URBAN FLOOD MODELLING IN KARLOVASSI AREA – SAMOS ISLAND, GREECE

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ABSTRACT

As flash flood events are becoming more frequent, the development of flood estimation methods for areas with limited or lack of data has attracted the interest of many scientists. The aim of the present paper is to develop a GIS based methodology in order to study the flood risk in Karlovassi basin.

The annual probability of a flood event is relatively high at Karlovassi area (Samos Island – Greece). Especially, after the forest fires that took place in the summer of 2000, during which 90.000 hectares were burnt in Kerketeas Mountain, the phenomenon has become more intense.

Primary data were collected from maps, literature, aerial photos and field work. The collected information data were analyzed through the use of the software ArcGIS in order to generate the appropriate background for the formation of the flood risk model. All the input parameters were weighted and the model was calibrated in situ through field work.

The proposed methodology and the preliminary results, as exported for the Karlovassi area, prove the suitability of GIS-based methods in the creation of flood risk maps.

KEYWORDS: Flood risk; modelling; Karlovassi, Samos.

1. INTRODUCTION

In recent years, catastrophic floods endanger human lives and cause heavy financial disasters of the private property. Between 1998 and 2002 Europe suffered more than 100 major floods that have caused 700 fatalities, the displacement of about half a million people and EUR 25 billion in insured economic losses. Floods are natural phenomena, which are likely to become more frequent and more severe as people live and work in urban areas inside floodplains, increasing in this way the surface run-off of storm waters. Additionally, climate change is expected to cause more extreme rainfall events that may lead to increased flood risks. It is estimated that between five and ten percent of Western Europe's population lives or works in floodplains and uses recreation or transportation facilities, which are also flood prone (Handmer, 2001).

The flood impacts can be enormous that's why knowledge of related risk is important to communities, insurance companies as well as the local authorities. However, the availability of data is always a critical parameter in any simulation of environmental systems that's why methodologies that provide initial estimation of flood risk can be proven to be valuable tools for the design and the strategic planning of flood protection infrastructures.

Flood risk analysis correlates with the probability of a flood event together with related negative consequences, such as injuries and/or deaths, damages on properties, social and economic disturbance and environmental degradation (Fountoulis and Mavroulis, 2008).

Until recently, flood protection policy was usually formed as a matter of local plans in isolated parts of the river's catchment, with no consideration for the impacts in the wider area of the basin. This approach has changed throughout the years and as proposed by the Flood Risk Directive 2007/60 CE the management and planning should be organized upon the catchment scale, taking into account the drainage basin characteristics (Fleming, 2002).

The catchment scale consideration provides the decision maker with the suitable technical background not only for the forecast and estimation of the flood event, but also for the evaluation of the related risk. This level of analysis favors the identification and mapping of flood prone zones, the formation of a holistic and an integrated flood management scheme as well as the consideration of possible future effects (e.g. climate change) in the:

- intensity and frequency of flood events
- proper planning for dealing with floods
- extent if the areas at risk

The main target of this study is to estimate the flood risk in Karlovassi area categorizing areas in different levels of susceptibility. In order to determine the parts of the drainage network, especially the parts which favor probable flood events, multiple processing steps were required, as described below. In particular, the flood risk estimations were based on the geometrical characteristics and the morphology of the study area.

The methodology applied, involved primarily the estimation of the streams' power and the flood risk related to these streams. Although the estimated stream power refers to the total basin area, it was calculated at the outlet of the catchment, where the dynamic energy of the total runoff has been transformed to kinetic energy.

The above mentioned calculations depend on the estimation of the basic characteristics of the river basin (Fountoulis et al., 2007, Karagiozi, 2008), which are:

- the mean elevation,
- the mean slope and,
- the relief index of the basins

These characteristics were estimated through the formation of the digital elevation model (DEM) of the study area. In order to produce the required secondary data, further spatial and quantitative analysis was performed.

In addition, the use of the elevation data and the relief simulation resulted into the vectorization of the drainage network and the basin of the study area, in two thematic layers (linear and polygon features). The production of the Digital Elevation Model and the further processing was carried out using the ArcMap v.9.2 software (ESRI Corporation).

2. STUDY AREA

2.1. Geographical setting

The study area is located in the North West part of Samos Island in a town called 'Karlovassi'. The annual probability of a flood event is relatively high; flood events cause damages mainly to Karlovassi and its surroundings. The flood risk was dramatically increased as a result of the devastating forest fires of July 2000, which burned almost 90.000 hectares in Kerketeas Mountain, east of Karlovassi and destroyed the vegetation cover in a big part of the island (Gournelos et al., 2001). The flood of October 2003, which caused extensive damages to the urban road network and the surrounding settlements, represents a typical example. In November 2001, another flood event, accompanied by debris flow caused severe damages near the streams' outlets in Karlovassi town.

The drainage basins of two streams were jointly studied (Fig.1): a) Megalo Rema, which crosses Karlovassi and discharges in the sea and b) Fourniotiko Rema which discharges east of the town and is well known for its substantial flood discharges during flash storms.

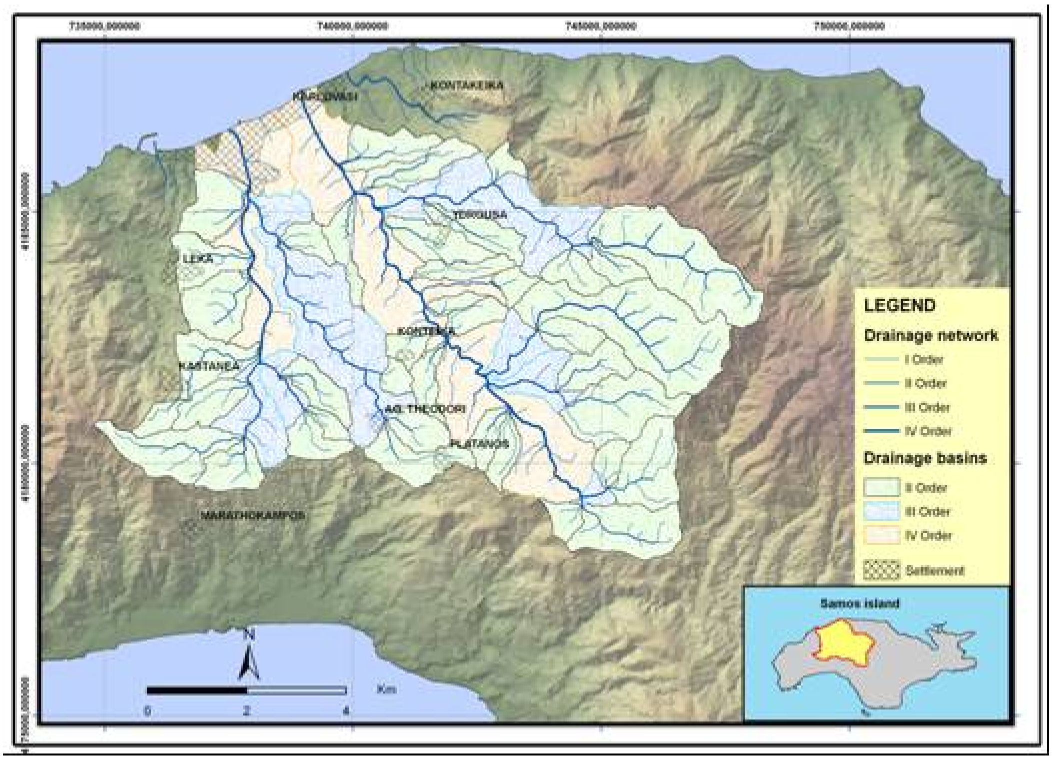

Figure 1: Drainage basins of Fourniotiko and Megalo Rema streams.

The Megalo Rema stream springs from Platanos and Kastania Mountains and the hills of Marathokampos. The morphology of the drainage basin is hilly and of relatively low angle slopes. According to the Strahler stream order classification, the drainage basin is IV order and is divided into 3 sub-basins of order III. The basin covers a total area of 25,2 km^2, while the length of the main river is 10,13 km.

As far as the Fourniotiko Rema is concerned, the morphology of the drainage basin is characterized by relatively steep slopes and low discharge rates, compared to other basins of similar size (Provatas et al., 2004). The drainage network is of dendritic type, which is the most common type and is dominated by typical sedimentary formations. According to the Strahler stream order classification the drainage basin is of IV order and is divided into 5 sub-basins of III order and covers a total area of 45,8 km^2. The length of the main river amounts to 13,51 km.

2.2. Geological characteristics

The Karlovassi basin constitutes a tectonic grabben with North-South direction, developed between Ampelos schists and Marathokampos-Kosmadei schists (Theodoropoulos, 1979; Papanikolaou, 1979).

The main lithological formations (Fig. 2 & 3) in the wider area of Megalo Rema stream's drainage basin consist of neogene sediments (marls, travertine limestones, clays, sandstones, breccias-conglomerates, volcanic tuff and tuffites). Among these, the most common are the marls and the travertine limestones, which cover extended areas and present significant thickness. In the lower parts of the valley, alluvial sandy-clay deposits overlay the thin-bedded marls. As for the catchment of Fourniotiko Rema, the lithological formations consist of Quaternary sediments downstream and marls, as well as schists-volcanic rocks upstream (Papanikolaou, 1979; Riedl, 1989).

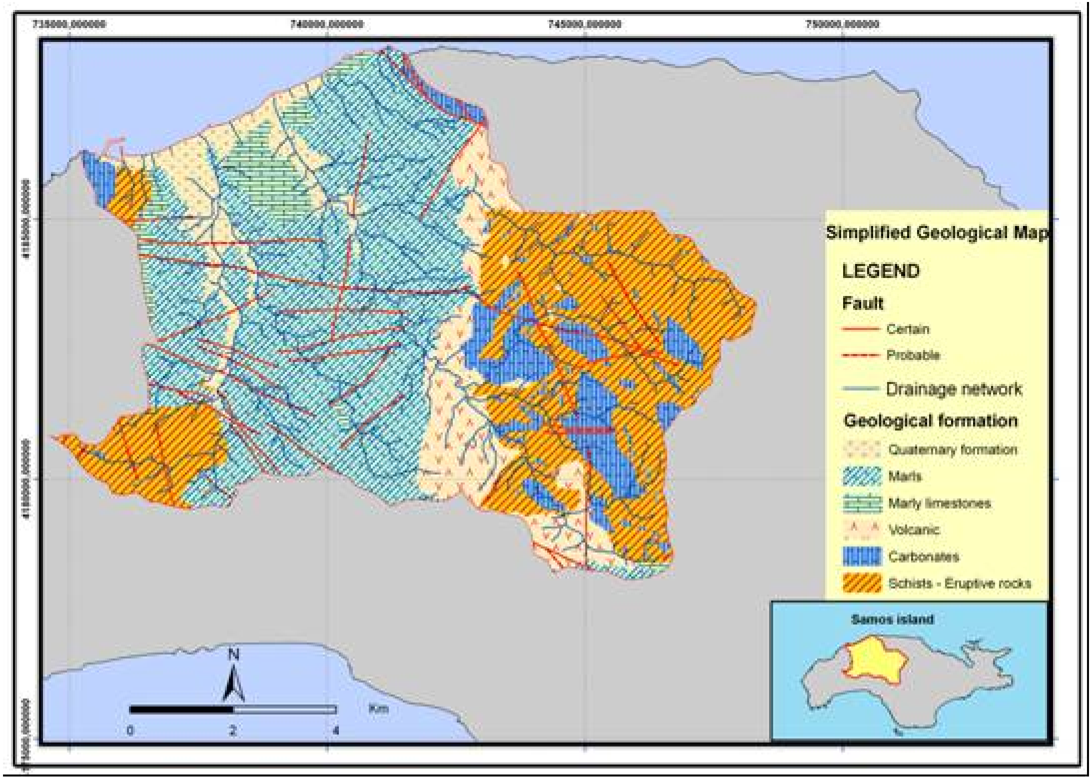

Figure 2: Simplified geological map of the Karlovassi grabben (edition of I.G.M.E. after Theodoropoulos, 1979).

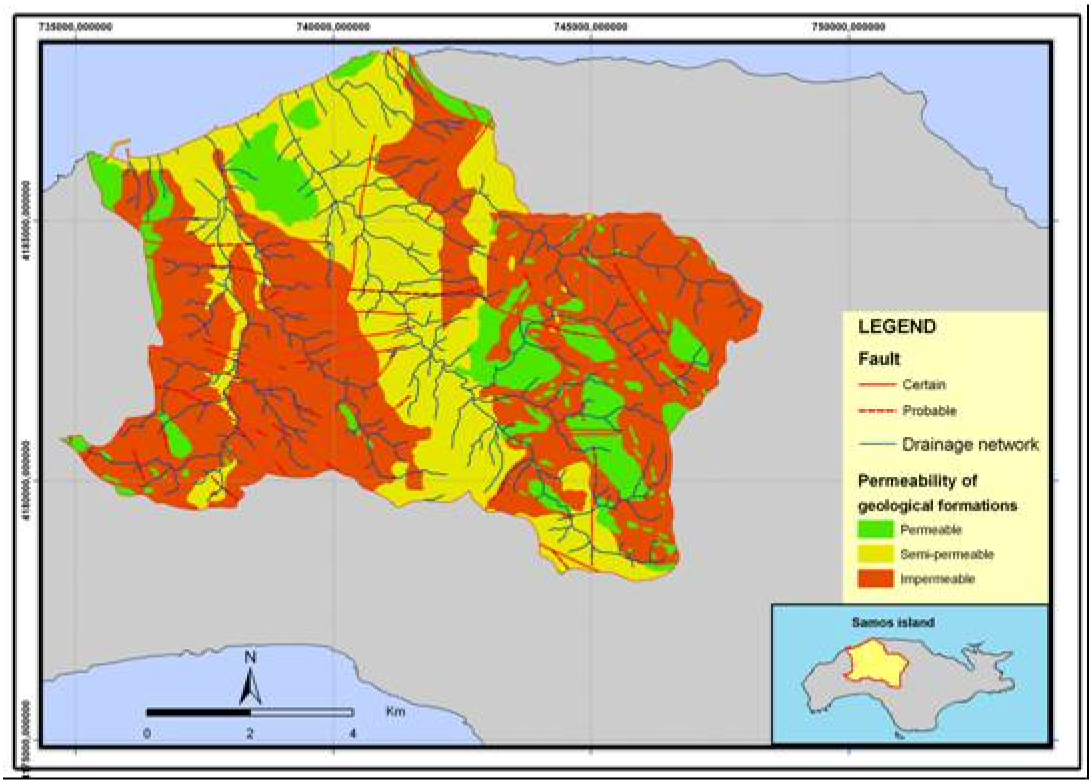

Figure 3: Permeability of geological formations of the Karlovassi grabben.

3. METHODOLOGY OF FLOOD RISK ESTIMATION

The main stages of data processing include a) the generation of the digital elevation model, b) the generation of the drainage network, c) the generation of the basins, and d) calculation of the parameters concerning the drainage basins (Figs. 4-7).

The generation of the digital elevation model was carried out through the use of primary data, as obtained by the digitization of the contours (20 m step) and the trigonometric points from the topographic maps of the Geographical Military Service (scale 1:50.000). The generation of the DEM involved two stages, the production of the 3-Dimensional Triangular Irregular Network (TIN) and the production of a digital terrain model in a rectangular block of cells (GRID). The TIN is a highly detailed representation of the surface and is based on triangles formed by joining three neighboring altitude points, which are selected using certain criteria (Schut, 1976).

The GRID includes altitude points in the vertexes of its cells arranged in rows and columns, which form a raster-data structure. The produced Digital Terrain Model (DTM) was used as primary data for the vectorization of the drainage network and the watersheds of the study area. After its completion, the DEM was checked for sinks and was modified, where necessary. The hydrological depiction of the drainage basins is a significant parameter for the calculation of the hydrological parameters and the further study of the drainage systems in the area of interest. For this purpose, the depiction of drainage basins of 2nd or higher order (polygon features), the basins' outlet (point features), as well as the drainage network (linear features) and its classification according to the Strahler stream order classification, were carried out.

For the calculation of the stream power the parameters used were the mean slope, the maximum and minimum elevation, the extent and the mean elevation of each drainage basin. Having completed these calculations and the overall study of the hydrological system, it was possible to proceed with the estimation of the flood prone areas, through the production of the final Flood Hazard map of the basins.

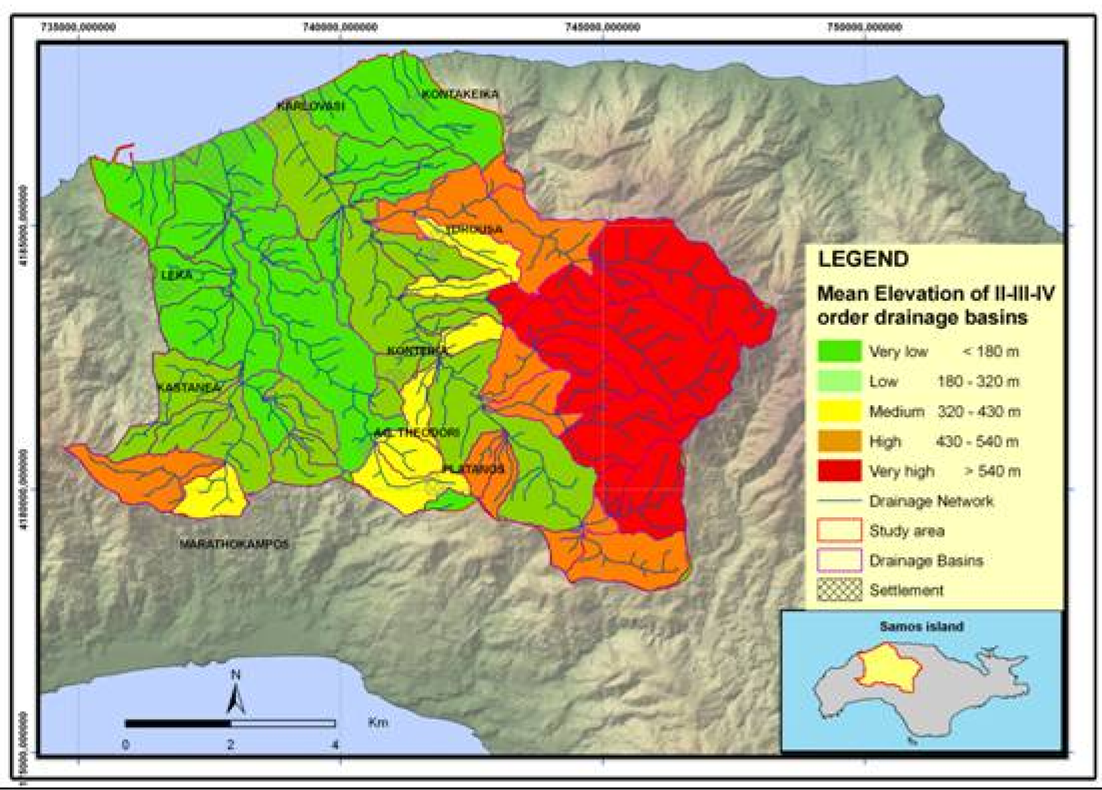

Figure 4: Mean elevation of the drainage basins.

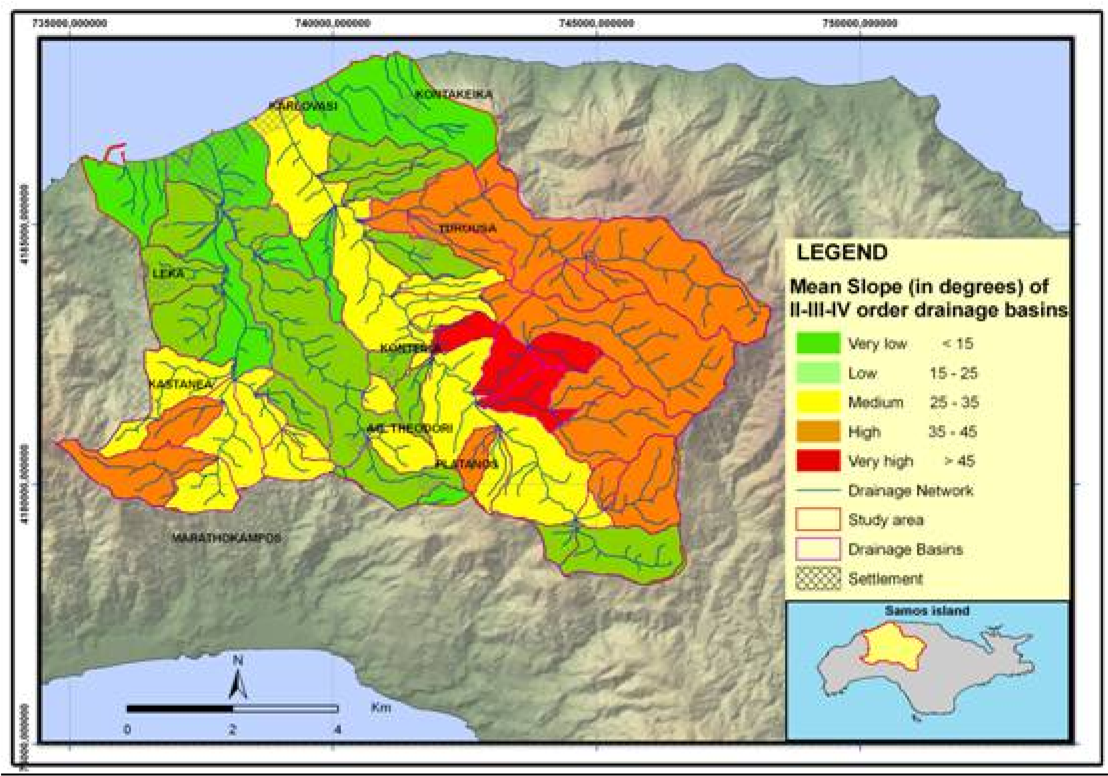

Figure 5: Mean slope of the drainage basins.

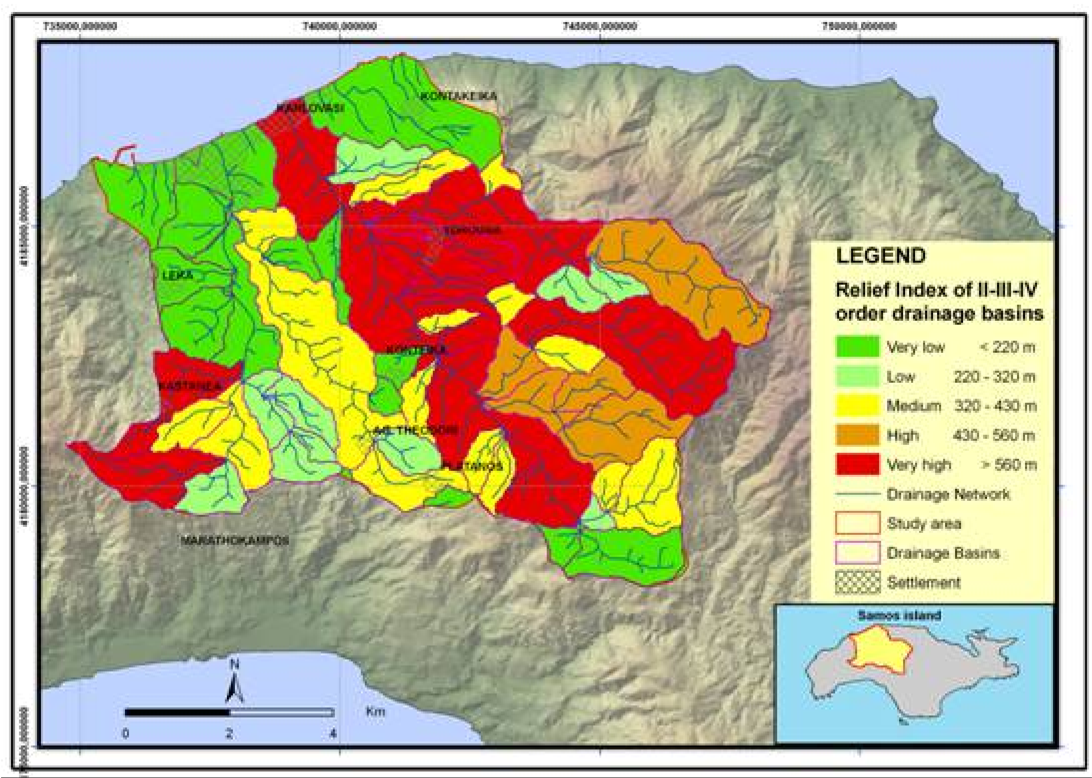

Figure 6: Relief index of the drainage basins.

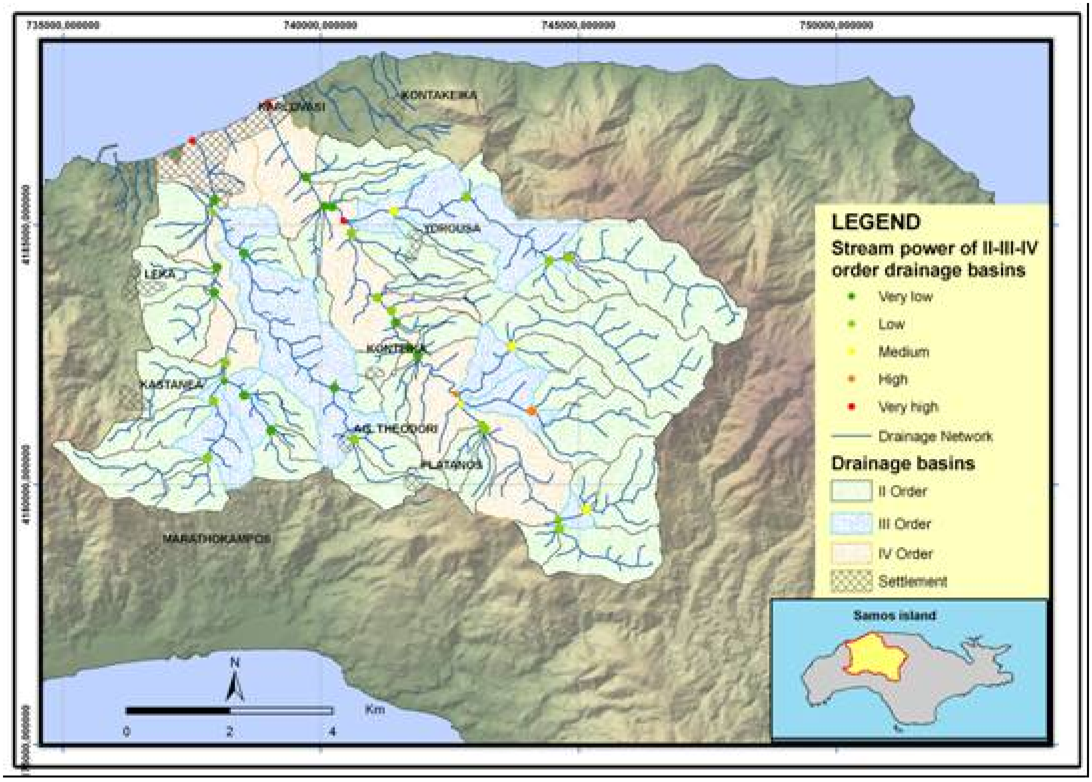

Figure 7: Stream power of the drainage basins.

The outlet of each catchment (of order II or higher) was considered as the site where the dynamic energy of the discharge has been transformed to the kinetic one.

In order to maximize the differentiation among the basins' outlets, the above mentioned parameters were used as input in a mathematical product, each one functioning as an "amplifier" to the total. The mathematical product does not comprise a measure of the rate relief of the stream power, but a very well defined quantitative measure for the comparison of the outlets.

Under the assumption that the expansion of the stream power is placed downstream, two more steps were taken for the better representation of the stream power: the calculation of each catchment mouth's elevation and the mapping of the low elevation region in the study area.

Finally, for the better definition of the high flood prone sites (according to the morphological characteristics), the map of the stream power was reinforced by two more limitations, that of the morphological slopes and that of the site elevation which has to be equal or lower than the elevation of the energy – relief point. For this reason, an extra calculation was necessary, so that the previous map be redefined taking into account the elevation and the morphological slopes.

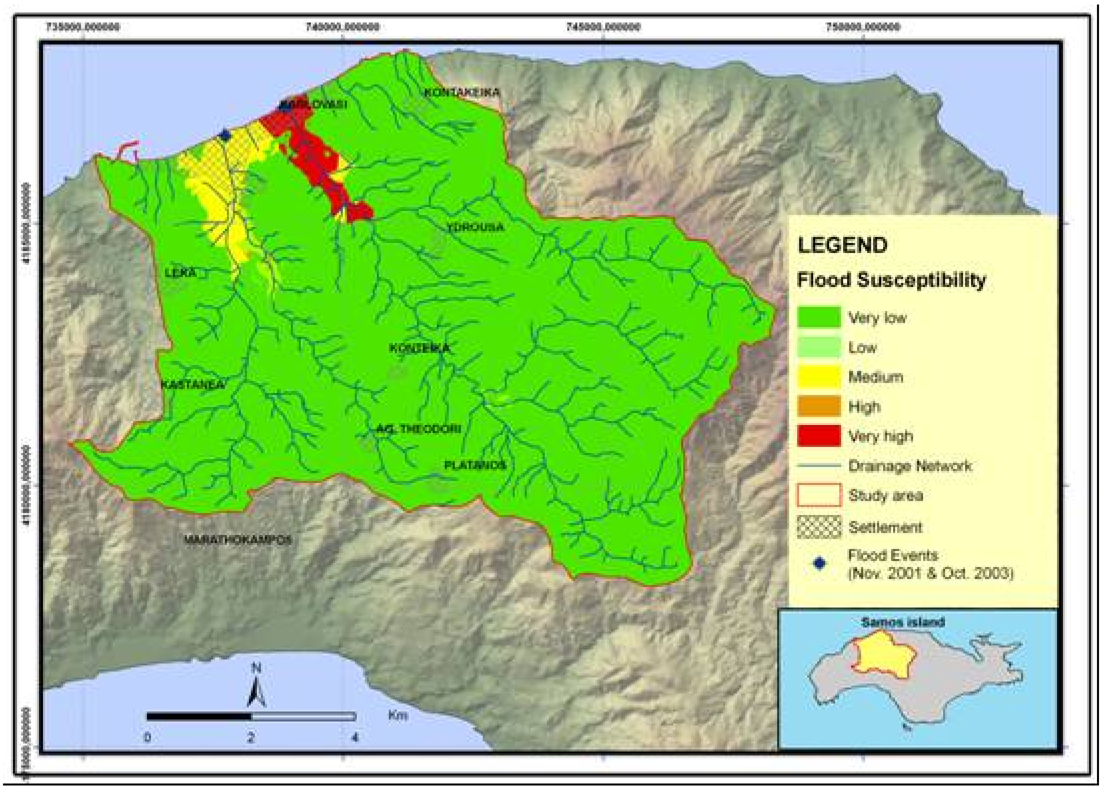

Figure 8: Flood risk in the Karlovassi drainage basin.

4. CONCLUSIONS

This study is focused on the generation of flood hazard maps, concerning the flood risk in the Karlovassi basin. The flood events in this area appear to be frequent due to the favorable conditions created by the physical parameters in the area, particularly after the extended forest fires and the human interference in the watercourse.

It must be mentioned, that this study constitutes a first approach of the flood risk in Karlovassi basin and should be combined in following studies, with meteorological data and data concerning the human interference, in order to reinforce the produced Flood Risk map.

The flood hazard map shows that the areas with medium up to very high flood risk are associated with areas of Holocene formations. Moreover, the susceptibility results deriving from this map are consistent with the in situ observation and the recent flood events that occurred in the area.

Flood preventing infrastructures should be constructed primarily in the upstream areas, so that the phenomenon is dealt with at its origin (Fountoulis et al., 2007, Fountoulis and Mavroulis, 2008). Another finding is that there hasn’t been any flood event in intra-basin high elevated areas and upstream of the sites in the river bed, where the stream power abruptly increases. On the other hand, these are exactly the areas where the main inbound volume of water will be gathered, before flowing towards the river mouths in the lower elevated areas. With respect to these characteristics, flood protection works in these areas are considered as most suitable and effective for the containment of flood events. In the low elevated areas, of high and very high values in the hazard map, little can be done for the prevention of the phenomenon, since protection works will be of very big scale, disproportionate cost and more importantly less effective On the contrary, it is advisable that institutional and regulative interventions and measures can be taken in the floodplains, in order to secure the physical operation of the flood plain, along with the protection of sensitive areas from human activities that increase further the susceptibility.

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