ESTIMATION OF THE PREFECTURE OF EVROS VULNERABILITY IN FLOOD CASES USING GIS AND FUZZY SET ALGEBRA

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ABSTRACT

Topographical and climatic conditions in the Evros prefecture are favorable for the manifestation of flooding phenomena, with possible catastrophic consequences. In the present paper, an assessment of flooding vulnerability for the whole prefecture shall take place, using the GIS software and approaches to vulnerability mapping. The maps to be created are the slope map, the flow accumulation map, the rain aggression map, the vegetation map, as well as the geological map. The combination of the aforementioned maps shall create flood vulnerability maps of the area. The factors and the total result shall take place with the classical vulnerability approach, as well as with the use of Fuzzy Logic. Then, the results will be compared to already observed floods. The results of the paper are capable of contributing to the delineation of the most dangerous areas and, consequently, to the successful application of various management plans.

Keywords: GIS, vulnerability, flood, risk, fuzzy sets

1. INTRODUCTION

Floods are an integral part of human life and one of the most frequent natural disasters. They occur due to water, running or standing, escaping from the areas which restrain it, or due to heavy precipitation. They are also generated by heavy or continuous rainfall exceeding the absorptive capacity of soil, and by the flow capacity of rivers or streams causing a watercourse to overflow its bank onto adjacent lands (Amini , 2010), resulting in human losses, crop and infrastructure damage, and siltation of reservoirs (Sanyal and Lu , 2004). The non-sustainable development of countries has led to an increase in the risk of flooding. We can say therefore that the adoption of viable models of economic, social and environmental development reduces these risks (Angelidis , 2009). In addition to this, in order to minimize the consequences of these catastrophic events, disaster managers and national authorities are in need of accurate information regarding the geographic extent of the areas at risk, to apply comprehensive and innovative risk management measures (Gitas et al. 2008, Mayer et al., 2008).

The European Union in supporting Member States and acceding States in the prevention, the restriction, and the confrontation of floods, issued the Directive 2007/60/EC of the European Parliament and Council of 23 October 2007, whose purpose is the establishment of a framework for the assessment and management of flood risk. In this context, the Member States must prepare a preliminary assessment of flood risks, flood hazard maps, flood risk maps and management for flood risk plans.

This Directive has led to the elaboration of many papers calculating the vulnerability of different areas, in which from which factors contributing to flooding phenomena are determined and classified by various techniques according to the risk and then, the most dangerous areas set using GIS, remote sensing and various models. Still, while reviewing bibliography, there are but very few papers that use new techniques, such as Fuzzy Algebra, CART or ANN. In contrast, most papers use Boolean Algebra.
The main purpose of the present paper is to study the extend of the said problem and to create the suitable tools for forecasting the most dangerous areas concerning the flooding phenomena, as well as to create the flood vulnerability maps, specifically for the Evros prefecture. The chosen tool was the GIS, which allows input, management, processing, spatial analysis, cartographic modeling, and visualization of complex and multi-faceted physical phenomena (Kalabokidis et al, 2007). It can also be applied in all four phases of the flood management process, namely in pre-flood planning, flood emergency management, post-flood recovery, and disaster mitigation (Goodchild and Glennon 2010, Seppanen and Virrantaus 2010). Besides the classical approach to the calculation of flood risk zones, there is also the fuzzy approach which is multi-valued and allows a natural way of data processing in problems for which the source of inaccuracy derives from the lack of clearly defined rules for the relationship between members of a set, in order to describe the corresponding variables used (zimmermann, 1983). The flood vulnerability mapping can lead to direct intervention in resulting incidents, with mild and combinatorial interventions, in order to prevent alteration of the landscape of the area and not to disturb its hydrological status.

2. STUDY AREA

The study area is the Evros prefecture, which belongs to the Thrace water district. It is the largest in range prefecture and the most borderline point of the Greek territory. It is an area of varying geological formation and morphology, with an area of 4,242 sq. km, out of which only the 424 sq. klm, belong to a mountainous area. An important hydrographic component of the prefecture is the Evros river, to which many small water streams lead, as well as the two main tributaries: the Ardas tributary, which stems from the Bulgarian side of the Koula mountains and flows through the prefecture in its entire width before reaching the Evros river and the Erythropotamos tribunary, which stems from the same direction and passes through the town of Didimoticho before reaching the Evros river. Moreover, two smaller streams, end up to river Evros, those of Loutros and of Dadia. The climate of the prefecture, continental and with an annual thermometer range exceeding 20 ° C, is characterized by harsh winters and hot summers.

The geomorphology of the region, combined with the significant spatial variability of rainfall, creates favorable conditions for the onset of flooding phenomena of strong intensity. Indicatively in May 1997, February and May 1998, and January 2003, the devastating floods in the broader river area had a major impact and huge cost in compensation and rehabilitation works. The region suffered severe flooding in the following years, with the flood in March 2006 being the worst in the last 50 years. Flooding in the river area also took place in February 2010. A favorable factor for the flooding onset which should also be taken into consideration is the disastrous fire that struck the region of Evros in August 2011, affecting an area of approximately 60,197 acres, changing completely the rainfall transformation mechanisms into runoff to the river network of the water-basin and favoring the occurrence of flooding.

At this point, it is necessary to mention that the usefulness of this paper lies also in the fact that the basin of the Evros river system is interstate (it is divided among the three countries of Greece, Bulgaria and Turkey in rates of 6, 66 and 28% respectively). The implementation of the Directive 2007/60/EC starts from Evros. The Hellenic Ministry of Environment, Energy and Climate Change via the Special Secretariat for Water launched the relative study on the area, which will establish hazard maps and flood risk maps, to which the adverse effects of floods, as well as the management plans for flood risk shall be impressed. Due, then, to the international character of the Evros waterbasin, the cross-border cooperation for the use and for the sustainable development and complete rational management of common water resources, while new approaches to addressing the flooding risks are created and introduced new approaches to addressing the risks of flooding.

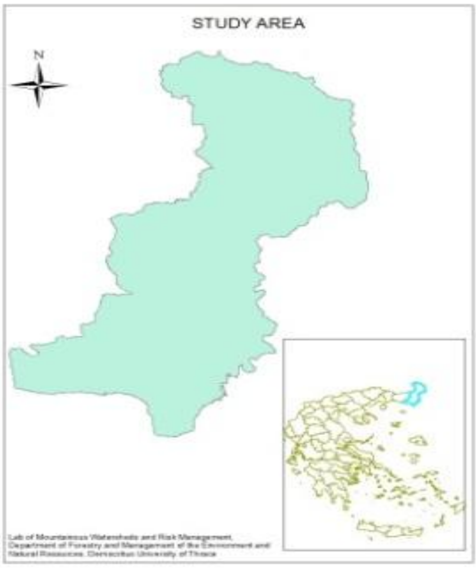

Fig. 1 Study area

3. METHODOLOGY

In order to enable the risk (or vulnerability) assessment of a region concerning the flood phenomena, an unequivocal definition of "flood" is deemed necessary. A "flood" is the elevation of the water level, i.e. the increase of the current supply and the water outlet from the river banks. The term "runoff surface" indicates the amount of water flowing on the surface, if certain losses (infiltration, evaporation) are subtracted from the total rainfall.
It is calculated by the formula: R = P-E-I, where
R = runoff, P = precipitation, E = evapotranspiration, I = infiltration
A provision is defined as the quantity of water passing per unit time from a particular cross-section of river banks. The provision size is often used as an indicator for assessing the respective discharge (Kotoulas, 2001).
The above formula will assist in understanding the factors contributing to the creation of the flood hazard, of which the primary one is the role of the rainfall (P). The main factors affecting the runoff (R) are the slope, the flow accumulation, the geological formations and the vegetation, which determines to an important extend the actual evapotranspiration. Finally, the geological medium is responsible for the amount of water infiltration into the underground sheets. In conclusion, the input data of the flood risk assessment model are rainfall, slope, flow accumulation, vegetation and geological medium.

3.1 Rainfall

In order to calculate the rainfall, the weather stations of Hellenic National meteorological service in Alexandroupolis, Soufli and Orestiada were used, as time measurements were common in them. At this point it should be noted that the most important role in the occurrence of floods is not played by the rainfall amount, but by its intensity. This is the reason for which the Modified Fournier Index (Morgan, 2005, MFI) was chosen to be used in this paper, as it presents for each study station a classification related to the intensity of rainfall and results from the equation:

$$MFI = \sum_{1}^{12} \frac{p^2}{P}$$

Where MFI: Modified Fournier Index, p: average monthly rainfall and P: the average annual rainfall. The MFI ratio expresses the aggressiveness sum of the average monthly rainfall of each station for one year. In the present paper the spatial integration of the calculated point files MFI took place with the Spline method. The rain aggressiveness classification map was based on certain bibliographical specifications (Morgan, 2005).In order to produce the final result , the model builder of the ArcGIS software was used.

Initially, the point data were created in the Hellenic Geodetic Reference System EGSA '87 and the prices of the MFI factor were introduced to a field of the point file in the attribute table. Then, an execution of the model took place, the structure of which is shown in the following figure:

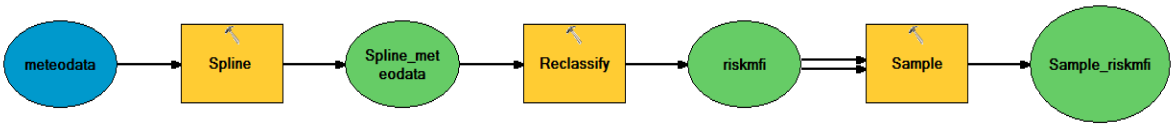

Fig. 2 Model of risk of MFI

3.2 Slopes

The morphological characteristics of a water basin , are capable of providing a first assessment of flood risk. Thus, areas with little slope have increased potential for flooding phenomena, while the more the slope increases, the more the risk decreases. In order to calculate the calibration slope soil map, initially the topographic maps of the Geographic Military Service were georeferenced and digitalized at a 1:50000 scale and at an elevation of 20m and then, the contours of the Evros prefecture have been imported in the ArcMap. This way, the three-dimensional Digital Elevation Model (DEM) of the study area was created and then the slope map was created with the contribution of the 3D Analyst software. In order to categorize the under consideration factors, the Shaban et. al methodology (2006) was followed, as it was also used in the other factors. The flood hazard map was calculated according to the following model:

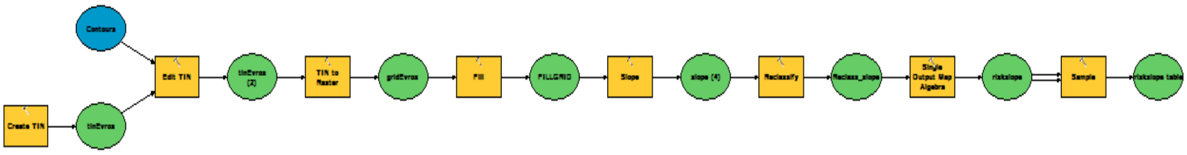

Fig. 3 Model of risk of slopes

3.3 Flow accumulation

The hydrological model Arc Hydro, which operates in a GIS environment, was applied in order to identify areas of significant surface water concentration and for these purpose raster grids of 100m and the flow direction for each cell was estimated on the basis of the three-dimensional terrain model (DEM). With the use of the appropriate algorithm via the flow direction map (flow accumulation - ArcHydro), the flow accumulation map was created, a map which indicates the number of cells contributing hydrologically to each cell of the raster grid. This map is particularly important, since it presents the water load which is being received by each point of the study area. Its production process is presented below:

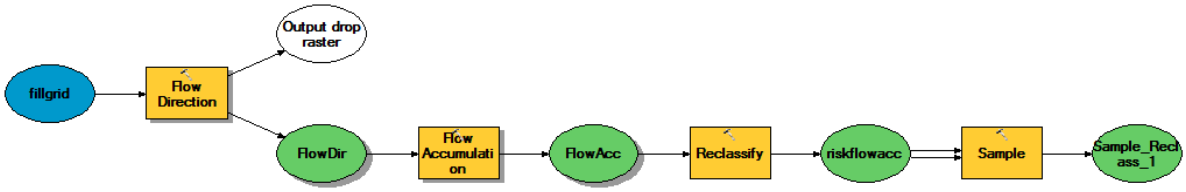

Fig. 4 Model of risk of Flow accumulation

3.4 Land use map

In order to create the land use map, we used the land use database of the CORINE European Environmental Agency. The classification of the vegetation includes forests, regardless of their kind, agricultural land, urban fabrics and sparsely vegetated area .It is necessary to note the disastrous fire which struck part of the study area in the summer of 2011 and which changed the land use. Since the CORINE database does not include the data of the said fire, its limits were digitized on the basis of the data of The European Forest Fire Information System (EFFIS) and the category of burnt lands replaced the pre-existing land uses. In the present paper, two different maps were produced, one before and one after the fire. The land use map of the area before the summer of 2011 was used for the model, the results of which were compared to the past floods. The other produced file was used for the creation of the future risk map. The input data of the model is the polygonal vegetation file, as well as the modified file which includes the burned areas. The model structure is as follows:

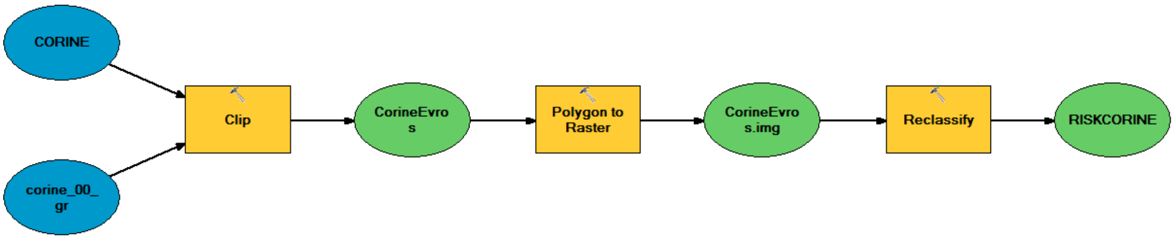

Fig. 5 Model of risk of CORINE

3.5 Geological substrate

In order to calculate the geology sheets risk, what was used was the hydrolithic map of institute of geology and mineral exploration 1:500.000. The map was georeferenced, digitalized and the result was the polygonal file of rocks. The model routine is similar to the land uses routine and appears in the following figure:

Fig. 6 Model of risk of geology

3.6 Weight factors

The calibration of the produced maps took place using weights factors from relative papers (Shaban et al. 2006, Morgan 2005), based on their estimated level impact to the flooding phenomenon and on repeated procedure and on the comparison of the results to the observed flood positions up to the achievement of the desired accuracy. Thus, the most important role in the study process of flood was given to the flow accumulation (32% effect), then to the rain aggressiveness (22%), land use (16%) and slope (18%) and the geological substrate (12%). The corresponding percentages after the fire are formed as following: 29%, 20%, 15%, 27%, 9%. Afterwards, the above thematic maps were adjoined by an algebraic addition of the weight factors of each cell and the classification of the produced map led to the result of the flood vulnerability map.

Table 1 Weight factors

	Contributing cells	**Weight**	**Balancing factor**	**Weight factors**	**Total**
Flow accumulation	>10000	10	4	40	132
	1000-10000	8		32	
	500-1000	7		28	
	200-500	5		20	
	0-200	3		12	
	MFI units				
Rainfall aggressiveness	200-300	8	4	32	92
	100-200	6,5		26	
	40-100	5		20	
	0-40	3,5		14	
	%				
Slope	0-8	8	3	24	69
	8-31	6,5		19,5	
	31-76	5		15	
	>76	3,5		10,5	
	Type of Vegetation				
Land use	Forest	2	4	8	74/122
	Agricultural land	3,5		14	
	Sparsely vegetation	5		20	
	Urban Fabrics	8		32	
	Burnt areas	12		48	
	Type of Rock				
Rocks	Metamorphic	3,5	2	7	41
	Flysch	5		10	
	Plutonic	4,5		9	
	Sedimentary granulous deposition	3		6	
	Non- Sedimentary granulous deposition	2,5		5	
	Granulous *molassic deposition*	2		4	
				TOTAL	408/450

Thus, the final map is a result of the following model:

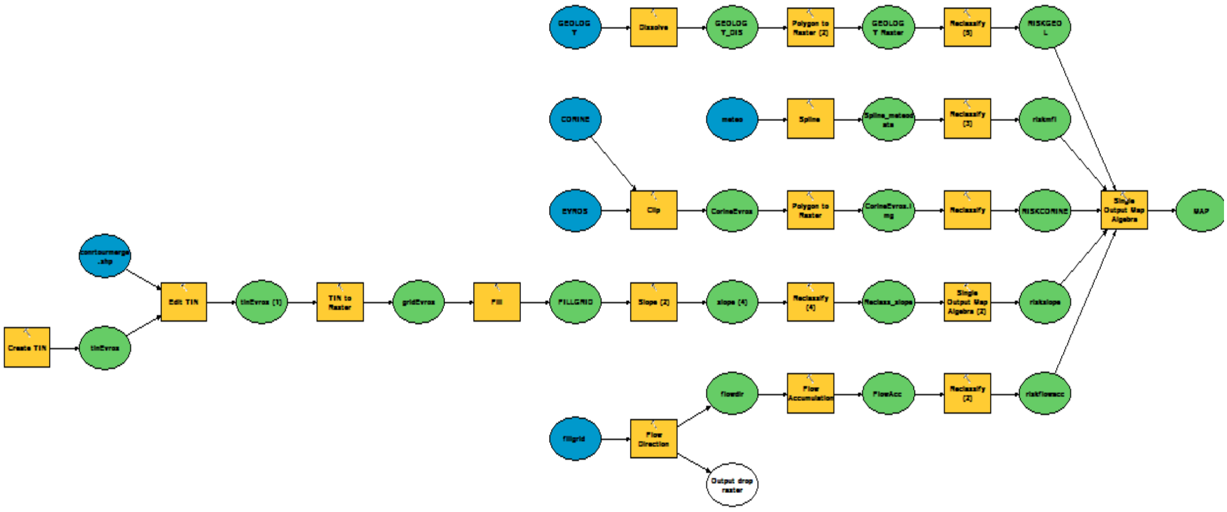

Fig. 7 Model of total risk

3.7 Estimation of vulnerability zones using Fuzzy Logic

In our case, expert knowledge is often expressed in terms such as nearness to some feature or in statements involving “sometimes” or “maybe”. Such semantic descriptions are useful but imprecise. Fuzzy Logic provides an approach that allows expert semantic descriptions to be converted into a numerical spatial model to predict the flood location.

3.7.1 Fundamental principles of the Fuzzy Logic Theory

The Fuzzy Logic is a superset of Classical Logic, which can be extended in order to handle truth values between "absolute truth" and "absolute false". The basic idea of the theory is that "the process of converting discrete sizes to unclear ones (fuzzification) allows to generalize a distinct theory in a continuous one” (Vlahavas et al., 2006).

Definition: Let there be a non-zero total, called X. A vague set A of X is characterized by the participation function $\mu_{A(x)}$: $X \rightarrow [0,1]$, where $\mu_{A(x)}$ is the participation degree of the xeX element to the vague set A. (Zadeh, 1965).

$\mu_{A(x)}$ is a real number $(0 \leq \mu_{A(x)} \leq 1)$ representing the degree to which x is an element of A and is called degree of membership or degree of truth or membership value.

The vague set A is characterized by the set of pairs $A=\{(x, \mu_{A(x)})$ where $x € X \}$. If $X = \{x_1,x_2,...,x_n\}$ a finite set and A a fuzzy set of X, then we use the notation $A=\mu_1/x_1 +...+\mu_n/x_n$

where μ_1/x_1 represents that μ_1 is the degree of participation of the x_1 to A and where + represents the union. It is evident that the greater the participation degree of an element is, the more it "belongs" to the set.

In the present paper, Linear was chosen as a degree function for the factors of vegetation, flowacc , geological sheets and rainfall, while MS Small was chosen for the slope factor. The choices of the functions took place using bibliographic references, as well as generate and test method.

The MS Small function is described by equations, depending on the product of a * m.

If $x > a * m$: $u_{(x)} = 1 - (b * s) / (x - (a * m) + (b * s))$

Where:

m = the mean, s = the standard deviation, a = a multiplier of the mean, b = a multiplier of the standard deviation. The a and b multipliers are input parameters.

If $x <= a * m$: $u_{(x)} = 0$

The Linear function is expressed by the following equations:

$$[x] = mim(\max(0, x), 1 = \begin{cases} 0 \ \ if \le x \\ x \ \ if \ 0 < x < 1 \\ 1 \ if 1 \ \le x \end{cases}$$

Let the generalized cut function be

$$[x]_{a,b} = \left[\frac{(x-a)}{(b-a)}\right] = \begin{cases} 0 \ if \ x \le a \\ \dfrac{x-a}{b-a} if \ a < x < b \\ 1 \ if \ b \le x \end{cases}$$

Where a, b ∈ R and α<b

Regarding the files with calculated values, such as the slope files, the flow accumulation files and the MFI files, the Membership functions use took place directly in their original values. For the vegetation and rocks files, their weight values were first reported as above, and then the corresponding equations were used. In order to produce the final risk map, what was used were the data results which were obtained by using the functions determining the degrees of participation and by combining the membership data using the overlay type “Add the minimum of the fuzzy memberships from the input fuzzy rasters”. The structure of the final model is shown in the diagram below.

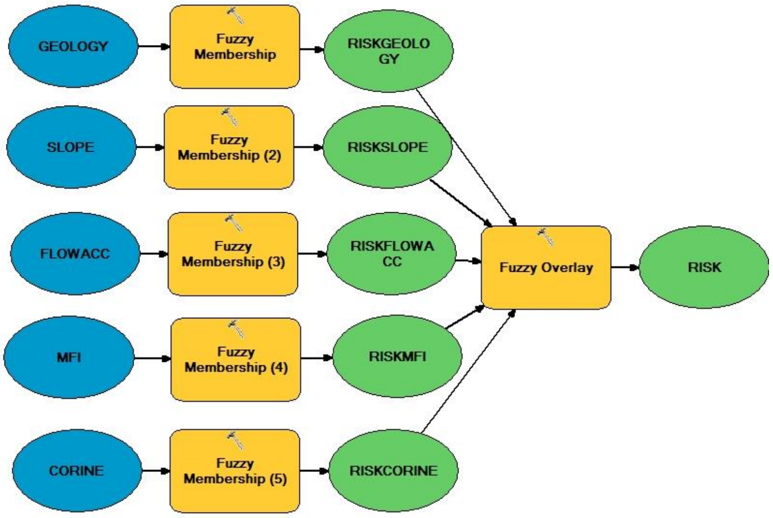

Fig. 8 Model of total risk using Fuzzy Logic

4. RESULTS

A problem that aroused during the bibliographic research was the one of the different use, by various sources, of concepts existing in the European Directive 2007/60, as well as in the earlier EU Water Framework Directive (Directive 2000/60). Therefore, it is useful to clarify these concepts and to specify them on their interpretation in the field of natural disasters and, more specifically, in their use by the aforementioned Directives.

Vulnerability: the sensitivity degree toward a natural hazard. It is associated with natural exposure to a catastrophic event that results in some kind of loss. It is also combined with the human ability / inability to resist, to be prepared and recover from the same event (Dalziell & McManus, 2004).

Risk: the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event (Source: EU directive 2007/60/EC).

Hazard: It is associated with the likelihood of an extreme event occurring ,that can cause a destruction of specific intensity at a given time and space (GTZ, 2004)

Flood hazard map: is a map, showing the extent and expected water depths/levels of an area flooded in three scenarios, a low probability scenario or extreme events, in a medium probability scenario (at least with a return period of 100 years) and if appropriate a high probability scenario (European Commission Environment).

Flood risk map: is a map, shall also be prepared for the areas flooded under these scenarios showing potential population, economic activities and the environment at potential risk from flooding, and other information that Member States may find useful to include, for instance other sources of pollution (European Commission Environment).

All the above lead to the fact that the name of a flood map depends on the information it provides. In the present paper, vulnerability maps were produced. Then, the flow accumulation vulnerability map is indicatively presented.

The flow accumulation map indicates that the areas with the major problems can be found in estuaries, and in general, in the route of the central rivers and streams of the region. More specifically, in the rivers Arda, Erythropotamos and as well as in the streams of Dadia, Ferres, Maistros and Makri. At the same time, the land use conditions and the rain aggressiveness hamper even further the whole situation.

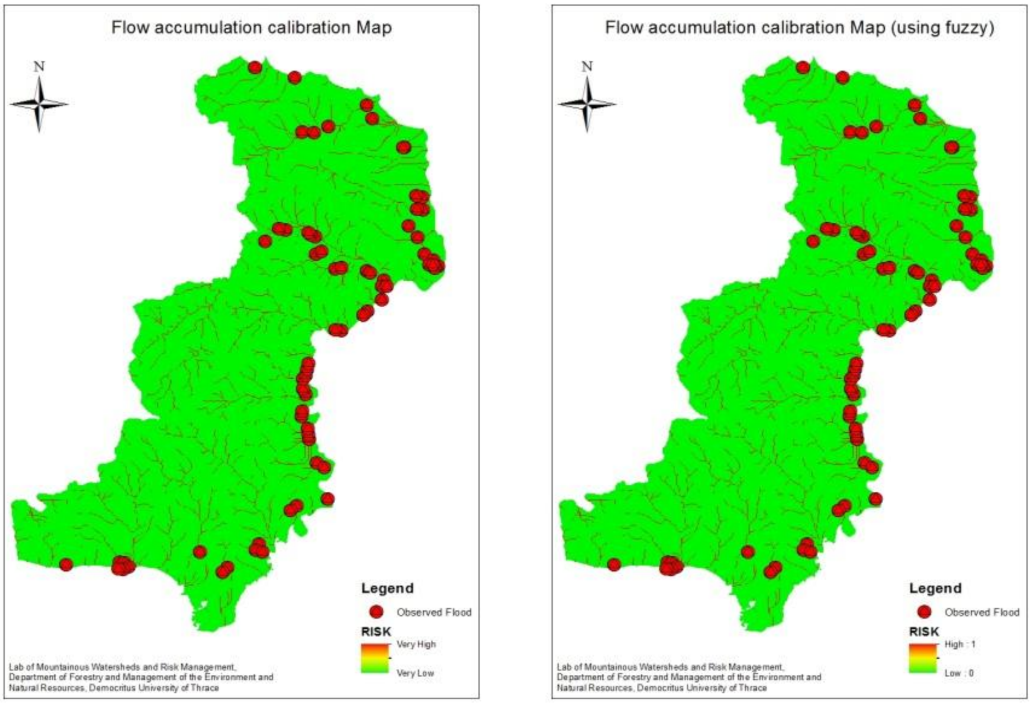

Fig. 9 Flow accumulation calibration map

The slope calibration map shows that in areas of very steep slope there is no significant flooding risk, as water rapidly funs off towards the lowland parts. The problem occurs mostly in the plains of the prefecture, where water occasionally reaches on high-speed and encounters significant resistance due to morphology and thus its speed is sharply reduced, while the water itself is stored on the surface. This is also confirmed by the map that we created, where one can see that almost all the observed floods occur in regions of lowland areas, which are characterized as of very high risk and occupy approximately the 80% of the total range of the study area.

The distribution of the rain aggressiveness, as it resulted from the calculation of the relative index (MFI) for each station and from the spatial integration of values,

Indicates that the aggressiveness of rainfall increases from North to South, until approximately the area of Alexandroupolis, where a reduction from East to West takes place. However, it should be noted that the distribution of rainfall stations do not completely cover the study area, because there is a deficit of stations, which should be taken into account for any expansion of the existing network.

Land uses also play an important role in protection from floods (e.g. natural vegetation, forests) and in aiding floods (e.g. urban fabrics). In the present case, the category of very high vulnerability was given to the urban fabrics, of high vulnerability to sparse vegetation, while crops were considered to offer some degree of protection, and areas of natural vegetation - forests present the lowest amount of vulnerability. After the fire, the category of the burned land was added, and it took the maximum vulnerability value, since it particularly contributes to flooding phenomena.

Finally, rocks were calibrated according to their permeability. The impermeable ones, like flysch , got the highest price vulnerability, while the permeable ones got the lowest price. In general, we can assume that the 80% of the area can be characterized of moderate to of very low vulnerability; while of high vulnerability is only the 0.71% of the area.

The combination of all the above thematic maps and the categorization to five categories of the final result with the equidistance method results in the map of flood vulnerability of the region. This said map shows that the eastern part of the study area is much more vulnerable than the western one, which is due to the presence of the Evros River and to the fact that it is the ultimate recipient of major streams. The sub region with the most important problem seems to coincide with the region of very high flow accumulation, which includes part of the main branches of the prefecture streams. The 6.39% of the area is of very high and high vulnerability, the vulnerability 21.58% is of moderate and the remaining percent is of low and very low vulnerability.

Table 2 Vulnerability per category

Parameters	**% PERCENT OF TOTAL AREA PER VULNERABILITY CATEGORY**				
	VERY LOW	**LOW**	**MEDIUM**	**HIGH**	**VERY HIGH**
Flow accumulation	92,04	2,04	1,54	3,24	1,14
Slope	-	0,03	0,52	19,39	80,06
Rain aggressiveness		9,59	32,7	57,71	-
Land use	-	33,74	56,94	5,86	3,46
Geological Sheets	14,27	37,51	28,48	19,03	0,71

In the second model, which the Fuzzy Logic is used in order to determine the flooding positions, it is not possible to categorize the risk areas limits by category, since they come from the Membership functions. The final vulnerability map, after the conversion of the fuzzy set to a real one, led us to characterize the 4.32% of the study area as of very high and of high vulnerability, while the 69.38% of it is characterized as of low and of very low vulnerability.

In order to check the results, the point file with the observed flooding and the extract values to point command were used, and then the comparisons of the methods took place, as shown in the table below.

Table 3 Total flood vulnerability and risk estimation

Boolean algebra			**Fuzzy method**	
Total flood vulnerability	**Risk estimation to the observed floods**	**Value**	**Total flood vulnerability**	**Risk estimation to the observed floods**
24,72	1	**Very low**	66,37	1
47,32	5	**Low**	17,84	2
21,58	28	**Medium**	10,63	13
4,23	24	**High**	2,92	16
2,16	11	**Very High**	2,24	37

The above show that the use of Fuzzy Logic model predominates in predicting risk zones, while at the same time it has a simpler structure and faster execution. However, both models are reliable and are an important tool for decision making.

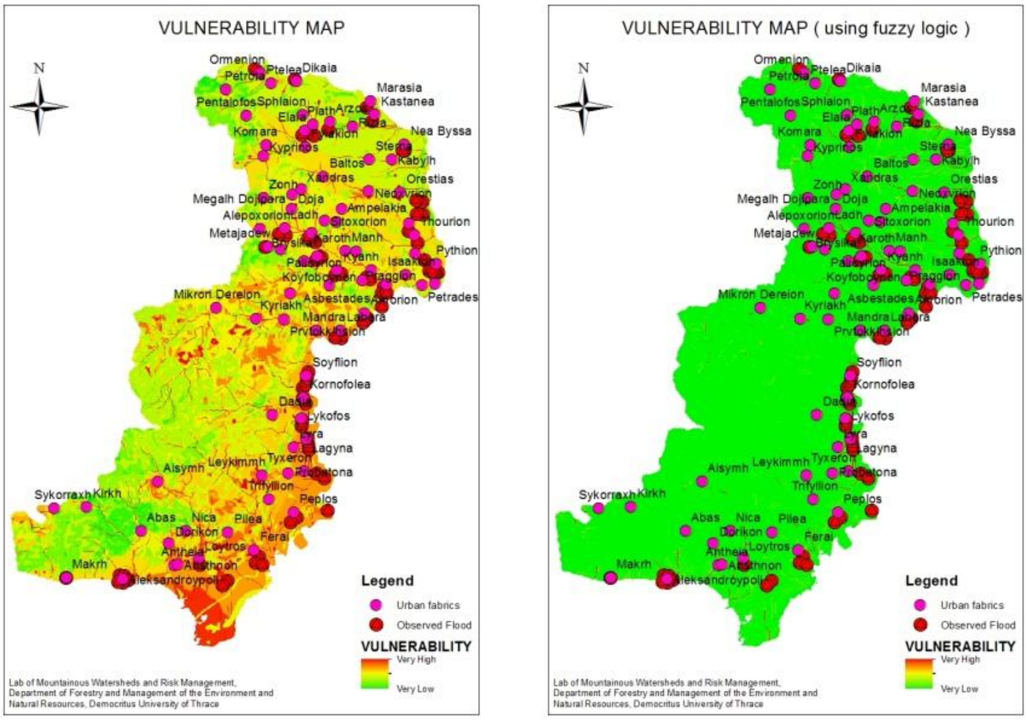

Fig. 10 Vulnerability maps (before the fire)

The areas presenting the greatest problem of flood vulnerability were estimated by the flood vulnerability map. There should be a further research in these areas in order to ascertain with measurements the accuracy of the calculations and to examine various additional factors such as socioeconomic and environmental / ecological conditions so that the level of priority protection in every one of them is attributed.
Then, the urban fabrics located within the aforementioned areas at high risk of flooding event were imprinted.

The comparison between the positions of the urban fabrics and the observed flooding positions shows that there is a considerable overlap which is due on the one hand to the importance of the role of urban fabrics as an favorable factor for a flood manifestation, while on the other hand the records of observations are based mainly in places of human interest (economic disaster), a fact which normally coincides with residential areas.

Afterwards, the vulnerability maps, as occurred after the fire, are presented, so as to enable their use in various scenarios and in the exact location of any technical projects.

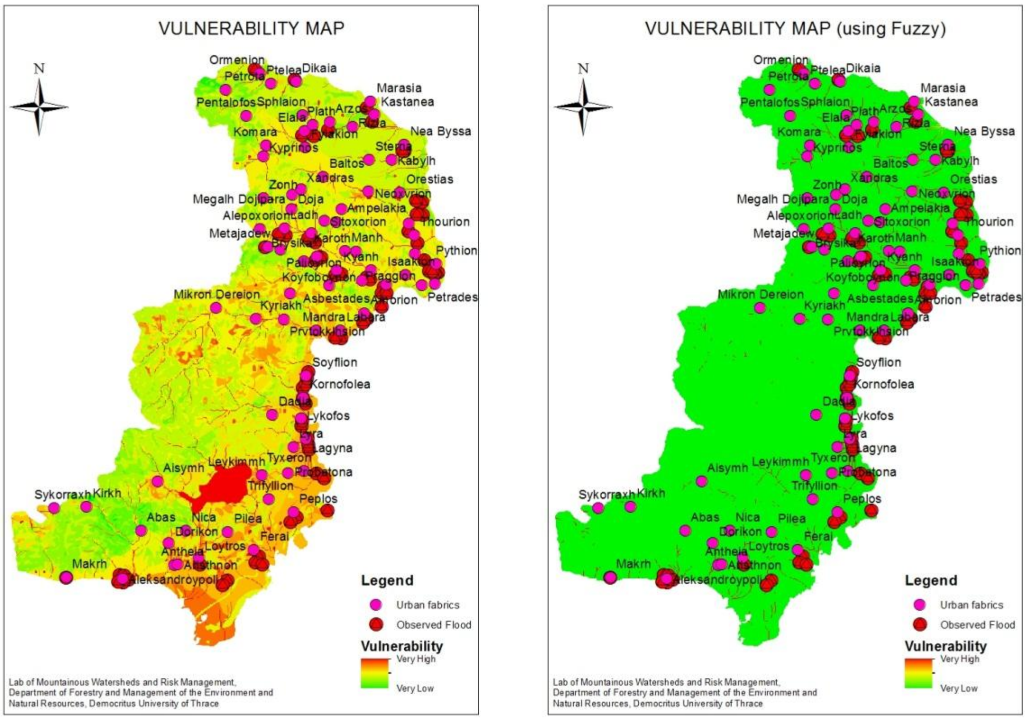

Fig. 11 Vulnerability maps (after the fire)

The maps above show that the model produced by the Boolean Algebra is more sensitive to changes of various factors and can lead to overestimation of some areas. On the contrary, the Fuzzy Logic model simulates better the various changes. A typical example is the burnt area in the region of Feres, where in the first case the one model characterizes the entire burned area as very dangerous, while the other considers very dangerous the segments adjacent to streams.

At this point, it should be noted that the exact causes of many floods in the study area are unknown. They might be due to local factors (which were analyzed above), to an overflow of the transnational river Evros or to a combination of both. In addition, the data of the models are in different countries and different agencies, due to the transnationality of the area, and thus resulting in the impossibility of implementing a common model in the waterbasin level.

Finally, it is deemed necessary, in order to better understanding the actual model, the use of more detailed maps, the repetition of the process, the further study on a smaller scale and the precise delineation of hazardous areas.

5. CONCLUSIONS

Therefore, one can easily understand the enormous general impact of this natural disaster in the sensitive region of Evros. The present work shows that the mapping of the prefecture areas vulnerable to flood events helps in recording the areas presenting such a severe problem and, consequently, in the proper coordination so as to avoid, except losses of human lives, phenomena such as property destruction and huge economic burdens incurring in this border region of Greece. Initially, there will be a localization identification of areas presenting severe relative problems and then there will be a detailed recording and delineation, by using a small scale mapping and by considering the prevailing socio-economic and environmental conditions. Furthermore, it is proposed to install a network monitoring water levels and rainfall in the region, with the possibility of telemetric control, aiming to the acquisition of important data over time and to the early warning in case of flooding. Constant monitoring and immediate intervention to minimize the impact of potential flooding will be combined with appropriate projects of anti-flooding protection, which should be designed and constructed wisely and taking into account the results of the aforementioned studies, in order for them to operate for the benefit of human and natural environment and for them to achieve their goal. Interventions should be mild and combinatorial (e.g. small scale dams in streams, small diversion canals in high infiltration zones, etc), while the establishment of flood protection zones is recommended, in order to avoid potential disasters but in order to allow the natural relief of the flood, too. Moreover, due to the transbountary nature of the area, there should be a relative organized and systematic movement with the cooperation of the three countries sharing the water-basin of the Evros river system. To sum up, flooding is an inevitable and indelible natural phenomenon. Still, it can be reduced through combined improvements in the prediction and management of river systems. The approach of flood vulnerability mapping helps in listing the areas presenting severe problems, thus becoming a tool to assist decision making, aiming to the mitigation of the impact of the phenomenon and to the ability of alerting the population in time.

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