How spatial variation of main hydrological parameters affects stream floods in the region of mount Ossa, Greece

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ABSTRACT: The sloping area on the North and North-East of Mount Ossa, opposite Mount Olympus, in the region of Thessaly, Greece, receives considerable rainfalls. However, despite its extended natural vegetation, severe problems have arisen due to floods. The existence of these problems is mainly based on two reasons: a) on the peculiarity of rainfall events combined with the local conditions (hydrologic, geologic, land use, etc.) and b) on the existing infrastructure works. In order to analyze and interpret the phenomena of local floods, in the frame of the research programme "Archimedes" which is materialised by the TEI of Larissa under the title "Spatial mapping and estimation of hydrological risk, emphasising the floods and draughts in urban and non urban areas of Thessaly and their environmental impacts" it is essential to record, evaluate and validate various hydrologic parameters of the corresponding study area. The Geographic Information Systems (GIS) is utilised to analyse and validate the information about topographic, hydrologic, geologic and soil data, along with land cover and infrastructure. Finally, the GIS are also used to produce and map complex hydrologic parameters, which consist of input data for hydrologic models as well as presentation of results.

INTRODUCTION

The region of the North and North East slopes of the mount Ossa, in Thessaly, Greece, is covered by rich and dense natural vegetation, forest trees, shrubs etc, especially chest nut trees, which, locally, is considered a valuable means for agricultural development. The level of rainfalls in the area is considerably high; almost three times higher compared to those taking place on the main part of Eastern Thessaly. This situation, combined with the local hydrologic conditions and the existing infrastructure, has resulted in serious problems concerning damages due to excessive flood events.

In the frame of the research program "Archimedes – EPEAEK II", co-funded by the European Social Fund & National Resources and realized by the Dept. of Civil Engineering of TEI of Larissa, Greece, the above region has been selected as a study area. The work is aiming at a fluent evaluation of hydrological parameters, which are related to the estimation of flood discharges.

These flood discharges, which actually constitute the main problem, take place occasionally during the winter and are due to the large amount of water in the streams. The problem, therefore, is originating to the:

- particularity of the rainfall events in this region,
- local conditions, i.e. hydrologic, geologic, land use, etc and
- lack of the necessary infrastructure works.

The environmental consequences of the above floods are highly crucial for both the cultivated areas and the local delta of Pinios river.

For recording and management of the necessary for this study local data, the Geographic Information System GIS-ArcView has been utilized. The use of GIS [1] is advisable for any presentation of the spatial variables and for this reason it has been treated as the main tool for a large number of applications, like water resources management [2], [3], [4], [5] etc.

As far as estimation of flood discharge is concerned, it has to be noted that there are spatial parameters, that after processing, create input data for flood simulation [6] through hydrological models [7], [8], like soil data, data of vegetation cover, land use, relief, stream network characteristics etc.

The processing of the above data, may directly lead to hydrological parameters, like the area of hydrologic basins, the slopes of the basins and their water streams, runoff coefficients etc.

PROCEDURE

For recording and plotting both the existing information and the resulted conclusions, the Geographic Information System GIS-ArcView has been utilized, so that the spatial variability of different parameters may easily be presented. The GIS is a powerful technology approachable and accessible to many users. This technology allows for an automatization in many procedures, therefore working in a complementary way for many analytical methods, which are utilized for aquatic resources management [1].

For analysis, estimation and evaluation of flood events on the study area, the collection and use of a variety of data is necessary. Some of this data may concern hydrological, soil and geological characteristics, use of land, vegetation cover, and terrain, along with the existing infrastructure works. The last one may comprise the road network, the cross section of natural water streams, technical works and crucial cross-sections that affect the flow of water.

For this reason the following tools have been utilized:

- Maps of Hellenic Army Geographical Service (HAGS), scaled at 1:5000 and 1:50000,
- Geological maps of the Institute of Geology and Mineral Exploration (IGME), scaled at 1:50000,
- Soil maps of the Ministry of Agricultural Development and Foods (MADF), scaled at 1:50000,

- A silvicultural map scaled at 1:20000 and
- A map of mount Ossa's soil cover, i.e. borders of forest vegetation species, scaled at 1:350000.

Apart from the above official data it was necessary to collect data from local field measurements; for this reason the following activities were realized:

- Soil samples taken from different locations all over the study area. The depth of samples may vary in the ranges of 0-30, 30-60 and 60-90 cm. Every location of sampling was recorded through a Geographic Positioning System (GPS).
- Elements of technical works, having the form of stream bridges, along the axis-road Omolion – Stomion – Karitsa, were recorded i.e. their cross sectional details along with the position of each work, through GPS, were saved in corresponding files. There were totally 46 positions of technical works, ranked from very small to very large stream bridges. Each one of the corresponding streams is basically connected to one or more watersheds.
- Topographic data for plotting the slopes along with the corresponding cross- sectional areas of the main streams that belong to the study region.

All the above cartographic information, related to the study area of mount Ossa are shown in Figure 1, where, the watersheds were drawn with a bold contour. They were then digitized and converted to GIS-ArcView format files, where, the inter-correlations among the geographic elements, i.e. their topological relations [1] along with their database connected to them were developed.

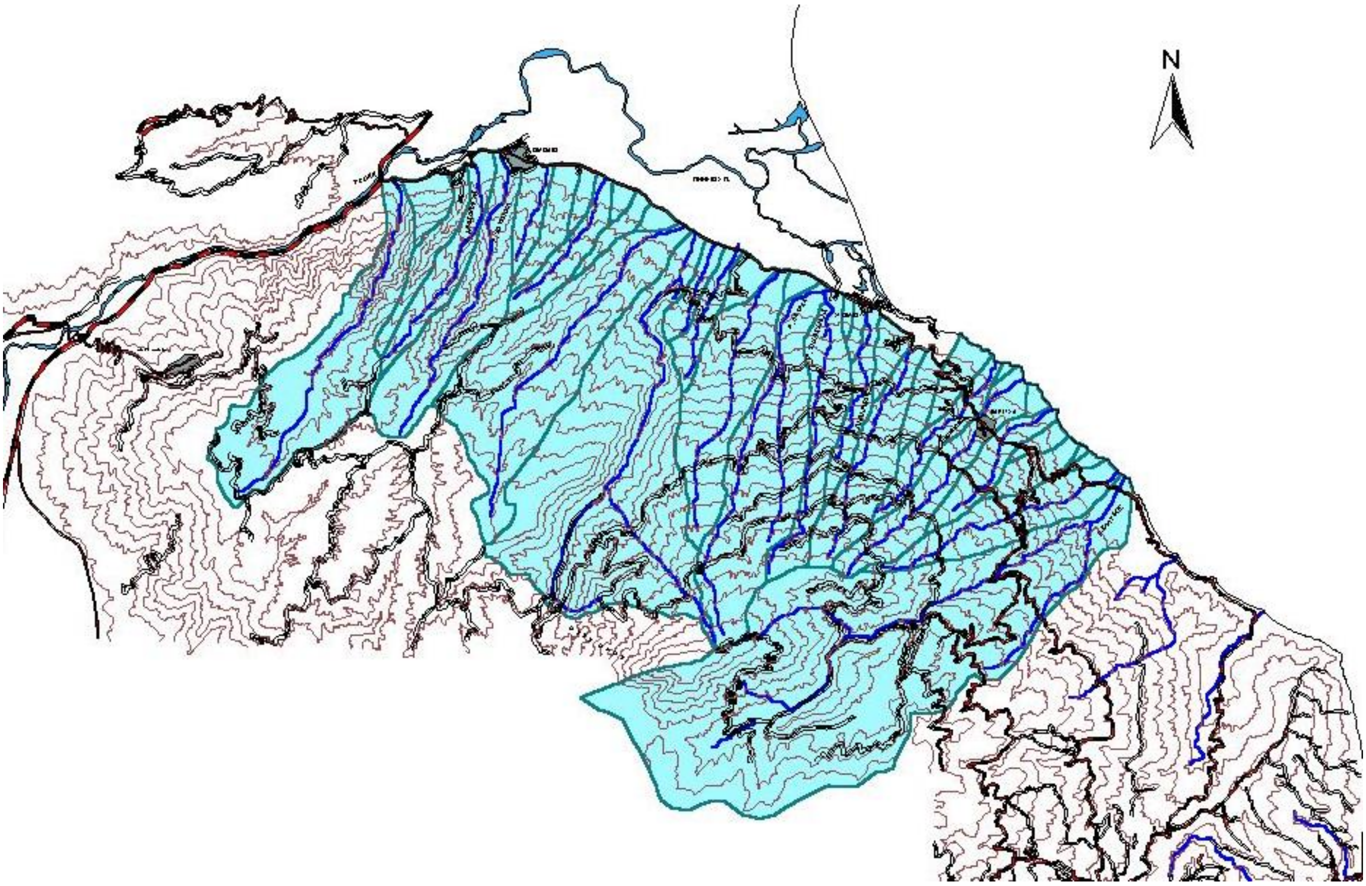

Figure 1: Topographic map of the local study area with the contours of watersheds, sc. 1:166300

On the top of them, there were created in the GIS files, secondary information, like:

- the borders of watersheds of the most important water streams, along with their area, average slope and data base,
- the database of water streams accompanied by their length, average slope and the corresponding locations of the selected cross sections, along with their geometrical characteristics,
- the database of soil samples, taken out of selected locations of the study area.

All these data were then combined and worked out to give results, which in turn became new data necessary to simulate the natural system.

The elaboration of elements comprises:

- Topological processing of hydrological and topographic data, i.e. hydrographical network, watershed areas, slopes of the earth and the water streams, as well as length and cross sections of water streams.
- Topological processing of pedologic maps along with their corresponding data.
- Topological processing of silvicultural maps and maps of vegetation cover.

The average slope of the watersheds has been calculated through the equation of Gregory & Walling, as described by Tsakiris [10]:

$$S_g = \frac{\Sigma L \cdot D}{E} \ , \qquad (1)$$

where S_g is the average slope of the watershed, ΣL is the total length of the contour lines, D is the contour interval of lines and E is the area of the watershed.

The outflow of the watershed could be estimated through the Soil Conservation Service (SCS) method, where, an estimation of the runoff curve number, *CN*, is required [9], [10], [11], [12], [13].

This coefficient is given in tables and varies according to the land use, to the management or practise, to the hydrological conditions and to the type of earth [9], [10], [11], [12], [13].

In the case that there are more than one land uses within the watershed, then, the so called composite curve number, CN_c, must be taken into account. This number is an areal weighted average of the watershed sub-regions and is calculated through the equation

$$CN_c = \frac{\sum CN_i \cdot E_i}{\sum E_i} = \sum_{i=1}^{n} CN_i \cdot \varepsilon_i \qquad (2)$$

where CN_i represents the runoff curve number for the sub-region *i*, E_i is the watershed area for sub-region *i*, and ε_i is the relative area of sub-region *i*, over the total watershed area ($\Sigma\varepsilon_i = 1$).

The composite curve number, CN_c, for every watershed has been calculated through the GIS-ArcView programme, provided, all the partial runoff curve numbers for every soil cover category within each watershed, have been taken into account.

RESULTS

In the above study area there are various species of forest vegetation and pastures as shown in Figure 2.

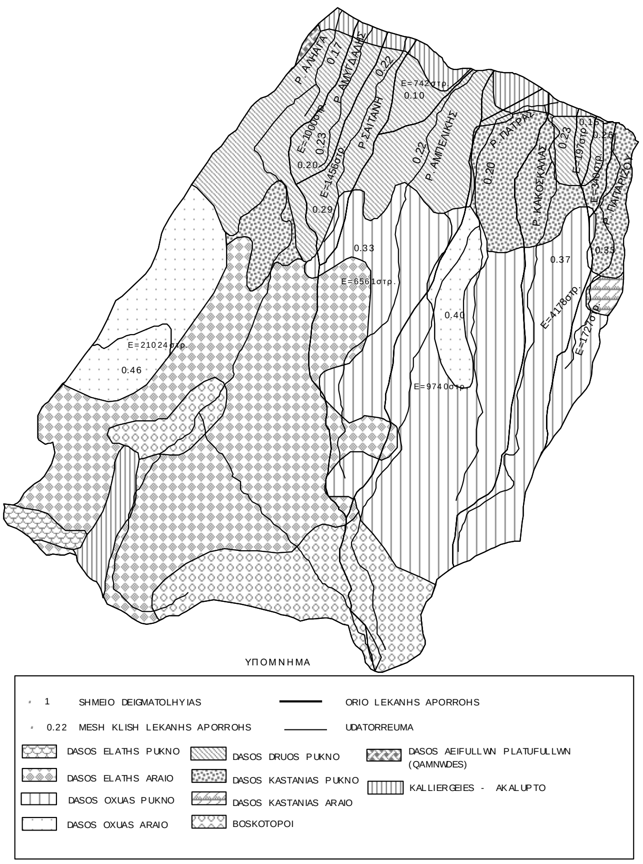

Figure 2: Part of the study area with categories of soil cover and soil sampling locations, scale 1: 82000

The elaboration of cartographic data along with the data and types of earthy plotting result in the estimation of:

- the area along with the average slope of the hydrologic watersheds,
- the slopes, the lengths and the cross sections of water streams.

Figures 2 and 3 represent graphically the above results.

An analysis of the soil samples taken from depths up to 90 cm, wherever feasible, leads to the conclusion that, according to the final infiltration rate estimates, the majority of the hydrologic soil groups belong to type A [9], [10], [11].

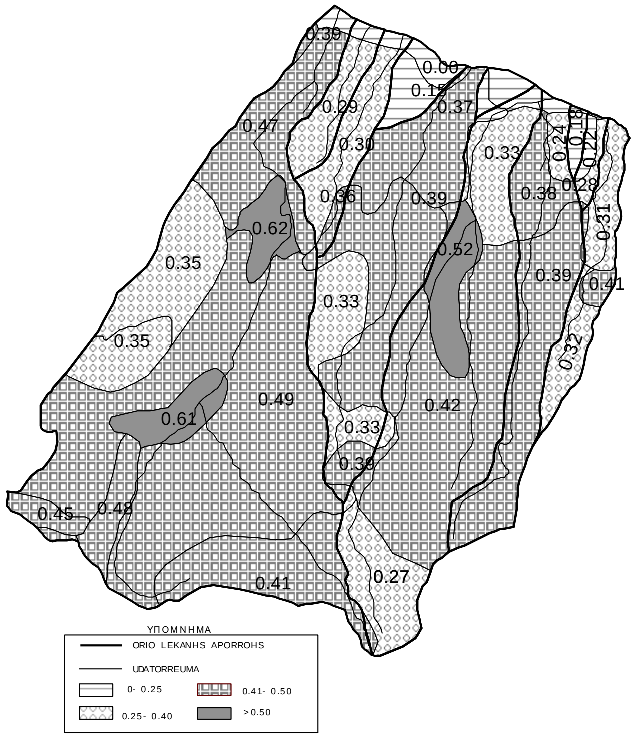

Figure 3: Map of average surface slopes per category of soil cover, scale 1:80000

In relation to the hydrological conditions, their characterization as normal, moderate or poor, it results from the combination of the earth slopes, the depths, the earth profile and the density of vegetation cover. Therefore, for each sub-region, i.e. region which is covered by different kind of vegetation, the value of runoff curve number, *CN* of SCS is defined [9], [10], [11], [12], [13], and then, through a topologic processing, the composite value of *CN*, CN_c, of every watershed is obtained (Figure 4).

CONCLUSIONS

The Geographic Information Systems have been proven a very useful tool for the above hydrological application in the region of the study area, located on the North and North East slopes of mount Ossa in Thessaly, Greece. It has been especially useful for tracing a mass of cartographic data, i.e. terrain, hydrographical network, vegetation cover – or land use from the geological or pedologic point of view.

It is also useful for process, management and valuation of hydrological parameters, along with the area, the slopes of hydrologic watersheds, the slopes, lengths and cross sections of water streams as well as the runoff curve number *CN* of SCS.

More and probably more useful conclusions on the above research are expected to be obtained after a full completion of the program, when, the spatial variation of flood risk in the study area, is going to be refereed.

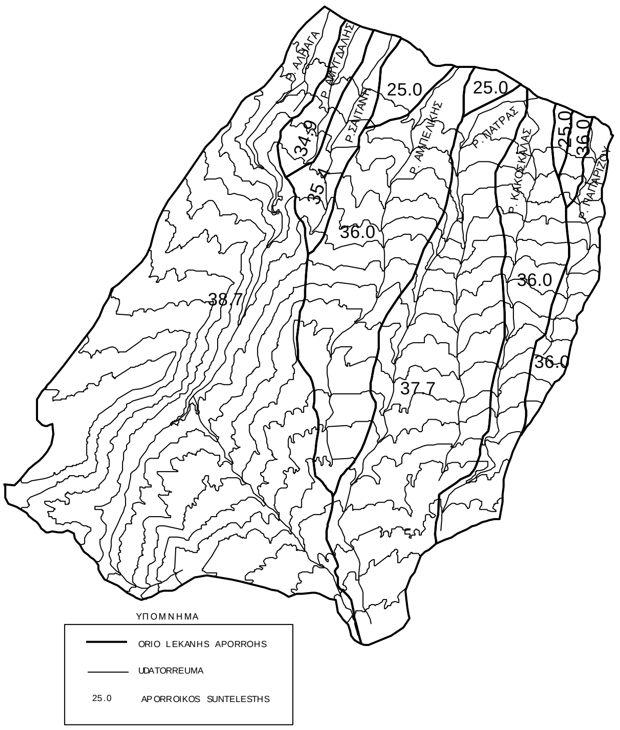

Figure 4: Map of composite runoff curve numbers *CNc* per watershed, scale 1:82000

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