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ORIGINAL PAPER

Assessment of flood hazard based on natural and anthropogenic factors using analytic hierarchy process (AHP)

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Abstract Flooding is the most common natural hazard in Greece, and most of low-lying urban centers are flood-prone areas. Assessment of flood hazard zones is a necessity for rational management of watersheds. In this study, the coupling of the analytical hierarchy process and geographical information systems were used, in order to assess flood hazard, based either on natural or on anthropogenic factors. The proposed method was applied on Kassandra Peninsula, in Northern Greece. The morphometric and hydrographic characteristics of the watersheds were calculated. Moreover, the natural flood genesis factors were examined, and subsequently, the anthropogenic interventions within stream beds were recorded. On the basis of the above elements, two flood hazard indexes were defined, separately for natural and anthropogenic factors. According to the results of these indexes, the watersheds of the study area were grouped into hazard classes. At the majority of watersheds, the derived hazard class was medium (according to the classification) due to natural factors and very high due to anthropogenic. The results were found to converge to historical data of flood events revealing the realistic representation of hazard on the relating flood hazard maps.

Keywords AHP · Flood management · Flood hazard analysis · GIS

1 Introduction

Floods are considered to be the most common natural disaster worldwide during the last decades. Their consequences are not only environmental but economic as well, since they may cause damages to urban areas and agricultural lands and may even result in loss of lives (Merz et al. 2010). The increase in floods and their destructive results worldwide require an ongoing improvement on identification and mapping of flood hazard. (Kundzewicz and Kaczmare 2000; Ebert et al. 2009).

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During the last years, prediction of flood hazard has been achieved by applying hydrologic and hydraulic models (Smith 1994; Anselmo et al. 1996; Booij 2005; Myronidis et al. 2009). However, these models require large-scale data, which are often unavailable.

Alternatively, flood hazard can be assessed using multicriteria analysis methods. Analytic hierarchy process is the most widely used multicriteria analysis method and has been applied to a wide range of scientific fields (social science, economy, earth science). The aforementioned method contributes to the understanding and deconvolution of complex problems using a hierarchical framework (Saaty 1980; Malczewski 1999).

Many different approaches have been used for flood hazard based on multicriteria analysis. Ologunorisa (2003), Mansor et al. (2004) and Sanyal and Lu (2006) used multicriteria analysis and combined the factors that determine flood hazard. However, these researchers did not take into account the importance of each factor.

In order to calculate the relative weight of each factor, correlation among factors influencing the flood hazard must be considered, due to the lack of relative experimental results. The most popular techniques for the estimation of the relative weight of each factor are the direct method of rating (Zangemeister 1971) and the pairwise comparison (Koelle 1975). The first one grades each factor separately and adds all grades into a constant sum (e.g. 100), while the second one relies on the comparison of factors in pairs and the expression of results into a range scale of a constant sum.

Gatzojannis et al. (2001) used the direct method of rating, in order to study the protective role of forests against torrential phenomena. Many researchers used pairwise comparison, within analytic hierarchy process method (AHP) and geographical information systems (GIS) to assess flood hazard (Emmanouloudis et al. 2008; Sinha et al. 2008; Meyer et al. 2009; Chen et al. 2011).

Comparative studies regarding the aforementioned methods revealed that the pairwise comparison leads to the most reliable results (Yalcin and Akyrek 2004; Grozavu et al. 2011). Furthermore, recent researchers (Scheuer et al. 2011; Wang et al. 2011) combined the analytic hierarchy process with fuzzy logic and genetic algorithms in order to incorporate the possible changes (climate change, land use change) over years into the assessment of flood hazard and management of water resources.

All the above researches took into account only the natural factors at the estimation of flood hazard. However, several studies about the causes and the mechanism of flash flood phenomena both in Greece (Stefanidis and Sapountzis 1998; Stathis and Stefanidis 2001; Stathis et al. 2007) and worldwide (Wohl 2006; Gupta 2007; Ruin et al. 2008; Andriani and Walsh 2009; Marchi et al. 2010) concluded that floods could have been avoided if no anthropogenic interventions existed within stream beds.

The purpose of the current study is to define two flood hazard indexes, regarding natural and anthropogenic factors of flooding. Subsequently, the watersheds of the Kassandra Peninsula (Northern Greece) will be classified upon these indexes, in order to prioritize management and protection actions.

2 Study area

The study area is located in Northern Greece (Fig. 1) and has an area of 365 km^2. The climate of the area belongs to the sub-humid Mediterranean zone according to the bioclimatic diagram of Emberger (1959), which is also confirmed by the vegetation spectrum of the area (Tsitsoni 1997). However, according to the climatic classification of Köppen

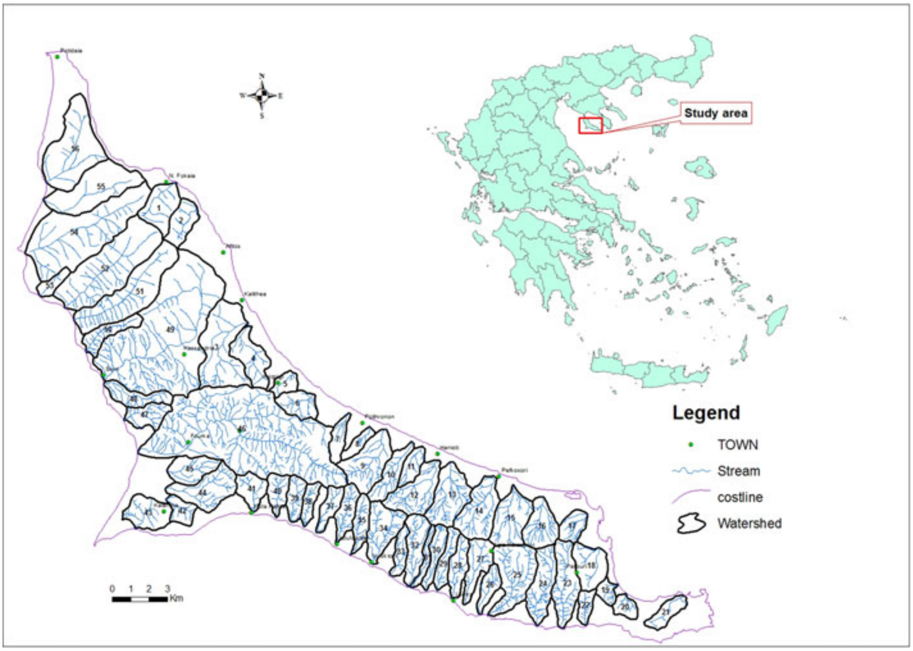


Fig. 1 The study area

(1931), the climate belongs to the Csa type. This means temperate, warm and rainy climate with mild winters and dry period during the summer. The mean annual precipitation is 595 mm and the mean annual temperature, 16.2 °C. Furthermore, the dry period is particularly extended from May until September.

The area is characterized as lowland with an average altitude of 146 m (maximum 340 m), an average mean slope of the watershed 30 % and an average main stream slope 5 %. As for the ground, the soils are loamy and clayey, with high contents of loam. The dominant bedrocks are sedimentary rocks, especially marls.

The vegetation belongs to *Quercetalia ilicis* floristic zone. The dominant forest species are Aleppo pine (*Pinus halepensis*) and shrubs (*Quercus conferta, Quercus cerris, Pistacia lentiscus*) which dominate in the canopy within stands (Mallinis et al. 2004). The forest cover is 38 % and the agricultural lands, 52 %. Moreover, it must be quoted that the area is one of the most well-known tourism destinations in Northern Greece.

3 Methodology

3.1 Factors of flooding

The identification of the flood genesis factors is the most important step at the assessment of flood hazard. The inclusion of the factors should be done within a framework ensuring that the whole problem is encompassed. Moreover, the set of factors should be kept to a minimum so as to reduce the complexity of the evaluation process.

After extensive literature review, the natural factors that determine the flood hazard were selected according to the conditions and the available data in Greece. The natural factors that were used in the current research were as follows:

- land uses, because vegetation, where it exists, acts as a protective mantle and regulates the runoff process
- geological subsoil and especially the torrential petrographic formations, both in terms of erodibility and permeability
- mean slope of the watersheds (%) and the main stream bed slope (%) as the slopes can aggravate or decrease the velocity of runoff water
- shape of the watersheds affects the concentration time of runoff and the form of the hydrograph. Roundish watersheds concentrate water quicker and lead to higher water discharges. On the contrary, elongated watersheds require a longer time of concentration of runoff so smaller discharges appear (under similar conditions)
- density of the hydrographic network which also affects the concentration time of runoff

Each factor was divided to sub-factors according to their influence on flooding. The sensitivity score of each sub-factor criterion to flooding took values from 1 to 3, where 1 means slight influence, 2 moderate influence and 3 high influence on flooding.

To define the influence of natural factors on flood hazard, the study first categorized the various factors in relation to flood genesis based on the literature reviews (Stefanidis 1992; Konstadinov and Mitrovic 1994; Mazzorana et al. 2009; Meyer et al. 2009; Mazzorana et al. 2011; Kandilioti and Makropoulos 2012). The natural factors and their influences on flooding are listed in the next Table 1.

The main anthropogenic interventions within stream beds that affect flooding are encroachments (narrowing of beds in plain areas), especially when the streams pass through urban areas. The narrowing is being caused by the banking up of the beds, performed for the extension of the riverside land, covering of streams, construction of buildings into the channel bed and inadequate technical works, such as bridges and ducts, for maximum discharge channeling. The existence of a well-shaped trapezoidal cross-section, with an adequate bottom width to reach maximum capacity often lacks due to human activities that alter stream bed geometry. This can be handled with the appropriate technical works for caisson of the beds. The anthropogenic factors (Table 2) were divided into two classes and took values from 1 to 2 according to their existence or not of the intervention.

3.2 Analytical hierarchy process

Analytical hierarchy process (AHP) is a multicriteria 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 (Saaty 1977, 1990). The former is applied on flood hazard assessment in various climatic environments. AHP makes the assessment of the contribution of each factor easier and overcomes problems such as overlapping and interrelation between factors.

For the estimation of the weight of each factor, the software expert choice v. 11 was used. The current software creates a hierarchy of the factors that are related to the problem. Using techniques of analytical hierarchy process and pairwise comparisons, the relative weight of each factor was estimated. The most common methodology for performing comparisons is the Saaty's (1980) comparative scale. According to this method, the

Table 1 The influence of natural factors on flooding

a/a	Factor	Class	Values	Influence
1	Land use	Cultivated lands, burren land	3	High
		Shrubs, pastures	2	Moderate
		Forests	1	Slight
2	Rock erodibility	Neogene, flysch, alluvial	3	High
		Schists, limestones	2	Moderate
		Crystalic igneous	1	Slight
3	Watersheds slope	>35 %	3	High
		15–35 %	2	Moderate
		<15 %	1	Slight
4	Main stream slope	>7 %	3	High
		3–7 %	2	Moderate
		<3 %	1	Slight
5	Rock permeability	Neogene, crystalic igneous, alluvial	3	High
		Schists, flysch	2	Moderate
		Limestone	1	Slight
6	Watershed shape	Roundish	3	High
		Semi-roundish	2	Moderate
		Elongated	1	Slight
7	Density of hydrographic network (km/km^2)	>3	3	High
		1,5–3	2	Moderate
		<1,5	1	Slight

Table 2 The influence of anthropogenic factors on flooding

a/a	Intervention	Existence	Description	Values	Influence
1	Encroachments	Yes	Plenty	2	High
		No	Almost non	1	Slight
2	Inadequate technical works	Yes	Designed for flood intervals less than 1 in 100 years	2	High
		No	Designed for flood intervals more than 1 in 100 years	1	Slight
3	Shaped cross-section at the plain area of the stream	No	Inappropriate	2	High
		Yes	Well shaped	1	Slight

comparative scale consists of integer numbers from 1 to 9, where 1 means that the factors are equally important and 9, that a factor is extremely more important than another. The comparison process was done separately for natural and anthropogenic factors, and the relative weight of each factor was assessed for both categories. Additionally, this software computes the consistency ratio derived from the comparisons among factors.

In order to check the discordances between the pairwise comparisons and the reliability of the obtained weights, the consistency ratio (CR) must be computed. In AHP, the consistency is used to build a matrix and is expressed by a consistency ratio, which must be <0.1 so as to be accepted. Otherwise, it is necessary to review the subjective judgments (Saaty and Vargas 1984, 2001) and recalculate the weights. The current software (expert choice v. 11), in the case that the consistency ratio is not accepted (>0.1), indentifies the most inconsistent judgment derived from pairwise comparisons and propose changes, in order to achieve the acceptable limits.

For computing the consistency ratio (CR), the following formula was applied:

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}$$

where CI represents the consistency index computing according:

$$\mathrm{CI} = \frac{\lambda_{\max} - n}{n - 1}$$

where $\lambda_{\max}$ represents the sum of the products between the sum of each column of the comparison matrix and the relative weights and n represents the size of the matrix.

RI is the random index representing the consistency of a randomly generated pairwise comparison matrix. It is derived as average random consistency index, computed by Saaty (1980) from a sample of 500 matrixes randomly generated (Table 3).

Taking into account the above mentioned, two flood hazard indexes were defined, one based on natural factors (N) and one based on anthropogenic factors (A). The equation that relates to these indexes had the following form:

$$N, A = \sum (W_i * X_i)$$

where N, A is the value of flood hazard for each watershed, X is the weight of factors i and W is the sensitivity score of each sub-factor criterion to flooding. Furthermore, the values that were derived from N and A indexes were grouped into four hazard classes according to the probability of flood occurrence. This classification was done by using the optimization method of classes distribution natural breaks (Jenks 1967) with the help of the spatial analyst tool of ArcGIS (ESRI 2004). The Jenks optimization method, also called the Jenks natural breaks classification method, is a data classification method designed to determine the best arrangement of values into different classes. This is done by seeking to minimize each class' average deviation from the class mean, while maximizing each class' deviation from the means of the other groups. In other words, the method seeks to reduce the variance within classes and maximize the variance between classes.

Finally, the watersheds of the research area were grouped, and based on the flood hazard, classes were derived from these indexes. The flowchart of the methodology can be seen in Fig. 2.

3.3 Data source

In order to achieve the goals of the research, the necessary data were derived from different sources. Therefore, in this study, a number of GIS layers were generated. These were land use, geology, drainage network, digital elevation model and watersheds shape.

Table 3 RI values

n	1	2	3	4	5	6	7	8
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41

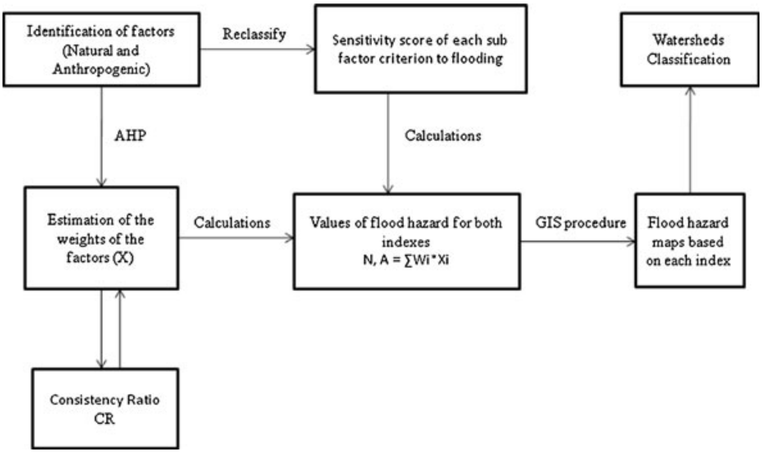


Fig. 2 Framework of analytical hierarchy process to assess flood hazard

The land use map was produced from vegetation map of the forest service of Kassandra, scale 1:200.000 and orthophoto maps scale 1:5.000. The geology map was produced from the maps scale 1:50.000 of the Institute of Geology and subsurface research of Greece. Moreover, the topographic maps scale 1:50.000 of the research area was digitized and the digital elevation model (DEM) was developed from the contour lines (20 m interval).

The shape of the watershed was determined empirical, from the shape that was formed after the delineation of the watersheds boundary on topographic maps. The watershed mean slope, main stream slope and the density of hydrographic network were estimated using the following formulas:

$$J_{\mathrm{w}} = \frac{\Delta H * \Sigma I}{F} * 100$$

where J_{w} is the mean watershed slope (%), ΔH, the intervals between the contour lines (km), ΣI, the total length of all the contour lines in the watershed (km) and F, the watershed area (km^2),

$$J_{\mathrm{b}} = \frac{\Sigma(L * J_{\mathrm{s}})}{\Sigma L}$$

where J_{b} is the main stream slope (%), L, the horizontal length of the stream's bed with a constant slope (m) and J_{s}, the slope of the above part of the stream's bed (%),

$$D = \frac{\Sigma L}{F}$$

where D is the density of hydrographic network (km/km^2), ΣL, the total length of the watershed streams (km) and F, the watershed area (km^2).

The different types of interventions arising from anthropogenic activities within stream bed were recorded after field observations. For this purpose, an appropriate sheet was used, which had the following form (Fig. 3).

4 Results

4.1 Evaluation of factors

The basic morphometric and hydrographic characteristics of the watersheds were calculated using GIS techniques (Table 4).

After the digitization of the appropriate layers, the land uses and geology maps were conducted. Based on these maps, the necessary parameters to assess flood hazard were estimated. The results from these procedures are shown in Figs. 4 and 5.

Also, the results from the records of the anthropogenic interventions for each watershed after field observation are given in Table 5.

4.2 Assessment of flood hazard

In order to assess the flood hazard, the natural and anthropogenic factors were identified and their influence on flooding was evaluated, by developing a pairwise comparison matrix for natural factors (Table 6) and one for anthropogenic factors (Table 7) of flooding.

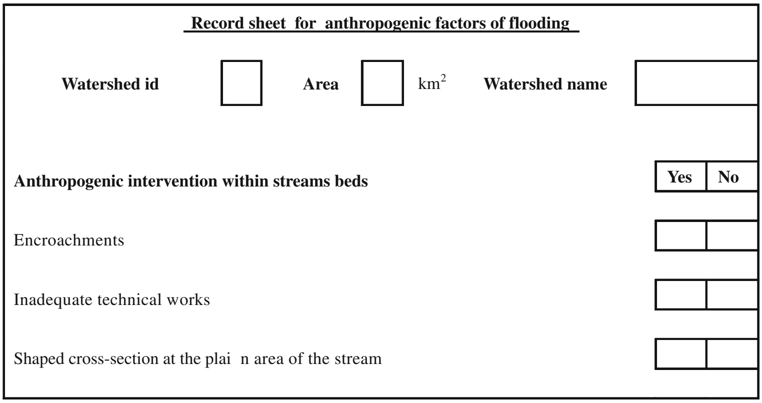
Additionally, the relative weight of each factor was calculated using the pairwise comparison method. The derived weights of the factors and the consistency ratio can be seen in Tables 8 and 9.

These comparisons indicated that the consistency ratio in both cases is rather smaller than 0.1, which is the limit of this method, so the weights of the factors are considered reliable.

Moreover, according to the research method, a value for flood hazard was calculated for every watershed, based on the flood hazard indexes (*N*, *A*).

The results that came out from these two flood hazard indexes (*N*, *A*) were grouped into four classes depending on the likelihood of flood hazard (low, medium, high and very high). The division was achieved according to the Natural Breaks method. This method compiles optimally similar values while maximizing the differences between classes.

Figures 6 and 7 present the flood hazard maps that resulted from the data of the flood hazard indexes *N* and *A* proportionally.



Record sheet for anthropogenic factors of flooding

Watershed id ☐ **Area** ☐ km² **Watershed name** ☐

Anthropogenic intervention within streams beds	**Yes**	**No**
Encroachments	☐	☐
Inadequate technical works	☐	☐
Shaped cross-section at the plain area of the stream	☐	☐

Fig. 3 Form of the appropriate sheet that was used for the record of anthropogenic interventions

Table 4 Morphometric and hydrographic characteristics of the torrential streams of the research area

Watershed id	Area (km^2)	Mean watershed slope (%)	Mean main stream slope (%)	Density of hydrographic network (km/km^2)	Watershed shape	Watershed id	Area (km^2)	Mean watershed slope (%)	Mean main stream slope (%)	Density of hydrographic network (km/km^2)	Watershed shape
1	3.95	13.0	1.00	2.05	roundish	29	2.11	40.1	6.00	3.75	elongated
2	2.86	12.3	2.00	2.22	semi-roundish	30	2.15	39.9	5.00	3.98	elongated
3	9.28	13.5	2.00	2.11	semi-roundish	31	1.24	41.2	3.00	4.09	elongated
4	4.00	17.7	4.00	2.67	semi-roundish	32	3.55	38.9	4.00	3.64	elongated
5	1.38	18.0	4.00	1.75	roundish	33	1.66	44.8	6.00	3.96	elongated
6	2.64	25.2	3.00	3.34	roundish	34	4.41	38.1	6.00	3.89	semi-roundish
7	1.73	23.1	10.00	2.16	elongated	35	2.19	40.8	2.00	3.94	elongated
8	1.27	24.4	2.00	2.04	elongated	36	2.47	42.1	7.00	4.19	elongated
9	5.56	29.7	2.00	3.19	semi-roundish	37	1.90	39.9	10.00	3.27	elongated
10	3.10	32.2	3.00	3.51	elongated	38	1.46	39.7	3.00	4.21	elongated
11	1.82	29.3	3.00	3.26	elongated	39	2.02	38.8	6.00	4.53	elongated
12	5.12	30.4	3.00	4.04	semi-roundish	40	2.04	37.5	6.00	3.47	semi-roundish
13	5.38	28.1	6.00	4.26	semi-roundish	41	2.42	36.7	7.00	2.64	roundish
14	5.44	30.4	6.00	4.00	semi-roundish	42	1.73	12.7	2.00	3.16	roundish
15	4.99	25.6	7.00	3.30	semi-roundish	43	3.66	17.2	1.00	2.42	roundish
16	3.82	26.2	7.00	3.96	roundish	44	5.23	23. 2	3.00	3.33	semi-roundish
17	1.99	24.6	8.00	4.32	roundish	45	3.23	18.7	7.00	3.01	semi-roundish
18	3.71	19.3	4.00	1.81	roundish	46	37.37	25.7	1.00	3.71	semi-roundish
19	1.11	28.8	9.00	3.35	roundish	47	2.50	30.7	2.00	3.80	roundish
20	1.31	25.6	5.00	2.62	roundish	48	2.81	25.9	1.00	3.93	elongated
21	1.96	19.4	2.00	2.03	elongated	49	30.94	13.5	1.00	2.62	semi-roundish
22	1.32	31.8	2.00	3.96	elongated	50	2.62	24.9	2.00	3.75	elongated
23	5.02	31.5	3.00	3.82	elongated	51	10.01	16.1	1.00	2.56	elongated
24	4.57	29.7	3.00	4.40	elongated	52	13.42	11.3	1.00	2.25	elongated
25	6.51	28.2	4.00	3.96	semi-roundish	53	1.25	11.8	1.00	1.58	elongated

Table 4 continued

Watershed id	Area (km^2)	Mean watershed slope (%)	Mean main stream slope (%)	Density of hydrographic network (km/km^2)	Watershed shape	Watershed id	Area (km^2)	Mean watershed slope (%)	Mean main stream slope (%)	Density of hydrographic network (km/km^2)	Watershed shape
26	1.85	30.4	2.00	3.73	elongated	54	16.16	7.8	1.00	1.89	semi-roundish
27	3.29	30.9	3.00	2.95	elongated	55	8.19	6.8	1.00	0.89	semi-roundish
28	2.59	36.4	6.00	3.26	elongated	56	9.99	6.5	1.00	1.55	semi-roundish

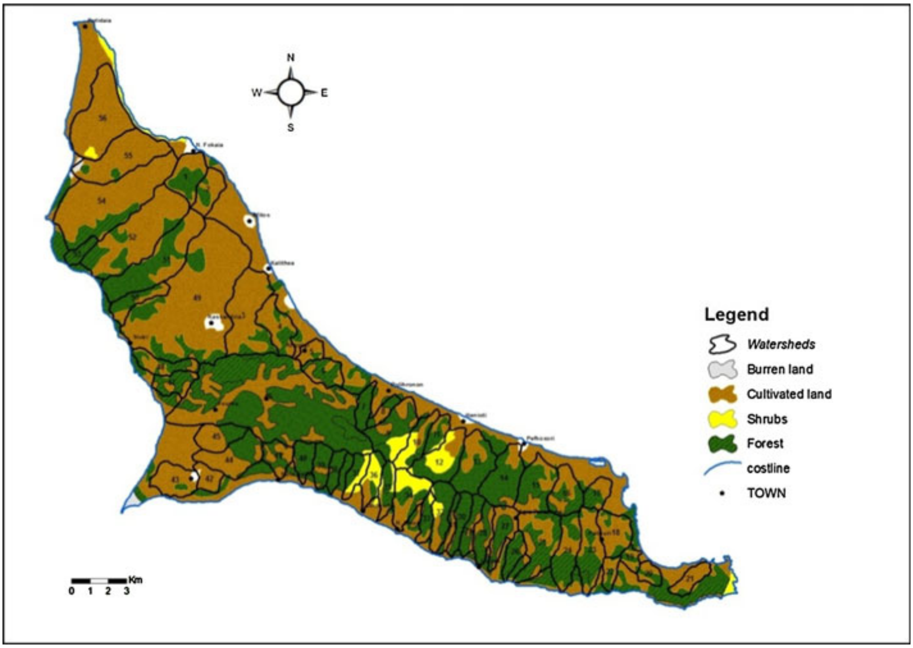


Fig. 4 Land uses of the study area

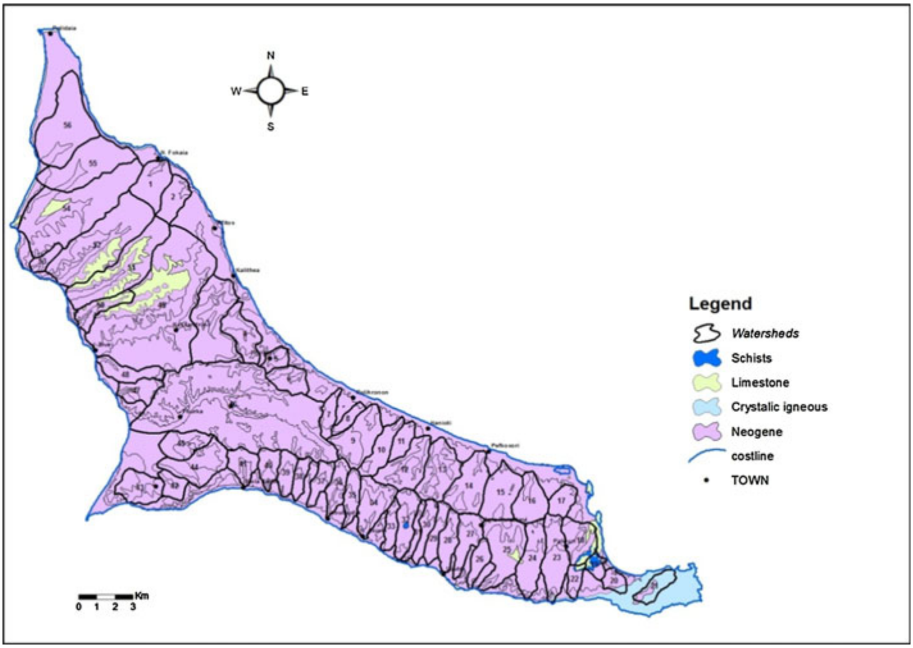


Fig. 5 Geology of the study area

Table 5 Anthropogenic interventions within stream bed for each watershed

Watershed id	Type of anthropogenic intervention			Watershed id	Type of anthropogenic intervention		
	Shaped cross-section	Encroachments	Inadequate technical works		Shaped cross-section	Encroachments	Inadequate technical works
1	No	Yes	Yes	29	No	Yes	Yes
2	Yes	No	No	30	Yes	Yes	No
3	No	Yes	Yes	31	Yes	No	No
4	No	No	Yes	32	Yes	No	No
5	No	Yes	Yes	33	Yes	No	Yes
6	No	Yes	Yes	34	No	Yes	Yes
7	No	No	Yes	35	Yes	Yes	No
8	No	Yes	Yes	36	No	Yes	Yes
9	No	Yes	Yes	37	No	Yes	No
10	Yes	Yes	Yes	38	No	No	No
11	Yes	Yes	Yes	39	No	Yes	Yes
12	No	Yes	Yes	40	Yes	Yes	No
13	No	Yes	Yes	41	No	Yes	Yes
14	No	Yes	Yes	42	No	No	Yes
15	No	Yes	Yes	43	No	Yes	No
16	No	Yes	Yes	44	No	Yes	Yes
17	Yes	Yes	Yes	45	No	No	Yes
18	No	Yes	Yes	46	Yes	Yes	No
19	No	Yes	Yes	47	No	No	Yes
20	No	Yes	No	48	No	Yes	Yes
21	Yes	No	No	49	No	Yes	Yes
22	Yes	No	No	50	No	No	No
23	Yes	No	No	51	Yes	Yes	No
24	Yes	No	No	52	No	Yes	Yes
25	Yes	No	No	53	No	Yes	Yes
26	Yes	No	No	54	No	Yes	Yes
27	No	Yes	No	55	No	No	Yes
28	No	No	No	56	No	No	No

4.3 Watersheds classification

Based on the results of flood hazard indexes and the flood hazard classes that were determined, the watersheds of the research area were classified into types. Characterization type was defined on the basis of flood hazard index (*N* and *A*) and the hazard class derived for each watershed (low, medium, high and very high). For example, N_2A_4 means that the flood hazard is medium due to natural factors and very high due to the anthropogenic factors. The results from the classification of each watershed are presented in the next Table 10.

Table 6 Pairwise comparison matrix: natural factors of flooding

	Land use	Rock erodibility	Watersheds slope	Main stream slope	Rock permeability	Watershed shape	Density of hydrographic network
Land use		3	3	5	5	5	5
Rock erodibility			2	4	4	5	5
Watersheds slope				2	3	4	4
Main stream slope					2	2	3
Rock permeability						1	2
Watershed shape							1
Density of hydrographic network							

Table 7 Pairwise comparison matrix: anthropogenic factors of flooding

	Encroachments	Inadequate technical works	Shaped cross-section at the plain area of the stream
Encroachments		2	3
Inadequate technical works			2
Shaped cross-section at the plain area of the stream			

Table 8 Relative weights of natural factors of flooding

Natural factor	Weight
Land use	0.375
Rock erodibility	0.235
Watersheds slope	0.153
Main stream slope	0.088
Rock permeability	0.058
Watershed shape	0.048
Density of hydrographic network	0.043
Consistency ratio (CR) $= 0.03 < 0.1$	

Table 9 Relative weights of anthropogenic factors of flooding

Anthropogenic factor	Weight
Encroachments	0.54
Inadequate technical works	0.297
Shaped cross-section at the plain area of the stream	0.163
Consistency ratio (CR) $= 0.01 < 0.1$	

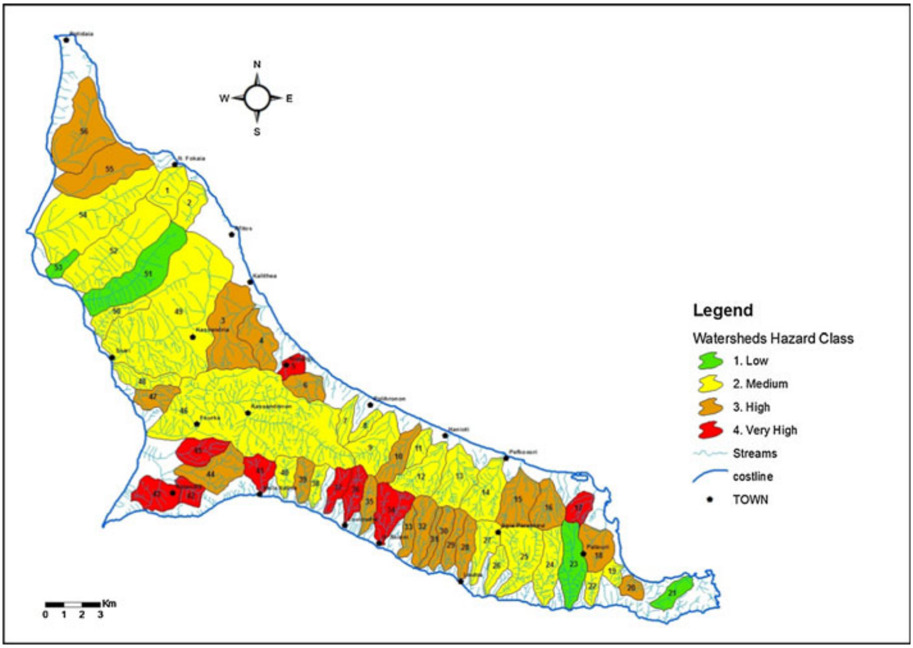


Fig. 6 Flood hazard map from natural factors

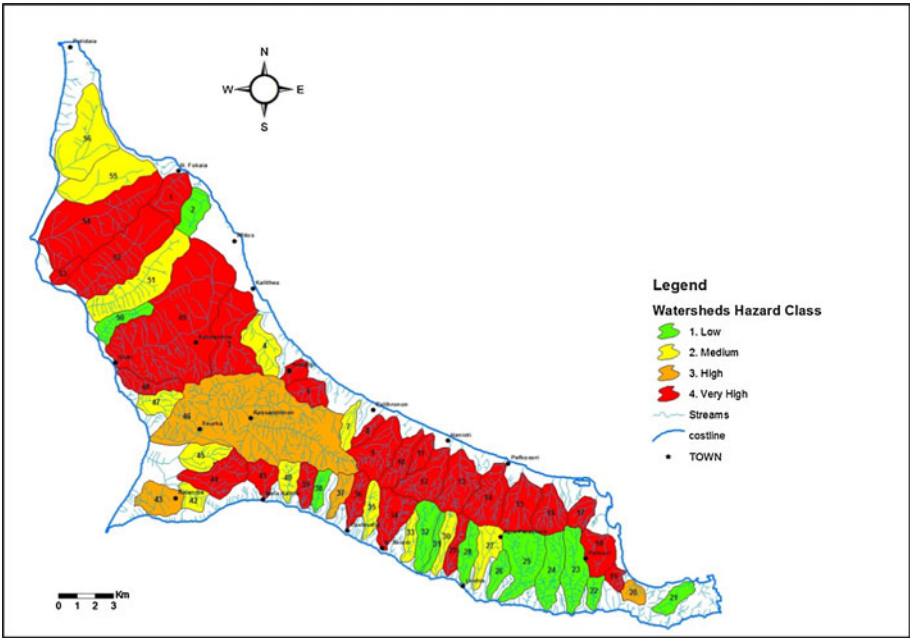


Fig. 7 Flood hazard map from anthropogenic factors

Table 10 Classification of the watersheds into types

Watershed id	Type	Watershed id	Type	Watershed id	Type	Watershed id	Type
1	N_2A_4	15	N_3A_4	29	N_3A_4	43	N_4A_3
2	N_2A_1	16	N_3A_4	30	N_3A_2	44	N_3A_4
3	N_3A_4	17	N_4A_4	31	N_3A_1	45	N_4A_2
4	N_3A_2	18	N_3A_4	32	N_3A_1	46	N_2A_3
5	N_4A_4	19	N_2A_4	33	N_3A_2	47	N_3A_2
6	N_3A_4	20	N_2A_3	34	N_4A_4	48	N_2A_4
7	N_2A_2	21	N_1A_1	35	N_3A_3	49	N_2A_4
8	N_2A_4	22	N_2A_1	36	N_4A_4	50	N_2A_1
9	N_2A_4	23	N_1A_1	37	N_4A_3	51	N_1A_2
10	N_3A_4	24	N_2A_1	38	N_2A_2	52	N_2A_4
11	N_2A_4	25	N_2A_1	39	N_3A_4	53	N_1A_4
12	N_2A_4	26	N_2A_1	40	N_2A_3	54	N_2A_4
13	N_2A_4	27	N_2A_2	41	N_4A_4	55	N_3A_2
14	N_2A_4	28	N_3A_1	42	N_4A_2	56	N_3A_2

From the Table 10, it can be seen that 9 watersheds are characterized as a very high natural hazard (id 5, 17, 34, 36, 37, 41, 42, 43 and 45). Five of these (id 5, 17, 34, 36 and 41) also belong to a very high hazard due to anthropogenic flood factors.

5 Conclusions

This study was an attempt to assess flood hazard using the analytic hierarchy process. Additionally, a distinction of flood events according to their causes was implemented and two indexes of flood hazard, one for natural (N) and one for anthropogenic factors (A), were identified.

In order to assess flood hazard, the above factors were determined and their relative weights in accordance with flood formation were estimated, using pairwise comparison. It was found that there are some factors that may also affect floods (e.g. rainfall intensity), although it is not possible to include them in the model, due to the lack of data.

Flood hazard maps at watershed scale in terms of natural and anthropogenic factors were generated. The analysis of flood hazard indexes pointed out that the flood hazard from anthropogenic factors was very high in the majority of the watersheds (48 %), whereas the flood hazard from natural factors was medium (43 %). Also, the historical data of flood events of the Laboratory of Mountainous Water Management and Control of Aristotle University of Thessaloniki revealed that most frequent flood phenomena occurring at the watersheds of Kassandra Peninsula belong to the category of very high flood hazard due to the anthropogenic index. This outlines that most floods occur due to human intervention into stream beds. Similar problems also appeared in other regions with intense tourism development and extensive urbanization (Rhodes, Zakynthos, Athens, Thessaloniki etc.) where the natural torrential environment is mild and the main cause of flash flood is manmade.

It is worth mention that flood hazard indexes defined in the current research are a useful tool for flood hazard assessment. The decision-makers can apply the presented methodology for identification and mapping of flood hazard, in order to organize the implementation of the appropriate projects for flood protection. Moreover, using the same indexes flood hazard maps can be recreated, taking under consideration the factors' change due to an extreme event (fires, urbanization, etc.). According to the conditions, available data and particularities of the study areas, additional factors could be defined and the relative weights for the totality of factors could be re-estimated. Finally, the formation of software for the automatization of techniques and processes used in the assessment of flood hazard can be the target of future research.

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