. 4, 5, 6, 7, 8, 9).

Input variables were obtained by different maps (topographic, geological, drainage system), field data, aerial photos and satellite images in GIS MapInfo environment. Fuzzy calculation has been done in Matlab software (ver. 1999).

The erodibility degree depends of the rocks resistance to erosion and is a function of the rocks composition and discontinuities. The second variable controls the intensity of the erosion. The last one is related to substratum's infiltration and the runoff quantity. The second step to this process is the formulation of the proper transforming rules (Boolean or Fuzzy) such as:

"If Vulnerability is high and slope is high then erosion is Very High".

It must be noted that the possible values of the linguistic variables can be crisp or fuzzy sets.

The final output variable (erosion risk) is the application of the transforming rules to input variables. In the case of the drainage basin at Korinthos, figure 10 & 11 represent the erosion risk maps for the Fuzzy and Boolean model respectively.

Conclusions

A relative simple methodology has been proposed to obtain erosion risk maps. In this area both models (boolean and fuzzy) delineate regions of erosion risk.

It is obvious that in the central and nothern part of Korinth drainage basin the input variables present high values and consequenly the erosion risk is high. This result is confirmed by the extreme erosional event of the last big flash flood in 14/01/01 in the Korinthos county.

The application of boolean logic rules present output data in discrete grid cells using crisp data sets. The most input variables used in such cases have no sharp boundaries and the fuzzy logical rules seem to be more appropriate.

Finally all produced thematic layers, as well as the coresponding databases were imported to the G.I.S. – web platform developed under the MapXtreme web interface, on an Windows NT server. This enables remote users to easily access, manipulate, print and update all chartographic and database elements. Another point is that multiple users may have access at the same time to the web-GIS as MapXtreme keeps an instance of each user's activity until logging off.

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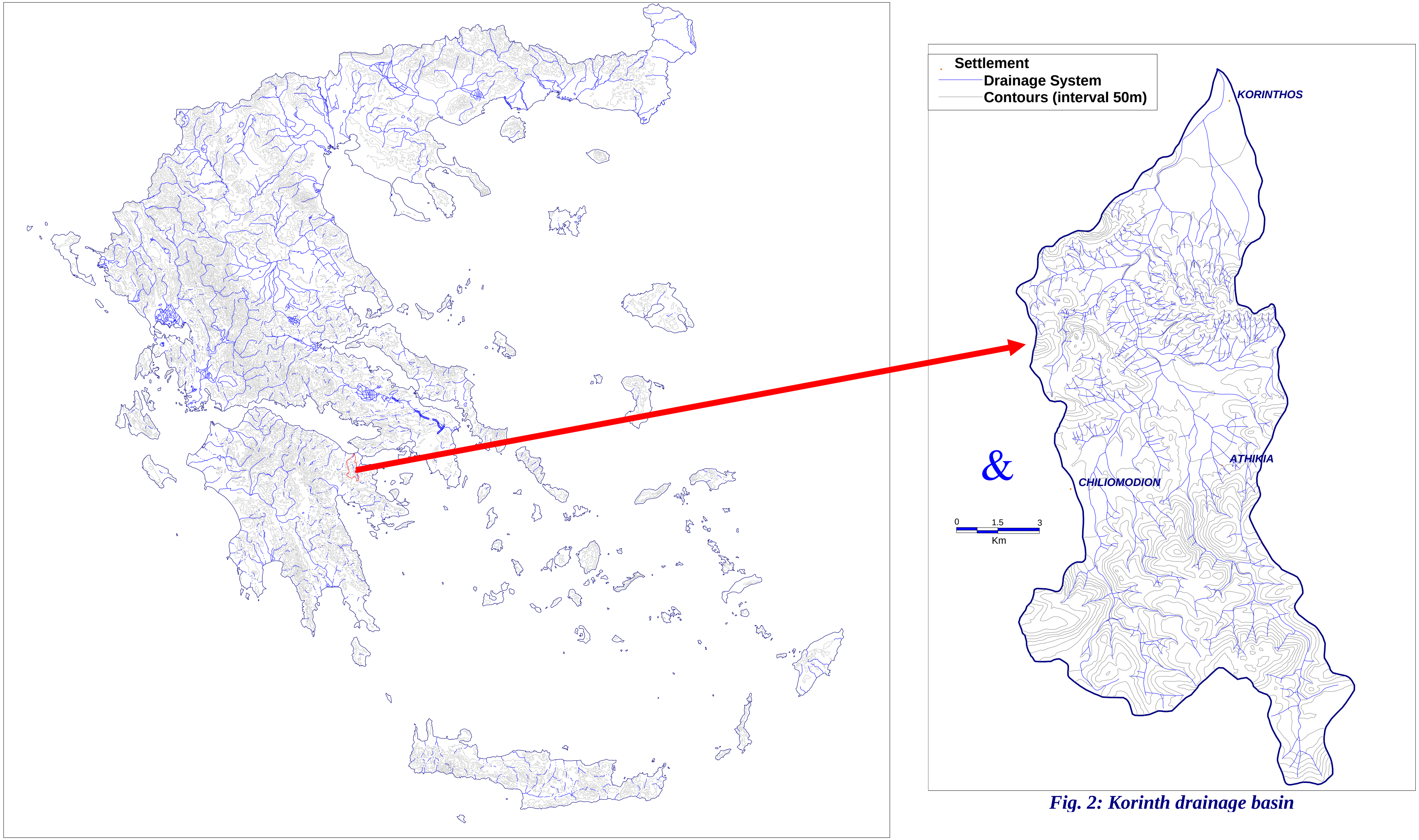

Fig. 2: Korinth drainage basin

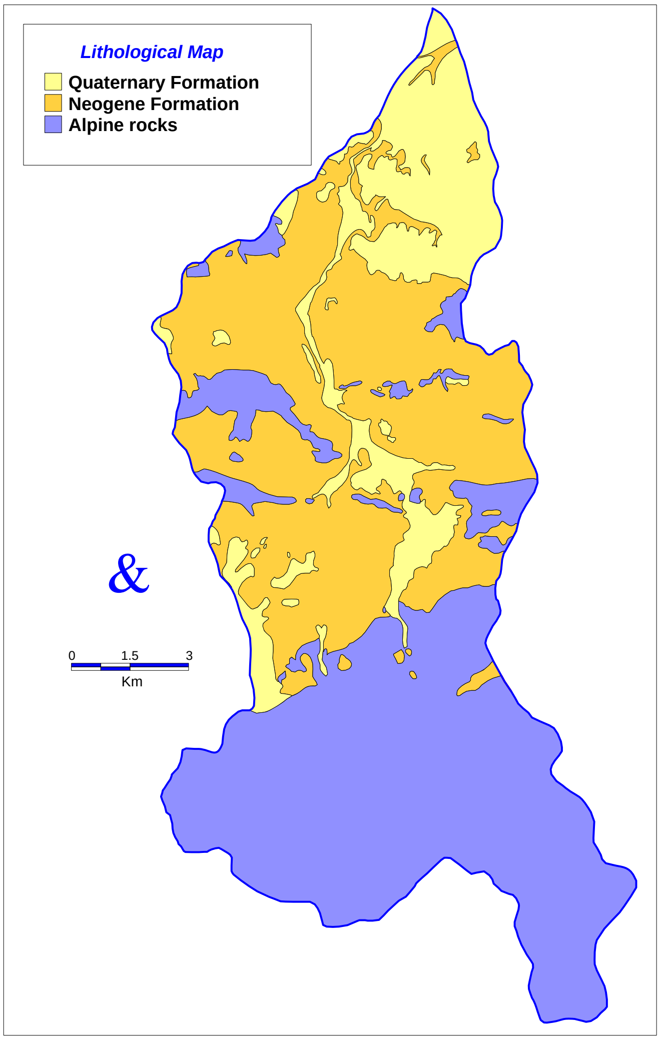

Fig. 3: The Lithological formations of the drainage basin of Korinth.

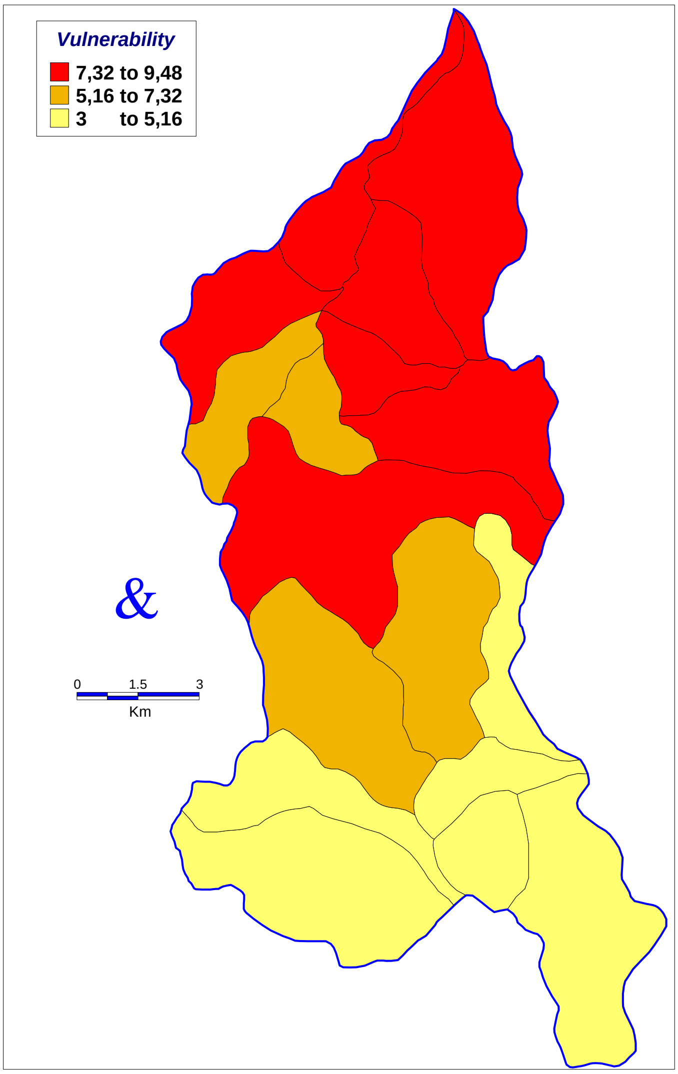

Fig.4: Vulnerability values distribution in Korinth drainage basin used in Fuzzy model.

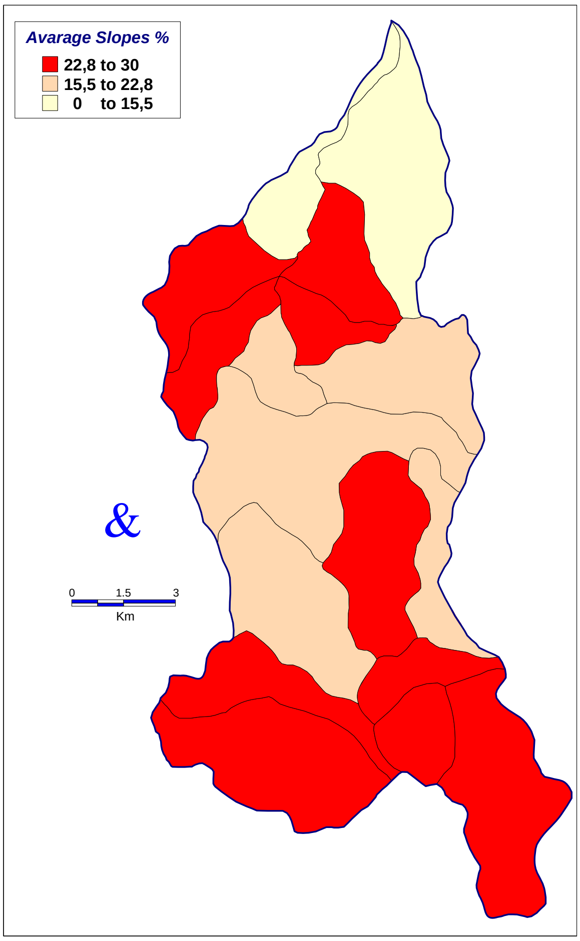

Fig. 5 : Avarage slope distribution of Korinth drainage basin used in Fuzzy model.

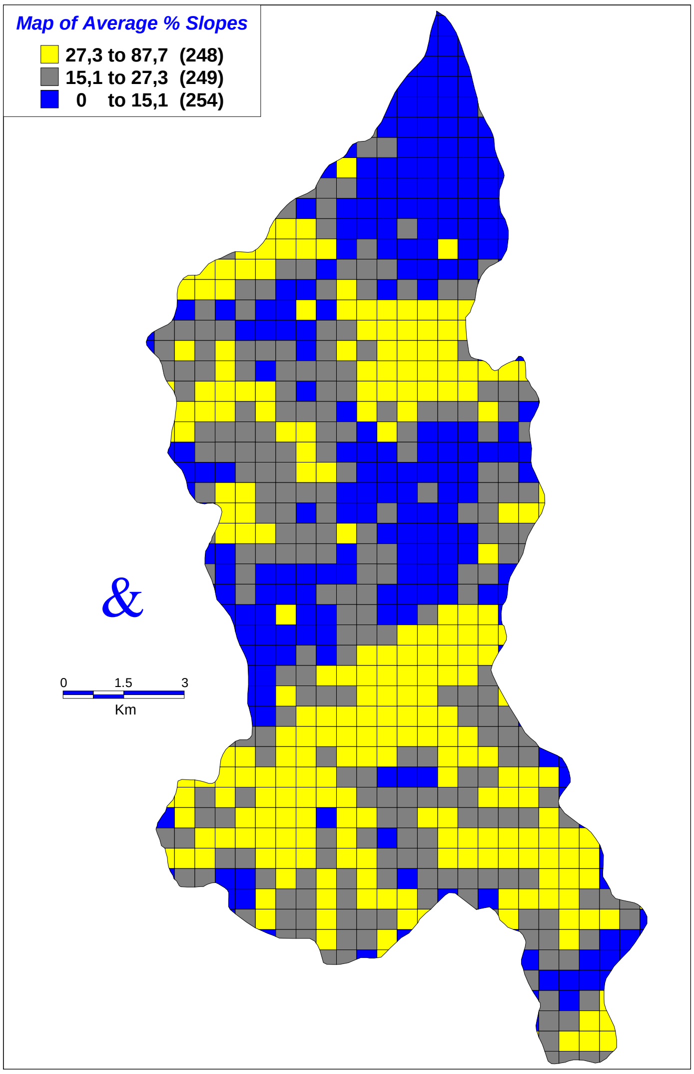

Fig. 8: The morphological slopes distribution in Korinth drainage basin used in Boolean model.

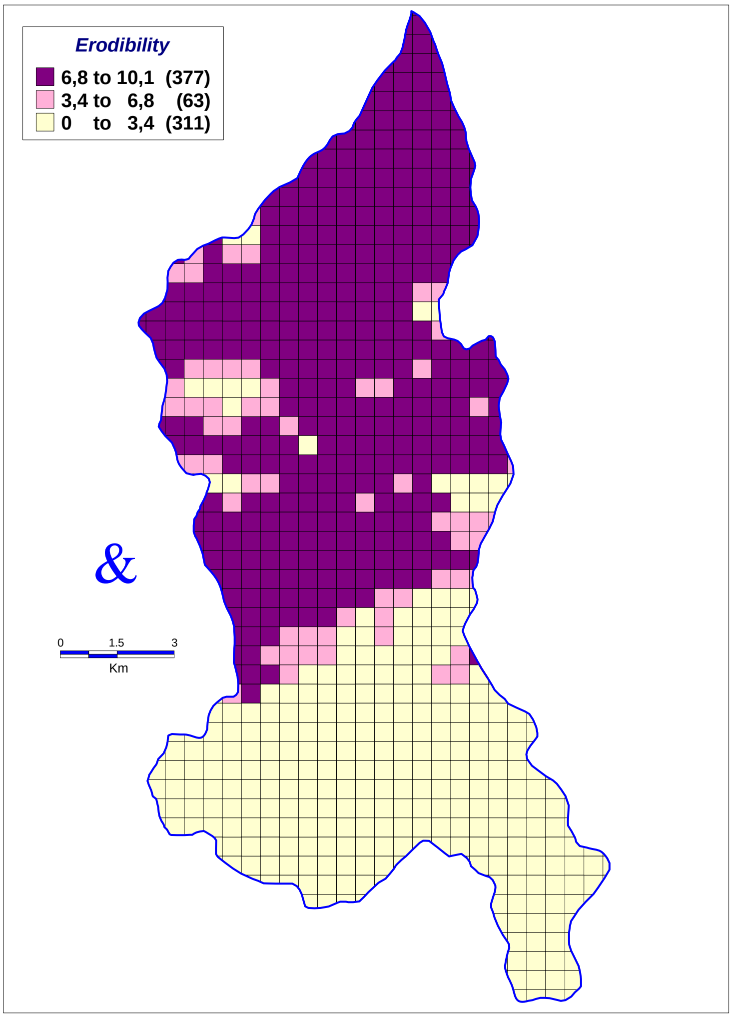

Fig. 7: The Erodibility distribution in Korinth drainage basin used in Boolean model.

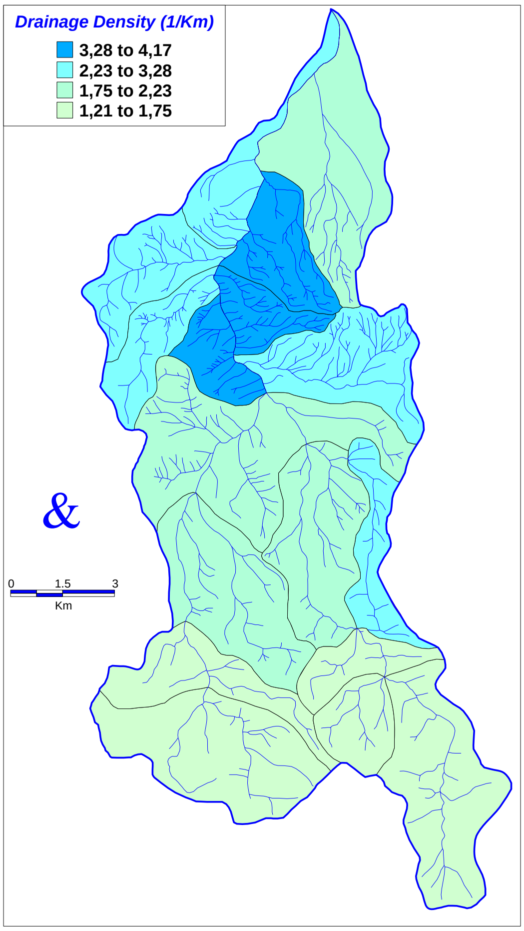

Fig. 6: Drainage density distribution of Korinth drainage basin used in Fuzzy model.

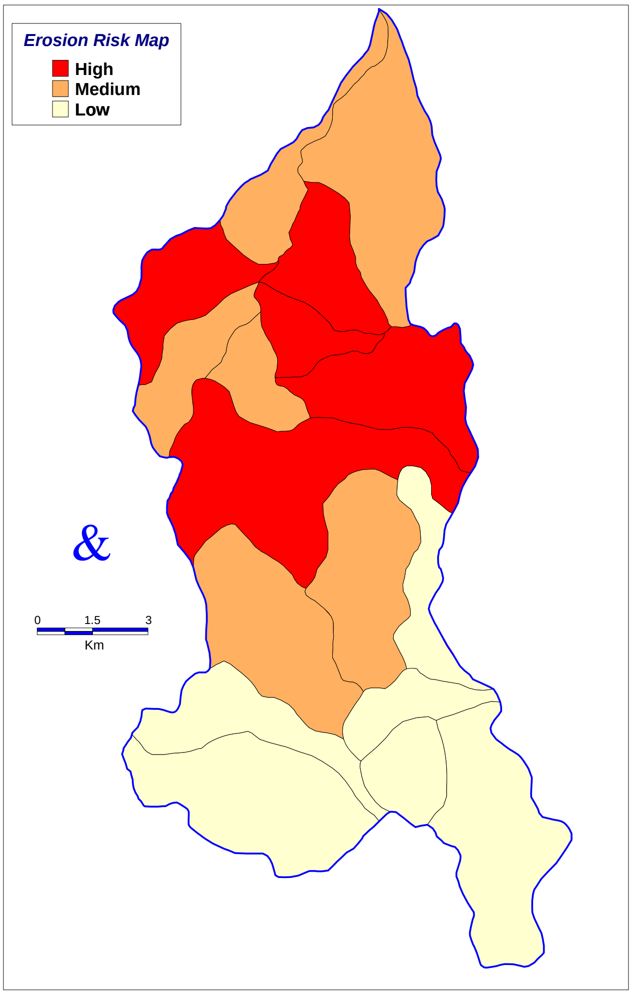

Fig. 10: Erosion risk map of Korinth drainage basin (Fuzzy model).

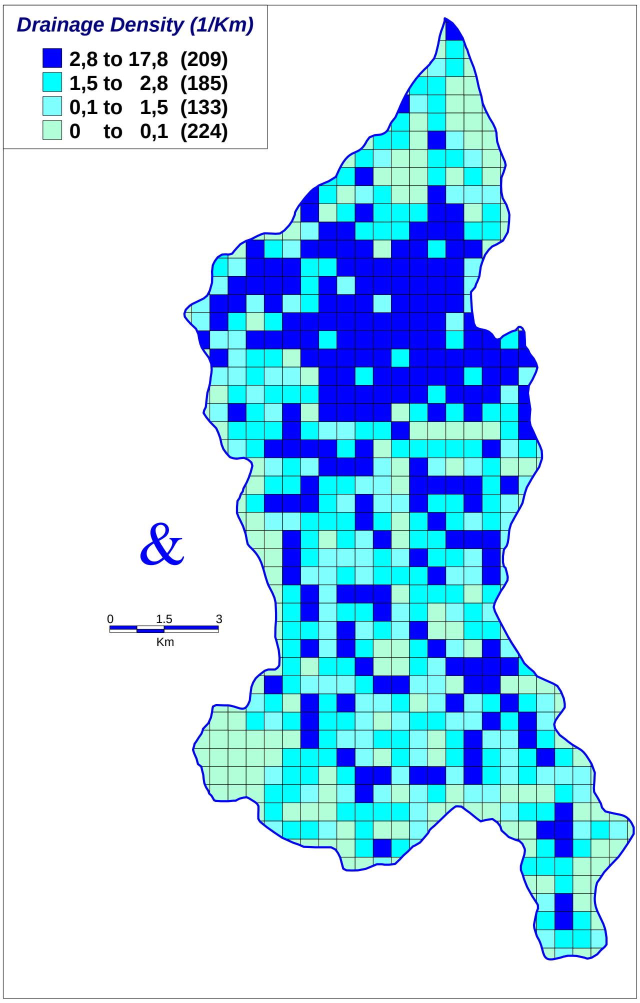

Fig. 9: Drainage density distribution of Korinth drainage basin used in Boolean model.

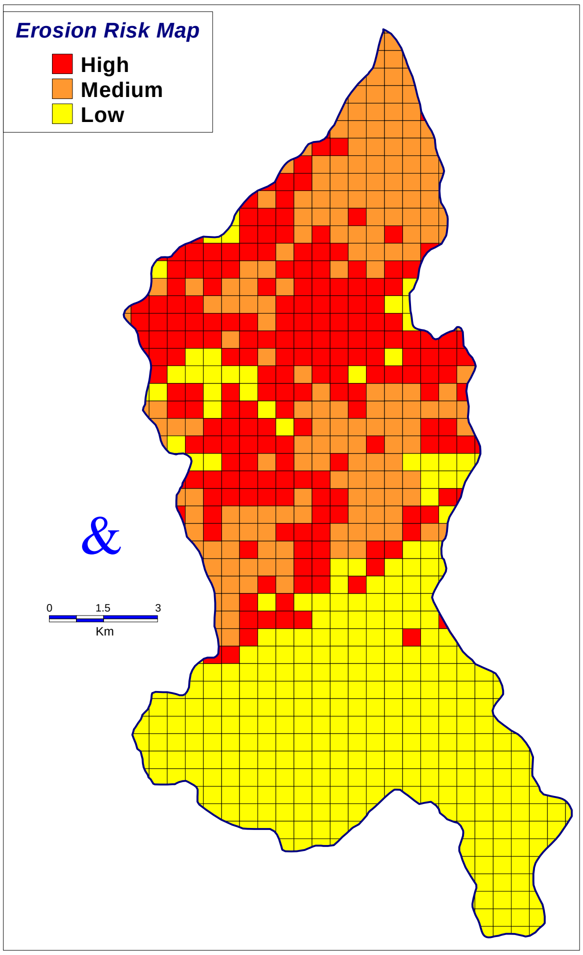

Fig. 11: The Erosion risk map of Korinth drainage basin (Boolean model).