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Flood hazard assessment of the Kerinitis River catchment, North Peloponnese, Greece

A. Kakonas[1], E. Karymbalis[1], C. Chalkias[1], N. Evelpidou[2]

(1) Department of Geography, Harokopio University, 70, El. Venizelou Str., 17671 Kallithea, Athens, Greece, gp217305@hua.gr
(2) Section of Geography and Climatology, Department of Geology and Geoenvironment, National University of Athens, Panepistimiopolis, 15784, Athens, Greece

Introduction

Floods are among the most dangerous natural hazards affecting the development of an area. In Greece, many drainage basins are relatively small with steep slopes, configured by steep streams with braided main channel morphology. These systems are usually dry, but experience extreme flash flood events of low frequency, but high magnitude. Such exceptionally high runoff may be a source of significant damage to human infrastructure. Despite the importance of these floods, the hydrological analysis of ephemeral streams in Greece has been especially difficult due to the lack of discharge gauges.

The aim of this study is to present a flood hazard assessment and mapping methodology for the Kerinitis River drainage basin which is located in the North Peloponnese. Additionally, the simulation of a flash flood event along the main channel of the river caused by an extreme rainfall event, similar to the storm that took place on January 11th and 12th, 1997 above the nearby catchment of Xerias River, using a surface GIS-based runoff model was attempted. The application of this modeling led to the direct runoff hydrograph along the Kerinitis main channel at the outlet of the basin (the apex of the fan-delta). The proposed methodologies are based on the application of GIS with the integration of various data concerning the study area.

Study area

Kerinitis is an ephemeral river with a dendritic drainage network, located in northwestern Peloponnese. Its drainage basin has an area of 82.94 km^2. It is a relatively elongated catchment along a S.SW-N.NE trending axis and reaches an elevation of 1760 m in its southeastern end. Lithologically, the basin consists of 53.23 % limestones, 9.25 % cherts, 7.13 % flysch and 30.39 % Plio-Pleistocene formations (mainly conglomerates sandstones and marls). The main channel follows a S.SW-N.NE flow direction for about 22.98 km and discharges into the Gulf of Corinth. At the mouth of the river, a fan-delta has developed covering an area of about 6.2 km^2. The broader area of the Northern Peloponnesus experiences a typical Mediterranean climate, with annual temperature averaging 13^{o}C. The mean annual precipitation in the basin ranges between 600 mm in the northern coastal region and 700 mm in the southern mountainous region. Rainfall is distributed relatively unevenly with about 75% of it occurring between the months of October and March. The river has flooded on numerous occasions especially downstream from the national highway that connects Athens with Patras near the apex of the fan-delta.

Methodology

For the Kerinitis catchment flood hazard assessment and mapping, a multi criteria model was applied. The model was based on criteria / factors controlling the water route when drainage system capacity is exceeded by high runoff. The selected factors include the morphological slope, the elevation, the mean annual rainfall, the flow accumulation, the distance from the main channels of the streams, the hydro-lithology of the geological formations and the land use. Morphological slope values were obtained from the slope map which was produced by a detailed (5m X 5m resolution) Digital Elevation Model (DEM) of the Greek Cadastre. The same DEM was also used to calculated flow accumulation. The geological formations of the study area were derived from the 1:50,000 scale geological map of the Institute of Geology and Mineral Exploration of Greece while land-use data were obtained from CORINE land cover 2018. Each factor was divided into five classes with specific boundary values. Integer numbers, ranging from 1 to 5, were assigned to every class with 1 representing very low physical vulnerability and rank 5 indicating very high physical vulnerability to flood hazard. To estimate the final weights for each factor the Analytic Hierarchy Process (AHP) method was applied. It is a multi-criteria decision making technique, which provides a systematic approach for assessing and integrating the impacts of various factors, involving several levels of dependent or independent, qualitative as well as quantitative information (Chalkias, 2015).

For the calculation of the maximum discharge at the outlet of the Kerinitis River catchment (caused by an extreme weather event similar to the storm that took place on January 11th and 12th, 1997, above the nearby catchment of Xerias River), the GIS-based unit hydrograph derivation method was adopted. According to this concept, the definition of isochrones (flow traveling to the watershed outlet) at time intervals is the key point for the construction of time-area diagrams (Chow *et al*., 1988). Hence a routing model (Du *et al*., 2009) has been implemented in ESRI ArcGIS10 environment. The topography of the land surface (DEM) is one of the most fundamental elements for this simulation (Karymbalis *et al*., 2012). DEM-based surface hydrological analysis was the first step in order to execute the rainfall-runoff model. DEM analysis led to various derivatives such as slope (surface analysis), flow direction, flow accumulation and flow length. Since the methodology adopted is based on the concentration time, calculations were carried out for the travel time of water within the catchment for both channel and overland flow. In order to separate these two types of water flow a suitable threshold on flow accumulation was selected. Having the flow accumulation and the various grids of rainfall the discharge at the channel of the river was calculated. Furthermore by using the appropriate equations both the channel and overland flow travel velocities for each cell off the basin was estimated and the travel time in each cell was computed from the travel distance. In order to design the isochrones for the rainfall event it was necessary to reclassify values of travel time. Finally, a convolution technique was implemented to construct the direct runoff hydrograph at the apex of the Kerinitis River fan-delta.

Results and Conclusions

The results of the flood hazard assessment are depicted on the map of Figure 1a. The study area was classified into five zones corresponding to areas of very high, high, moderate, low and very low flood hazard. It is obvious that flood prone areas (of high and very high physical vulnerability to flood hazard) are distributed mostly along the main channels of the Kerinitis River and its major tributaries. Particularly prone to floods are the overbank areas along the lower reaches of the Kerinitis main channel. The fact that the same area is also marked as highly prone to floods at the maps constructed for the study area in the frame of the assessment and management of flood risks by the Greek Ministry of Environment and Energy shows the validity of the proposed methodology. Additionally, the fan-delta plain downstream of the National highway is also of high vulnerability due to the low relief and the high discharge of the river at the apex of the fan in case of extreme rainfall events. Significant part of the highly and very highly vulnerable area is occupied by economically important cultivated land while most of the settlements of the catchment are located in flood prone areas.

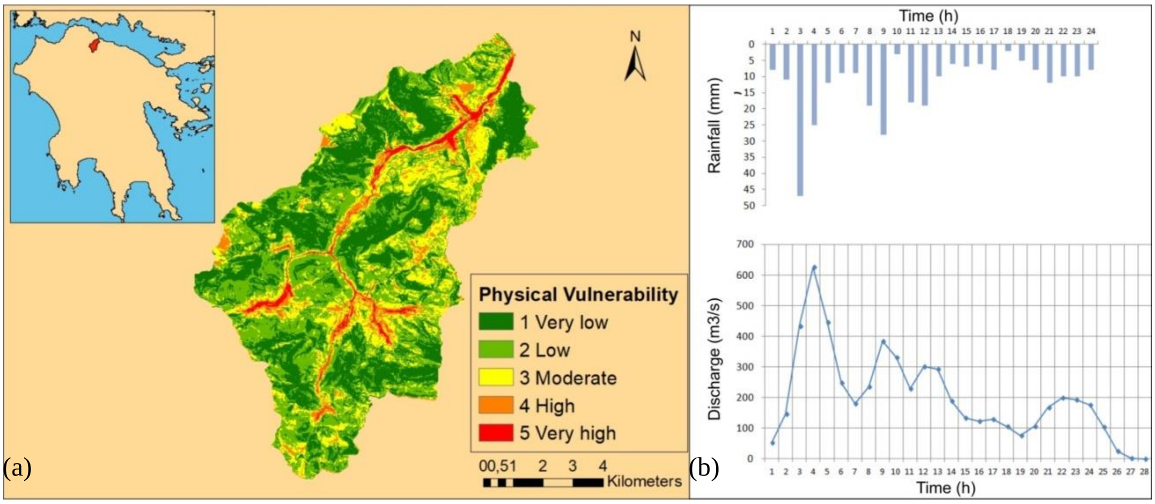

Figure 1. (a - left) Flood hazard assessment map of the Kerinitis River catchment and (b - right) direct hydrographs of the river at the apex of the fan-delta for the extreme rainfall event. 1 hourly stream discharges were obtained from the GIS-based hydrological analysis. The hydrograph includes also the 1 hourly mean rainfall above the catchment area.

Figure 1b displays a combined diagram of the hydrograph produced by the applied model that corresponds to the outlet of the catchment with the hyetograph temporally defined for the total duration of the event (x-axis). The analysis of the model-derived hydrograph for the Kerinitis River is relatively simple since the base flow at this part of the main channel is usually very low. The shape of the produced hydrograph is typical of a flash flood. It is sharp, with a relatively short time base and steeply rising limbs for each of the four peaks. The hyetograph, in the form of an upper axis histogram, is comprised of the hourly accumulated precipitation, over the entire catchment area. The model-derived hydrograph follows the mean rainfall pattern above the basin with four discharge peaks. The diagram shows that the basin's response to the precipitation is very quick. The first peak (~630 m^3/sec) occurred almost one hour after the first precipitation maximum (47 mm) and corresponds to the maximum discharge. We did not manage to validate the model since there are no gauging records in the study area. However, the findings of the proposed methodology are in agreement with the results of previous studies in catchments with similar characteristics (Karymbalis *et al.*, 2012, Tsanakas *et al.*, 2016).

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