Flood Susceptibility Assessment using G.I.S. An example from Kassandra Peninsula, Halkidiki, Greece.

Kafira V.[1], Albanakis K.[1], Oikonomidis D.[1]

1 Aristotle University of Thessaloniki (AUTH), Faculty of Sciences, Department of Physical and Environmental Geography, vkafira@gmail.com

ABSTRACT

Floods are natural phenomena and are an integral part of the water cycle. The majority of them are the result of climatic conditions, but are also affected by the geology and geomorphology of the area, topography and hydrology, the water permeability of the soil and the vegetation cover, as well as by all kinds of human activities and structures. However, from the moment that human lives are at risk and significant economic impact is recorded, this natural phenomenon becomes a natural disaster. Flood management is now a key issue at regional and local level around the world, affecting human lives and activities .

The majority of floods are unlikely to be fully predicted, but it is feasible to reduce their risks through appropriate management plans and constructions. This study was carried out due to the repeated catastrophic floods that have occured in Kassandra peninsula, Halkidiki, Greece and more specifically in the area of Fourka, causing numerous damages. The main purpose of this study is to evaluate the contribution of remote sensing technology and Geographic Information Systems (GIS) in assessing the susceptibility of this region to flood events.

Kassandra is facing “anthropogenic” floods; human interventions on streams, the beds of which have been trampled to build houses and hotels or have been converted into roads, are causing flooding after every heavy rainfall. The streams crossing settlements and areas with high touristic development have been intensively modified by humans, as the pressure for real estate development land is growing.

In particularly, several areas in Kassandra are facing high risk of extensive flood occurrence, since fires happened in the past and flood protection infrastructure has been seriously damaged.. Such examples are the catastrophic fires in August 2006, which destroyed 60 % of the forested area of Kassandra and the dramatic floods that followed in September 2007.

This study concentrates on the construction of a flood susceptibility map, of the study area, by combining vulnerability elements, using the Analytical Hierarchy Process/ AHP (Saaty, 1980). After processing of a digital elevation model (DEM), important secondary data were extracted, such as the slope map, the flow direction and the flow accumulation. Together with additional thematic information (e.g. geological maps, land cover etc.), these led to the final four major factors for creating the flood susceptibility map,i.e. the Topographic wetness index, Lithology, Roughness - Land cover and Vegetation cover index (NDVI). These factors were co-evaluated, in order to produce the final map, which categorizes the area into zones of higher to lower flood susceptibility.

Keywords: GIS, flood, susceptibility map, Kassandra peninsula.

1. INTRODUCTION

The European Parliament and the Council of 23 October 2007 adopted Directive 2007/60 / EK on the assessment and management of flood risks, which entered into force on 26th of November 2007. This directive complements the water Framework Directive 2000/60 / EC, regarding the management of flood risk. The main objective of Directive 2007/60 / EC is to assist Member States in preventing, reducing and preventing flooding. The Directive establishes the European framework for flood risk management that builds on and is closely coordinated with the Framework Directive (2000/60 / EC) on the waters. The science of remote sensing in combination with Geographic Information Systems introduced new methods in the management of natural ecosystems. The possibility of longitudinal monitoring of the Earth's surface in short time and at a relatively low cost allows the recording of changes that occur in the natural environment and thus facilitates treatment or anticipation of potential problems.

The purpose of this study is to evaluate the contribution of Remote Sensing and GIS technologies in flood management, by constructing flood susceptibility maps.

Figure 1 Pictures of previous floods in the study area

2. STUDY AREA

Kassandra is a peninsula and a municipality in Halkidiki, Greece, which has a triangular shape and is washed by the sea. Cape Poseidi represents the apex of the triangle, while the canal of Potidaia, on the northern tip, separates the peninsula from the main land of Halkidiki, so that it becomes an island. The extent of Kassandra is approximately 355 km^2.

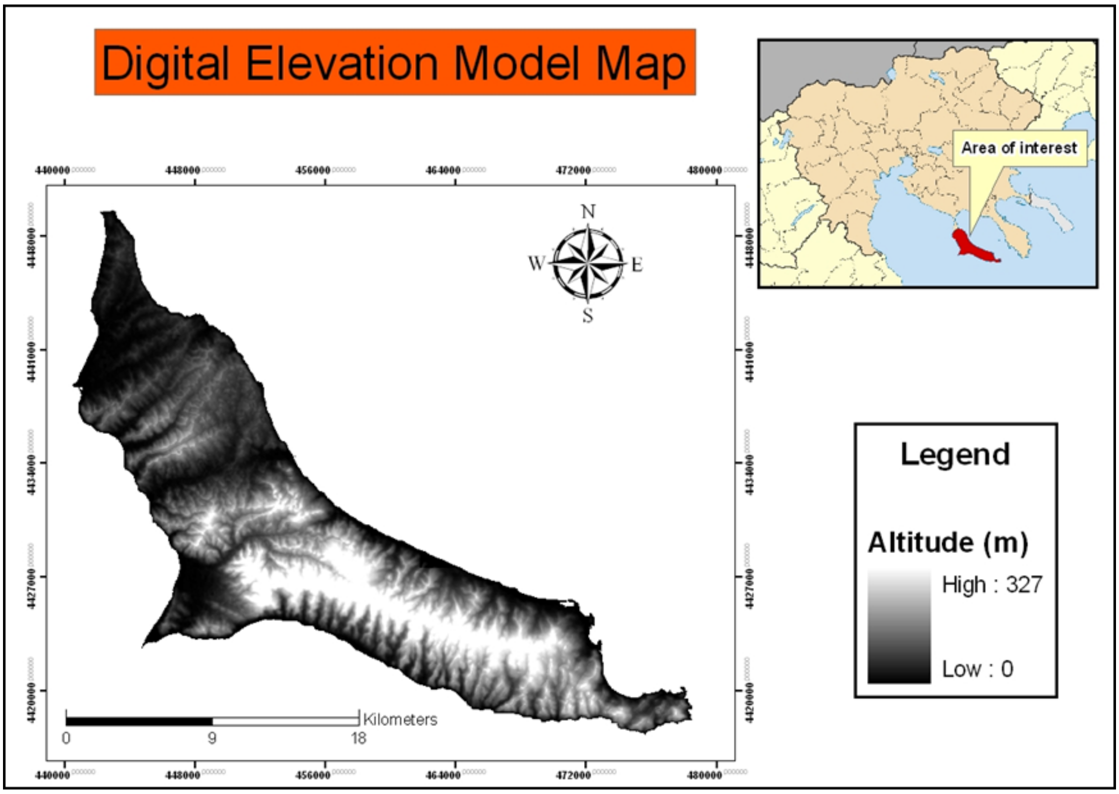

Figure 2 Digital elevation model of the study area

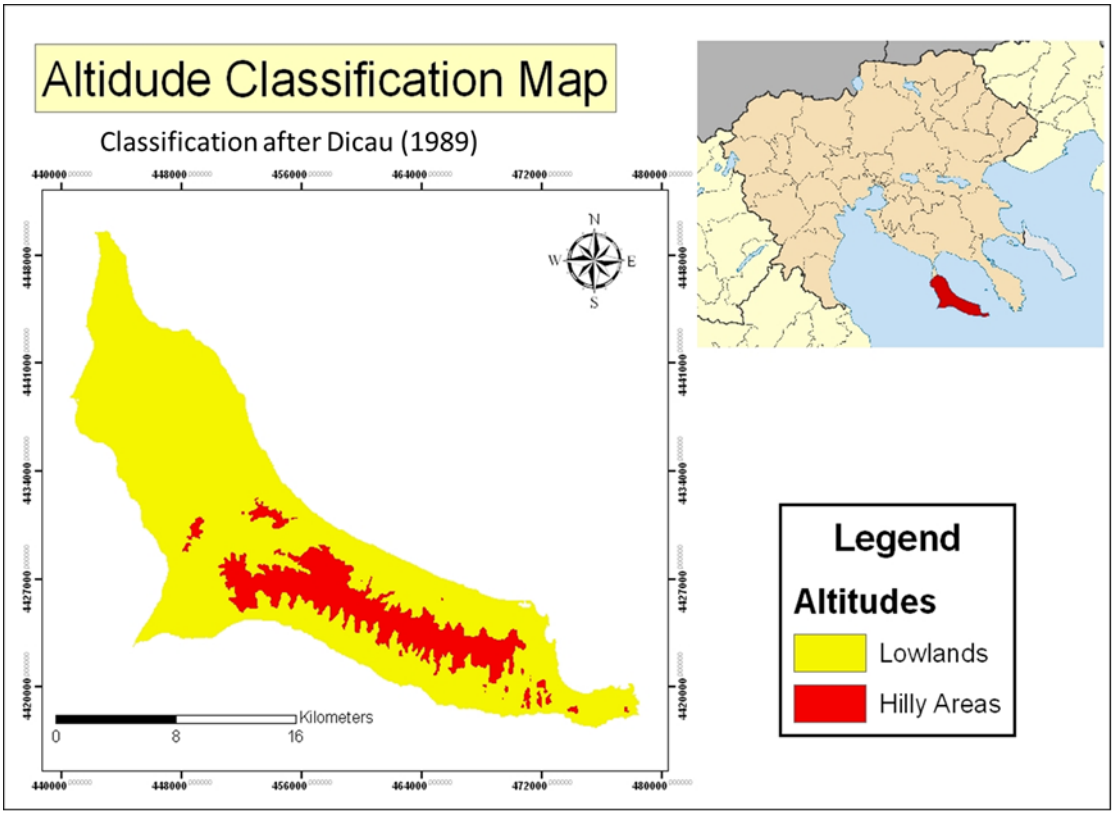

Figure 3 Classification of the altitudes of the area after Dicau, 1989.

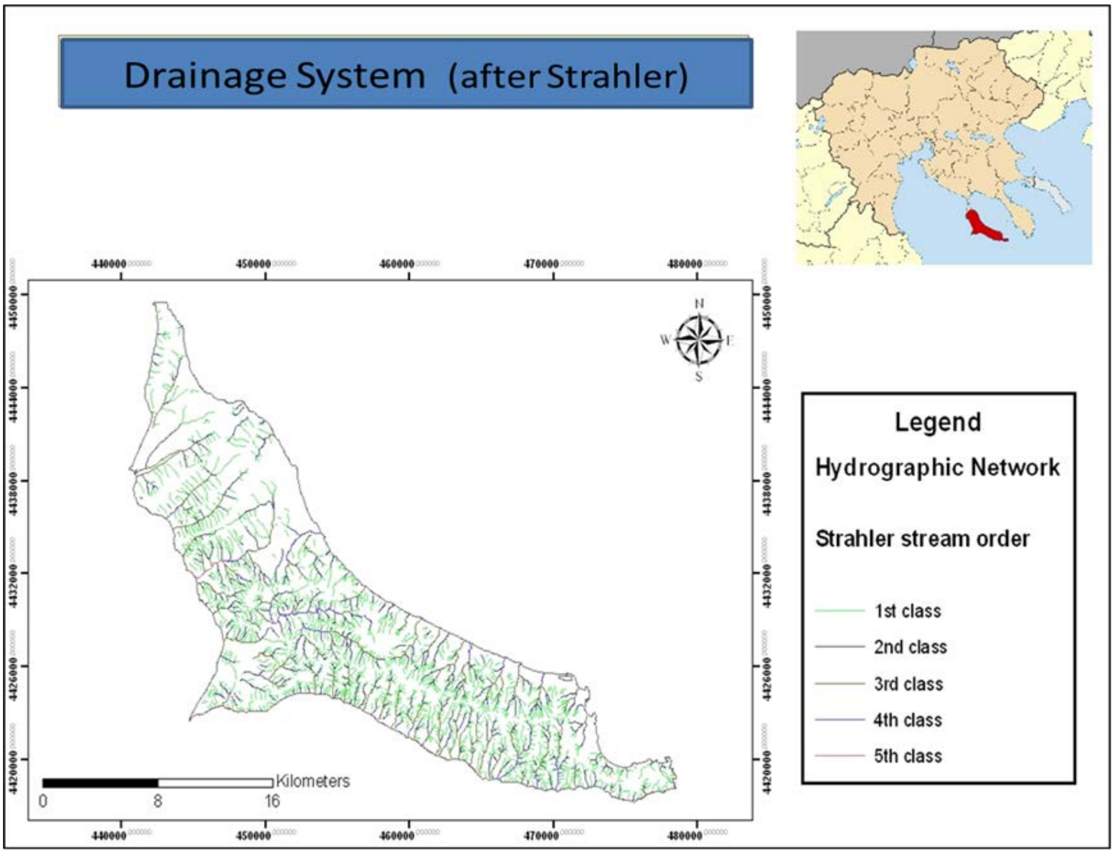

Figure 4 Drainage system after Strahler of the study area.

3. DATA AND METHODOLOGY

3.1 AVAILABLE DATA

Firstly, after suitable processing of the geological and topographic map of Kassandra , the Aster G-DEM of the study area and a Landsat 7 ETM+ image with date 24/08/2000 the following information was extracted:

- Drainage network
- Geologic Formations
- Land Cover
- Watersheds and study area boundary

From which afterwards, new information was derived, such as maps of topography, lithology, land use, land cover. In the end with co-evaluation of these factors the flood susceptibility map of the study area was created.

3.2 GIS FOR FLOOD SUSCEPTIBILITY ASSESSMENT

A GIS can be used to construct a map of susceptibility to flooding, which indicates the areas where flood is most likely to occur. In this study, the four most significant factors for the construction of the flood susceptibility map were considered, that greatly affect the occurrence of floods in the study area. These factors are:

- The topography
- The permeability of the lithological formations in the region
- The roughness - Land Cover
- The vegetation

From the factors mentioned above the following levels of information were produced:

- map depicting moisture distribution, based on the topography
- map depicting the permeability of the geological formations
- surface roughness map
- vegetation map

Ratings were assigned to the above levels, based on their importance to the occurrence of flooding. These rating were calculated with the help of "Analytic Hierarchy Process" (Saaty, 1980; Domakinis, 2005). Subsequently, these levels were combined and co-evaluated for the classification of the region into zones according to susceptibility to floods. The factors that affect flooding, as well as the information derived from them are presented henceforth

3.2.1 SLOPE MAP

A parameter that can be derived from further analysis of digital elevation models for further analysis is the slope of the terrain, which is the most widely, distributed known topographic size element and, very high importance very important for each every geomorphological research study.

Firstly the Slope map of the study area is created based on the Aster G-DEM, subsequently, by taking into account the classification of slopes of the terrain suggested by Demek (1972), which was then adopted by the Commission Geomorphological Survey and Mapping (Commission on Geomorphological Survey and Mapping) of the International Geographical Union (IGU - International Geographical Union), the slopes of the area were classified into 6 main categories:

- Slope 0 ° - 2 ° (0% - 3.5%): Level to slightly sloping terrain (floods fields, flattening surfaces, terraces). Start corrosion cap type. Absence of problems in human activities (transport, construction, agriculture, forestry).
- Slope 2 ° - 5 ° (3.5% - 8.7%): Slightly sloping terrain (foot valleys, dune slopes).
- Slope 5 ° - 15 ° (8.7% - 26.8%): Strongly sloping terrain (slopes of valleys, tectonic terraces).
- Slope 15 ° - 35 ° (26.8% - 70%): Curt (150-250) to extremely steep (250-350) terrain (slopes of middle mountain valleys).
- Slope 35 ° - 55 ° (70% - 135%): Steep terrain (steep slopes of high mountain valleys, slopes formations hogbacks, limestone canyon slopes).
- Slope> 55 ° (> 135%): Vertical relief (vertical slopes in areas of sandstone and limestone mountains). Lack of soil. (Demek, J., 1972; Nikolaidou, 2009).

The slope map of the study area resulted from the processing of digital elevation models (DEM) using the software Arc Map (Spatial Analyst extension), and the classification of IGU (Demek, 1972):

Table 1. Spatial distribution of the slopes of the study area after Demek (1972)

Slope in Degrees	Area (km^2)	Percentage (%)
0 - 2	57	16,23
2 - 5	95	27,06
5 - 15	160	45,57
15 - 35	39	11,11
>35	0,1	0,03

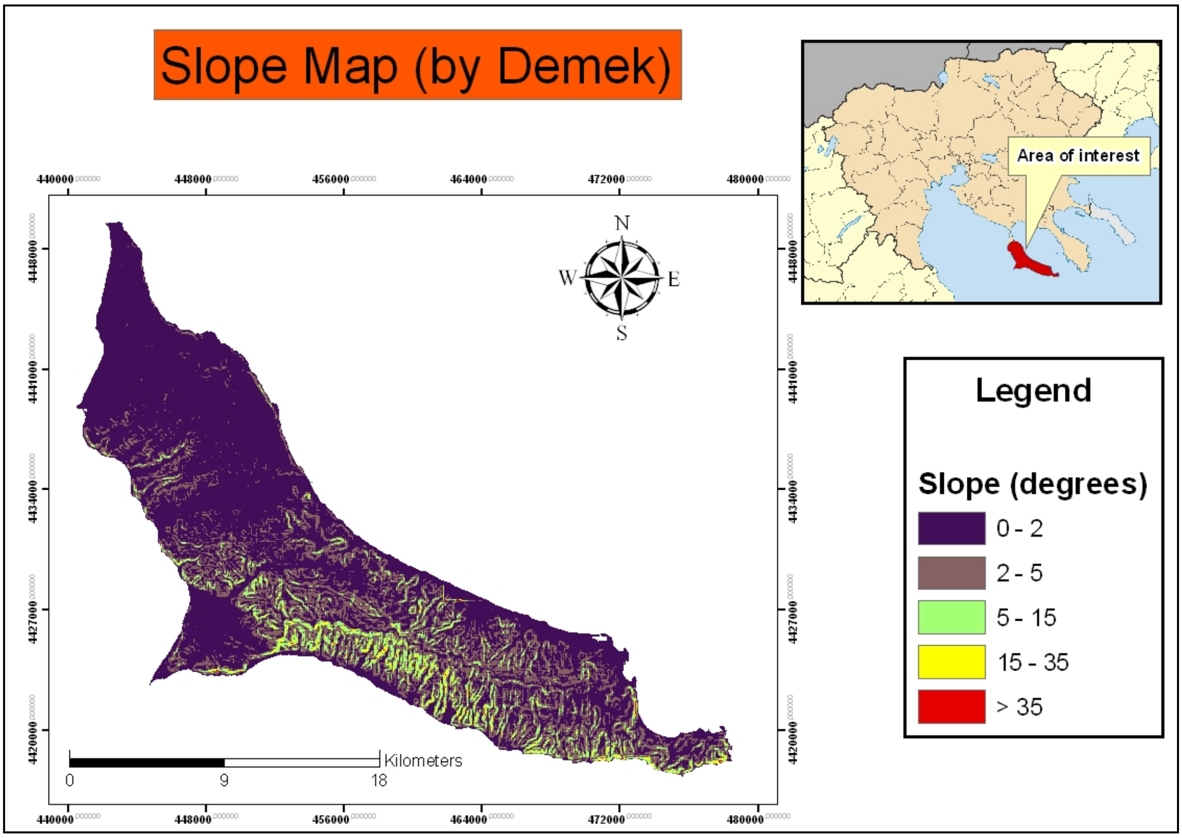

Figure 5 Slope map of Kassandra, Halkidiki (slope classification after Demek, 1972)

3.2.2FLOW DIRECTION

The "downstream" flow (flow direction) in each pixel of DEM depends on the elevation of this point relative to its neighbors. The possible directions are eight, namely E, SE, S, SW, W, NW, N and NE. (Nikolaidou, 2009). Flow Direction calculates the direction of flow for a given matrix. The water that is stored in each cell will flow to the neighboring cells with lower altitude.

In this context, using the Hydrology Modeling tools of Arc Map and the digital elevation model of the study area, the flow direction was calculated for each pixel.

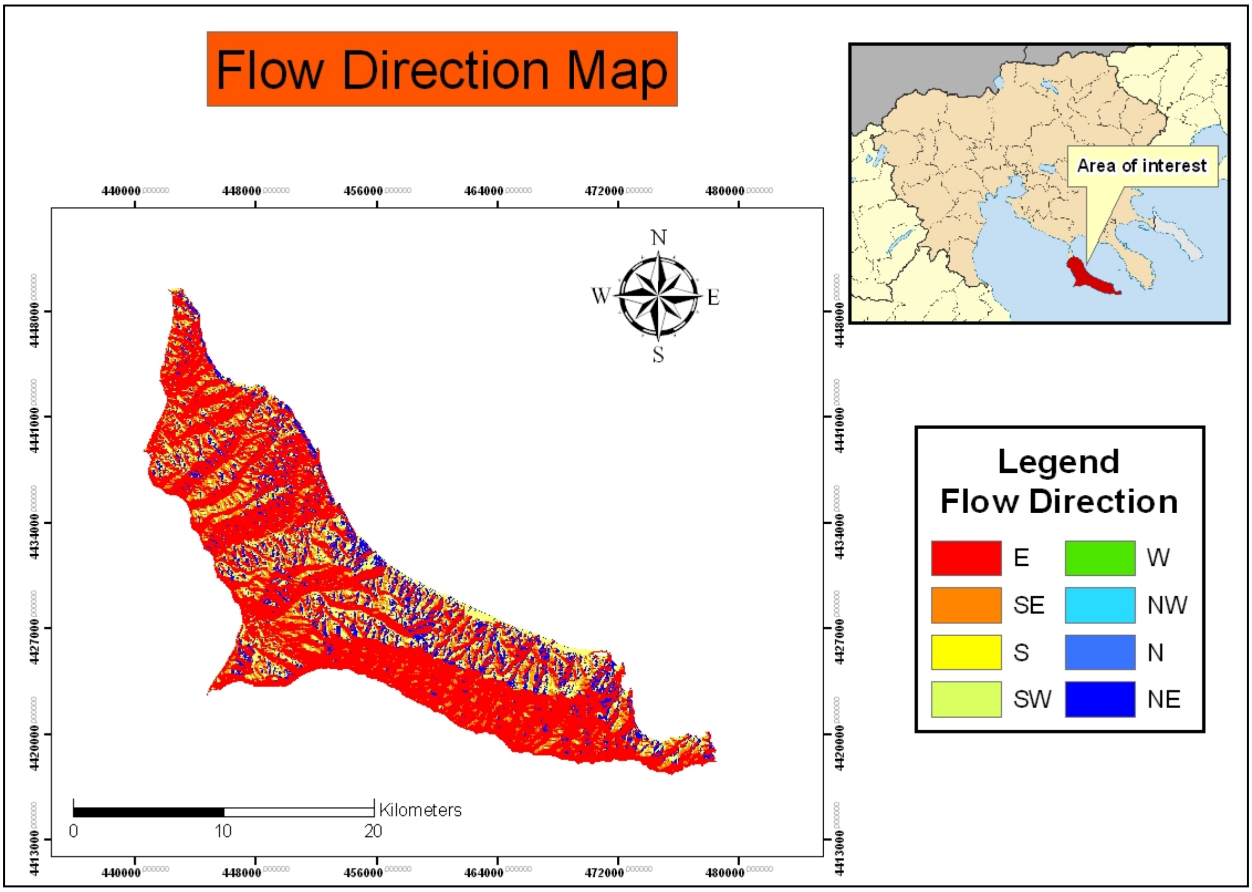

Figure 6 Flow direction map of the study area

3.2.3 FLOW ACCUMULATION

The accumulation of flow is the quantity of water, which will move to each pixel from its neighbors and eventually accumulated to it. The calculation of the total flux that is concentrated in each pixel is possible, based on the flow direction of the neighboring points.

The Flow Accumulation function computes the flow accumulation grid (flow accumulation grid) which includes the accumulated number of cells above the cell, for each cell of a given grid. From the Flow Accumulation Grid, opening the Properties panel and selecting the Source, one can observe how many cells there are in the grid, the size of the cell, which is the maximum flow accumulation in cell number and what drainage area meets (Maidment and Robayo, 2002).

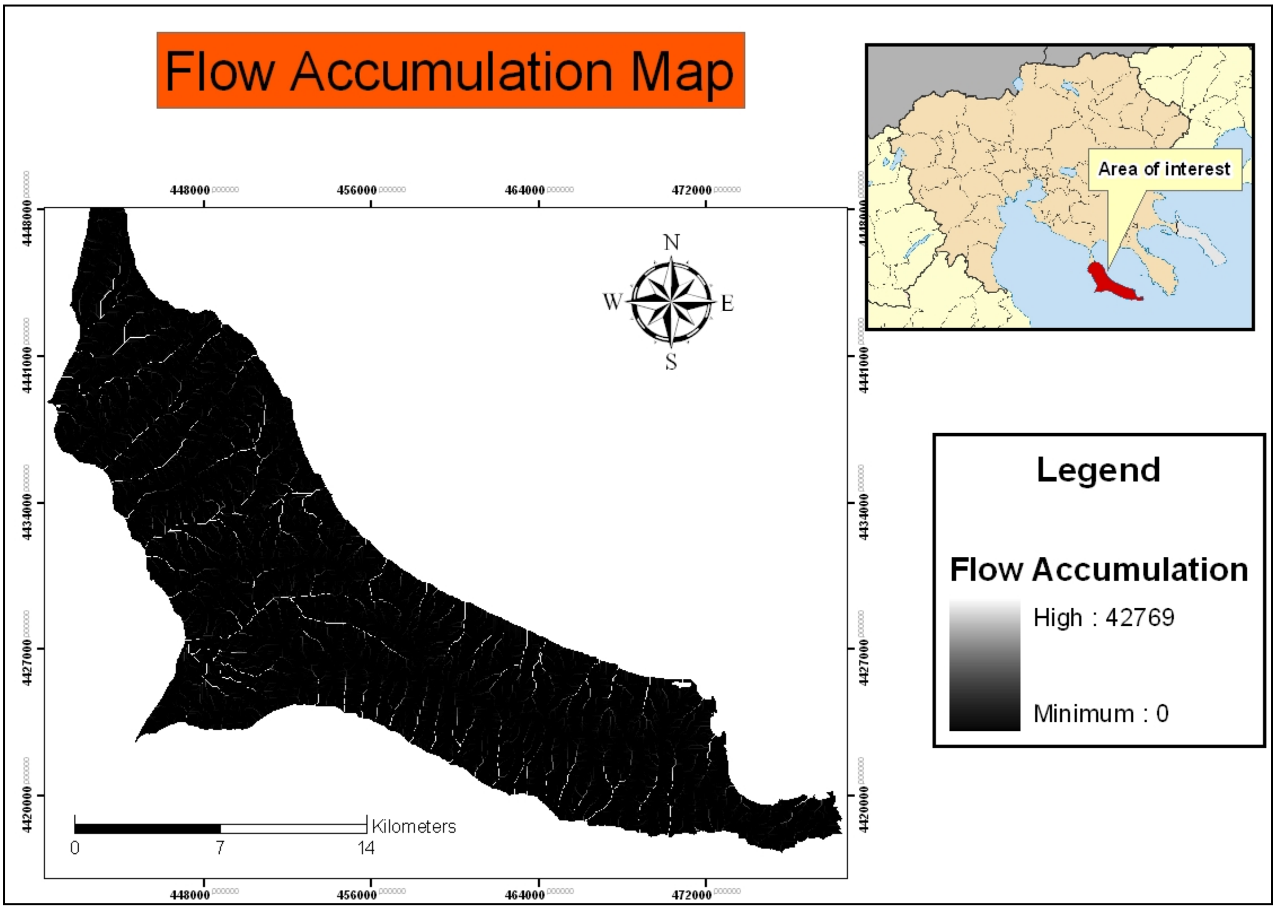

Figure 7 Flow accumulation map of the study area

3.2.4 TOPOGRAPHY - TOPOGRAPHIC MOISTURE INDEX (TOPOGRAPHIC WETNESS INDEX).

The topography is one of the most important factors controlling the spatial variation of hydrological conditions. (Burt and Butcher, 1985; Seibert et al., 1997; Rodhe and Seibert, 1999; Zinko et al., 2005; R. Sørensen, U. Zinko, and J. Seibert, 2006)

The topographic moisture index (Topographic Wetness Index / TWI) is a simple mathematical parameterization of potential soil moisture applied in many studies. The index is calculated based on slopes and therefore depends on the digital terrain data. (Haas, 2010).

TWI has been developed by Beven & Kirkby (1979) and is defined by:

TWI = ln (a / tanb)

Where **a** is the local upslope contributing area (m^2) from flow accumulation raster and **b** local slope angle (degrees).

The topographic moisture index (topographic wetness index) or index moisture (wetness index) or topographic index (topographic index), is the most widespread second derivative of digital elevation models (DEM) and it is used to describe the effect of topography on the distribution of soil moisture in an area.

The greater the extent of the local catchment area and the smaller the tilt angle, the higher the index value and may therefore be expected moist soil (Beven and Kirkby, 1979; Quinn et al., 1991). The study of the spatial distribution of the topographic index in association with the various landforms carried out the classification and interpretation of its values. The ridges are characterized with low values, while the lower parts of the slopes, particularly the concave regions and the bases of the valleys have high values (Rodhe and Seibert, 1999; Paraschou 2005).

On the map below (fig. 8) which was extracted from the DEM with the help of the TAS (Terrain Analysis System), the distribution of topographic moisture index in the study area can be seen. Three categories of index values (low, medium, high) were defined, for each of which the area and the percentage % of the total area were calculated.

The classification given in each category corresponds to their hazard. Increased index values declare more dangerous areas (rating 3) while reduced index values show low flood risk areas (rating 1). From the map showed that 1.42% of the study area has high value of the index, 17% moderate and 81% low.

Table 2 Table 3 Percentage out of the total area for each wetness index category in the study area

Wetness Index	**Area (km^2)**	**Percentage (%)**
Low	286	81,48
Medium	60	17,09
High	5	1,42

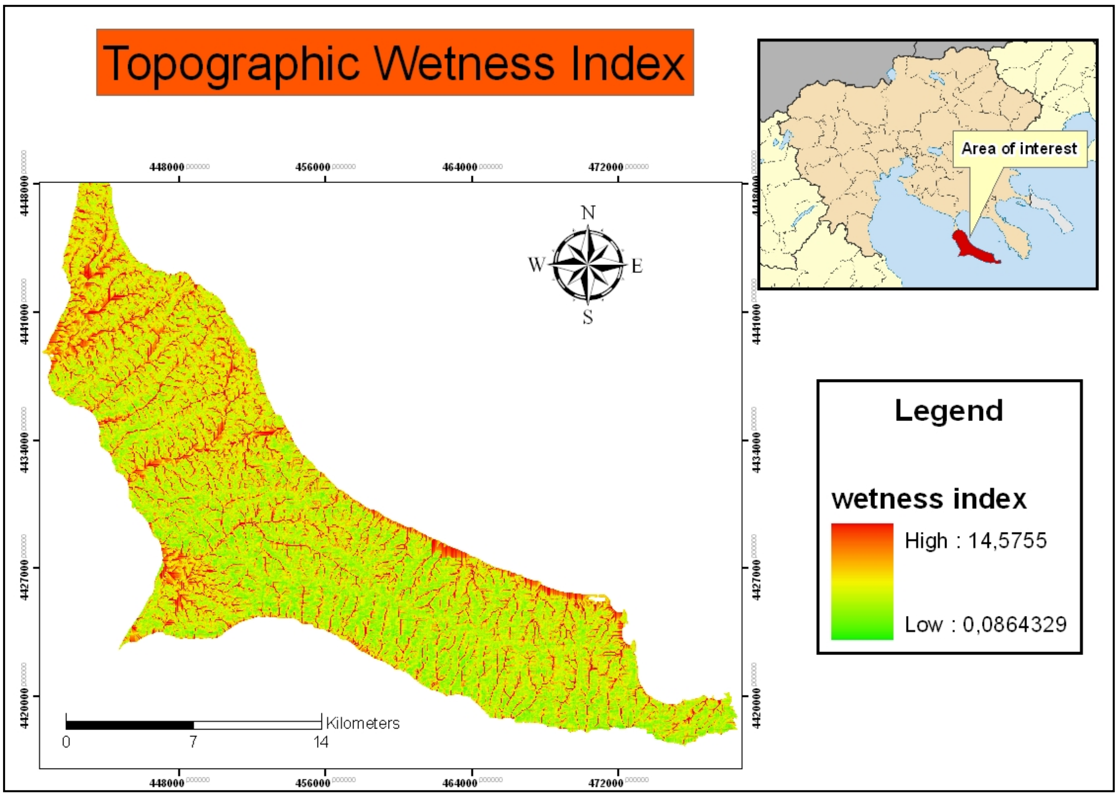

Figure 8 Topographic wetness index map of the area

3.2.5 LITHOLOGY – ROCK PERMEABILITY

Beyond the topography of a region important factor which affects the outflow and thus flood the runoff is lithology of this region. Each rock has its corresponding permeability which depends on its composition. The permeability (or hydraulic conductivity) is a property of the rock and is connected with the ease or difficulty of moving water into the mass. A measure of permeability is the permeability coefficient or the coefficient of Darcy. This factor has units m / sec, cm / sec, 1 meinzer, 1 darcy. In Europe, m / sec are commonly used (The SI Metric System of Units and SPE Metric Standard) .

The permeability coefficient depends on the pore size of the soil material and therefore it is not material's property but do vary according to the degree of concentration. For example, sand has a much higher permeability when it is dry and undisturbed rather than condensed with very dense structure. It seems therefore that the permeability coefficient depends on the type of soil material and its relative density.

A rock with large permeability coefficient has relatively little resistance to the flow of water through it and may allow high speed infiltration. The exact opposite happens with a rock that has little permeability, i.e. has low permeability. The latter shows relatively large resistance to the flow of water through it and may allow really low speed flow filtration.

So there are rocks more or less permeable, but it should be noted that completely impervious rocks, i.e. rocks that have zero permeability coefficient ($k = 0$) seem not to exist (Soulios, 1996).

Yet, completely conventionally and arbitrarily rocks are divided into three categories according to their permeability (this categorization is universally accepted and was adopted for practical reasons) (Soulios, 1996):

- Permeable rocks (high permeability) k ≥ 10-5 m / sec
- semi permeable rocks (moderate permeability) 10-5> k> 10-7 m / sec
- impervious rocks (low permeability) k ≤ 10-7 m / sec

Table 4 Percentage distribution of rock permeability in the study area

Lithogical Permeability	**Area (km^2)**	**Percentage (%)**
High	125	35,61
Medium	113	32,19
Low	113	32,19

Thus, according to the permeability map, about 35% of the region is covered with permeable rocks, while the rest is made up of impermeable and semi permeable.

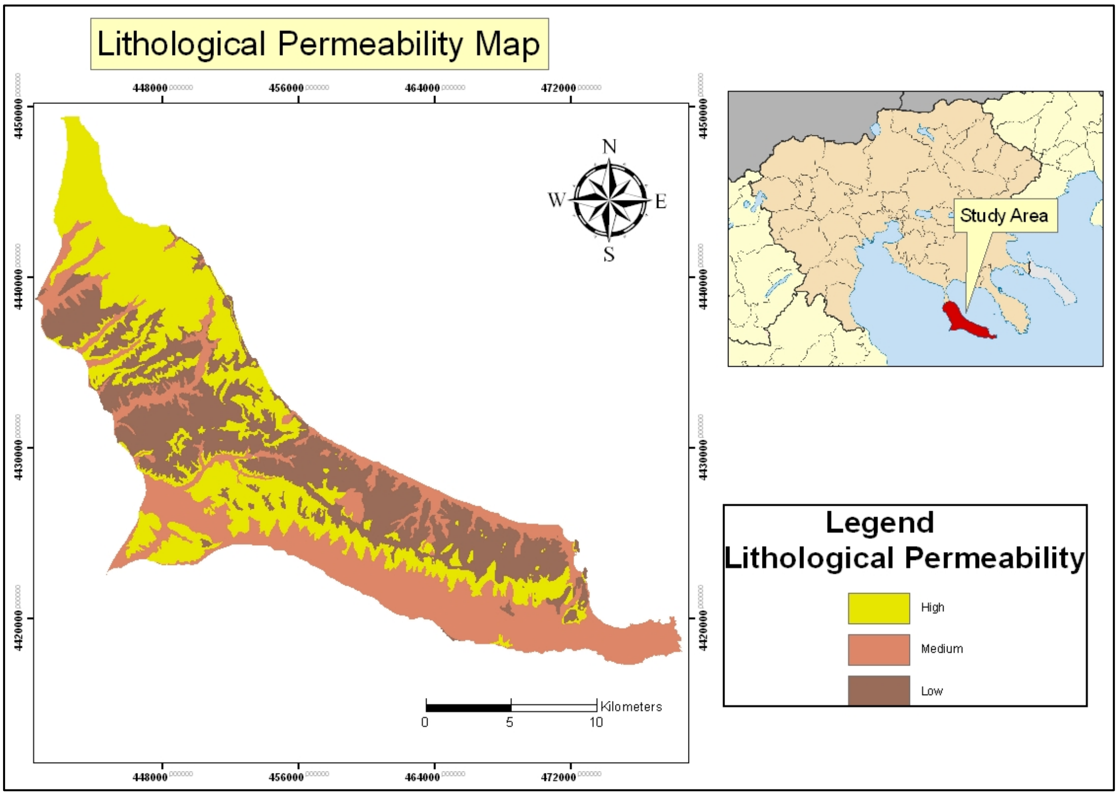

Figure 9 Lithological permeability map of the area

3.2.6 ROUGHNESS - LAND COVER

The land cover in the study area is given by the program CORINE LAND COVER 2000. Based on the rate Strickler (Strickler coefficient) (e-EcoRisk, 2004), which gives a roughness value in each land cover code of the CORINE LAND COVER 2000.

Small roughness in an area (large coefficient Strickler) favors movement of water downstream so that makes it more dangerous. Conversely, as the degree of roughness is increased (decreased value by Strickler), increases the resistance encountered by the water in motion with a consequent reduction in its velocity and hence it's danger.

In this specific study area roughness values were defined as follows: 0.12, 4, 5, 6, 7, 8, and 10. The value 0.12 corresponds to high surface roughness while greater values correspond to lower roughness.

Land Cover Codes	112	121	142	211	223	242	243	312	313	321	323	324	421
Strickler Coefficient Codes	5	5	4	8	5	6	7	5	5	10	7	7	0,12

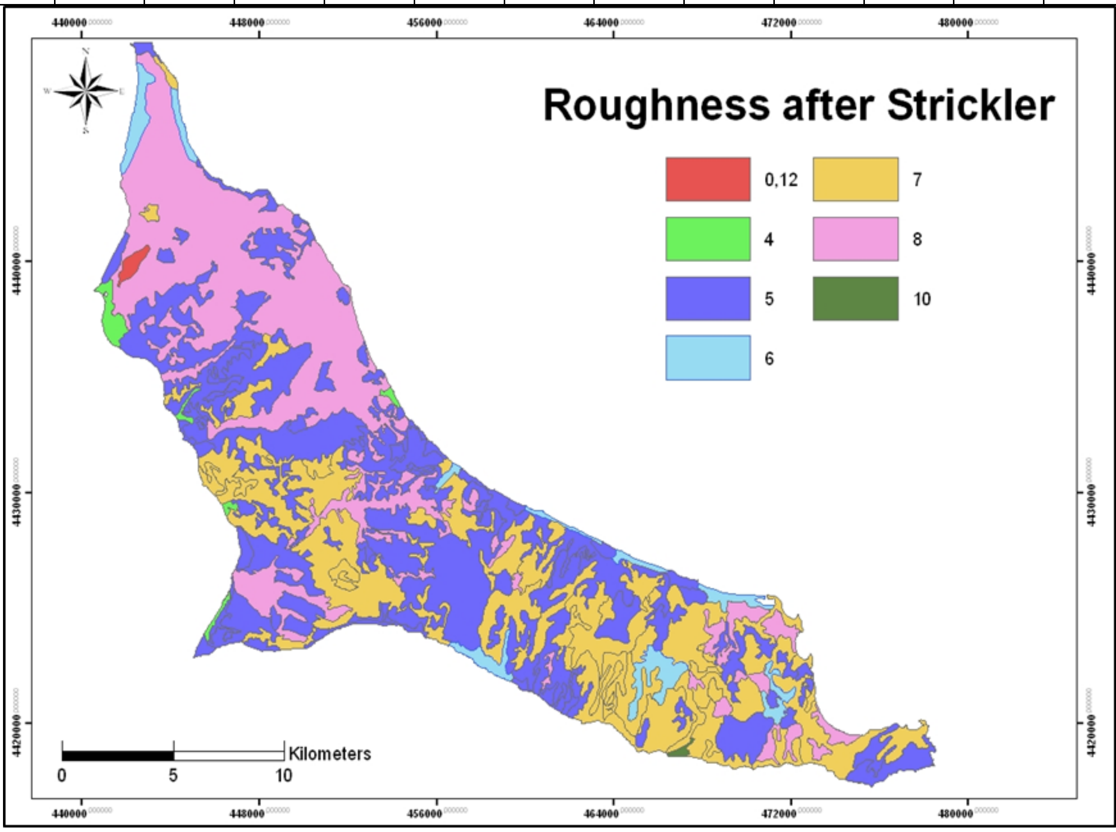

Figure 10 Roughness codes after Strickler.

Table 5 Correlation of Srickler with Corine codes and the area they cover.

Strickler Coefficient	**Corine Land Cover Codes**	**Corine Label Level 3**	**Area (km^2)**	**Percentage (%)**
0,12	421	Salt marshes	1,02	0,03
4	142	Sport and leisure facilities	3,04	0,97
5	**112, 121, 223, 312, 313,**	**Discontinuous urban fabric,** **Industrial or commercial units,** **Olive groves,** **Coniferous forest,** **Mixed forest**	**132,65**	**38,01**
6	242	Complex cultivation patterns	12,66	3,62
7	**243, 323, 324**	**Land principally occupied by agriculture, with significant areas of natural vegetation,** **Sclerophyllous vegetation,** **Transitional woodland-shrub**	**100,49**	**28,79**
8	**211**	**Non-irrigated arable land**	**98,76**	**28,29**
10	321	Natural grasslands	0,36	0,10

3.2.7 VEGETATION INDEX - VEGETATION (NDVI)

Bibliographically there are several vegetation indices and many tasks related to their use, but the basic idea is, that the ratio of near infrared to red is usually high in the case of healthy vegetation. This means that in case of illness or lack of vegetation, a decrease of reflectance in the near infrared reflectance and an increase in red, occurs (Syllaios, 2000).

A well-known index is the normalized difference vegetation index (Normalized Difference Vegetation Index - NDVI). This index was used in this study and was calculated by the equation:

$$NDVI = \frac{NIR - R}{NIR + R}$$

where NI.R (Near Infrared) is the spectral band of the near infrared and R (Red) the red spectral band .

The satellite image which was used in the present work is a LANDSAT 7, (acquisition date 24-08-2000). After process with ENVI software the above index takes the form (Syllaios, 2000; Fourniadis .A. 2002):

NDVI = ((TM+4) – (TM+3)) / ((TM+4) + (TM+3))

The NDVI values range theoretically from -1 to 1, as derived from the mathematical equation above. Values above zero indicate the presence of green vegetation (chlorophyll) or bare soil (values close to zero), while values below zero indicate the complete absence of vegetation and the presence of water, snow, ice and clouds. (Dalezios, 2002; Ciro, 2006).

Table 6 Indicative values of NDVI index in different land cover types (Dalezios, 2002).

Type of Land Cover	**NDVI (scale from -1 to 1)**	**NDVI (scale from 0 to 255)**
Thick Vegetation	0.500<=NDVI<=1	210<=NDVI<=255
Medium Vegetation	0.140<=NDVI<0.500	118<=NDVI<210
Scarce Vegetation	0.090<=NDVI<0.140	105<=NDVI<118
Bare ground	0.025<=NDVI<0.090	88<=NDVI<105
Clouds	0.002<=NDVI<0.025	83<=NDVI<88
Ice and snow	-0.046<=NDVI<0.002	70<=NDVI<83
Water	-1<=NDVI<-0.046	0<=NDVI<70

Therefore, the image areas with high NDVI (light gray color) are those covered by vegetation, due to the high reflectance of vegetation in the near infrared and low in red. Instead, the image areas with low NDVI values (dark gray colors) are those where the absence of vegetation in observed, such as over residential areas, airports or bare soil (erosion areas).

For best visual results, the different shades of a gray can be replaced with different colors. This method is called “false color display” (pseudocolour display). With the software ENVI, the above technique applied to the original image NDVI, and presented below (fig. 11).

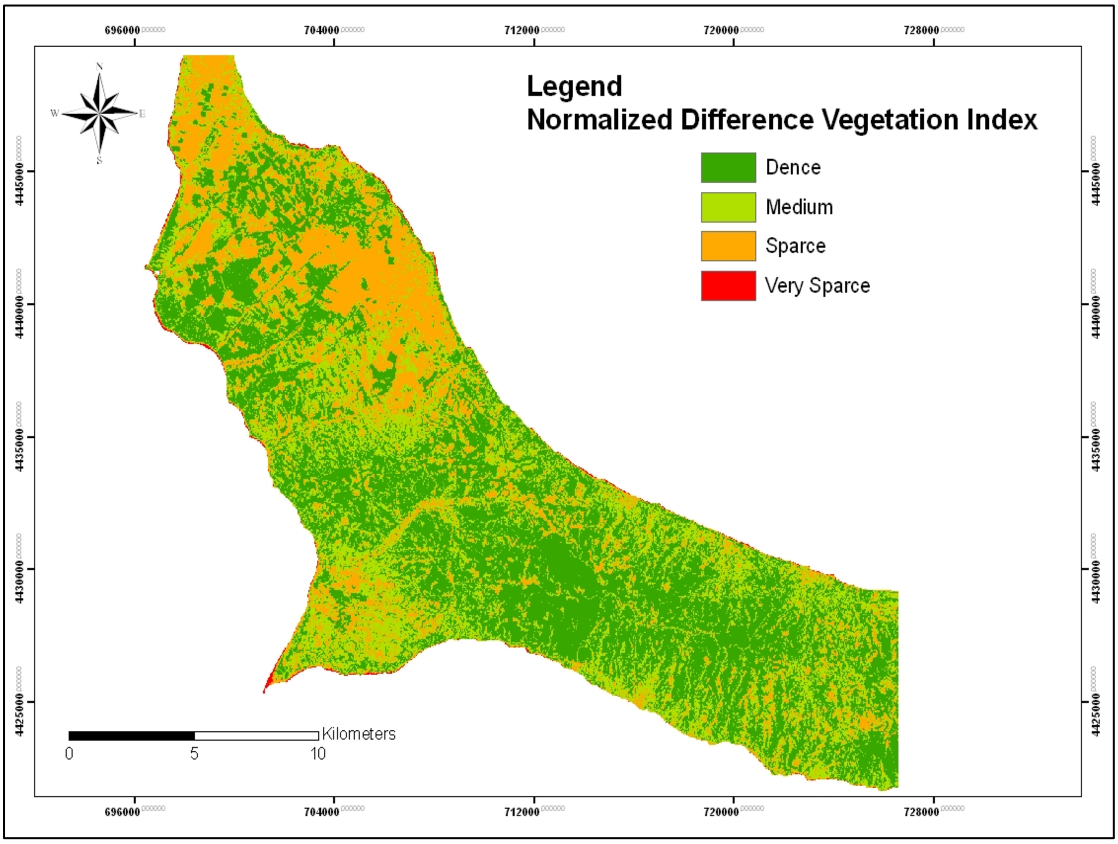

Figure 11 Normalized difference vegetation index of the study area.

Having created the vegetation map of the study area is then defined using the sub-classification of the program ArcGIS are four categories of vegetation:

- Very sparse vegetation (0 -100)
- Sparse vegetation (101-160)
- Medium vegetation (161-210)
- Dense vegetation (211-255).

The results are given in table 8. Finally, the areas corresponding to the above classes were calculated, as well their percentage with respect to the entire region. Each vegetation class was given a rating, with respect to its influence to flood occurrence.

Table 7 Percentage distribution of vegetation in the study area

Distribution of Vegetation	**Area (km^2)**	**Percentage (%)**
Absent	39	12,26
Sparse	140	44,03
Medium	96	30,19
Thick	43	13,52

The lack of vegetation favors movement of the water downstream, after the water is not retained by the root system of plants, resulting to flow more rapidly and thus becomes more dangerous. Conversely, where we have dense vegetation water meets greater resistance to movement as it is held in the root zone of plants thereby reducing its speed and therefore less dangerous.

3.2.8 FLOOD SUSCEPTIBILITY MAP

Each spatial component of vulnerability can be mapped under the condition that there is sufficient information on its distribution. Thus, when performing a risk assessment against natural risks for a large area, the results can be expressed in the form of hazard maps.

So through mapping, the variation of the intensity of a risk is depicted from one location to another and an attempt is made for quantification based on the victims and the damage brought about. Therefore, the creation of hazard maps aims to estimating the position of the likelihood and severity of future relative risk events in order to assess, mitigate or prevent any losses.

Despite these advantages, however, the hazard maps show some disadvantages since they are very general and represent a static view of reality, so that they must be renewed periodically, whenever relevant new data are available. Reliability, strength and flexibility of mapping can be increased with the use of Geographic Information Systems (GIS).

To create a flood susceptibility map in the study area, initially, it is necessary to identify the factors that will be included as important and relevant to that event. The factors are not subject to a quantitative restriction. In order to select and integrate them into the model, it is necessary to have documented scientific knowledge of their adverse effect on the phenomenon and the existence of relevant data for the area to which the model is applied (Moyssiadou 2010).

In the case of flooding in the study area, the flood susceptibility map was produced after co-evaluation of the parameters of the topographic wetness index, the rock's permeability, the land cover roughness and the vegetation.

The co-evaluation was determined after the percentages with which each factor affects the episode flood event in the region. The "weights" for each factor were calculated separately.

For the calculation of "weights" for each factor the method of "Analytic Hierarchy Process» (Analytical Hierarchy Process / AHP) is used, a methodology of multivariate modeling (multi attribute modeling) which was developed and initially implemented by Saaty (Saaty, 1980). Under this method, all possible pairs between the factors are formed and then a numerical value from 1 to 7 is given to each factor, depending on how important the factor is considered in relation to someone else. The value of **1** indicates that a factor is as important as someone else; while the value of **7** indicates that the factor is much more important than another. Fractional values indicate that a factor is less meaningful than someone other. These values are chosen arbitrarily from the researcher, however, there should be subject to some restrictions which are defined by the logical relationship between the parameters, such as:

- knowledge of natural processes
- reasons for the appearance of the phenomenon
- previews experience

Also the values corresponding to each factor should not have much difference between them. The following tables are given the conversion of preference factors into numerical values.

Table 8 Importance of factors and convert in numeric value

Importance of factors	**Value**
Very High Importance	7
High Importance	5
Medium Importance	3
Low Importance	1

In the following Table we see all possible pairs among the factors in each of whom was given a numerical value from 1 to 7, depending on how important it is believed to be in relation to someone else.

Table 9 Pairwise comparison of factors affecting the flood occurrence

	Topographic wetness Index	**Lithogical Permeability**	**Land Roughness**	**NDVI**
Topographic wetness Index	1	3	6	7
Lithogical Permeability	1/3	1	3	4
Land Roughness	1/6	1/3	1	2
NDVI	1/7	1/4	1/2	1
TOTAL	1,643	4,583	10,5	14

Using the table above, the method of arithmetic average (arithmetic mean method) was applied, in order to calculate the weights of the factors as follows:

- topographic wetness index → w1 = 0,584
- lithological permeability → w2 = 0,248
- land cover roughness → w3 = 0,103
- vegetation index → w4 = 0,065

In the following Table you may see the results.

Table 10 Calculation of weights (weights) for each factor by the arithmetic mean method

	Topographic wetness Index	**Lithogical Permeability**	**Land Roughness**	**NDVI**	**Average**
Topographic wetness Index	1/1,643=0,609	3/4,583=0,655	6/10,5=0,571	7/14=0,5	0,584
Lithogical Permeability	0,203	0,218	0,286	0,286	0,248
Land Roughness	0,101	0,073	0,095	0,143	0,103
NDVI	0,087	0,055	0,048	0,071	0,065

Then the classifications provided under each factor multiplied by the analogous weight, and summed together to produce the final susceptibility map. Thus, the final value M for each pixel in the area of study is given by:

$$M = w1X1 + w2X2 + w3X3 + w4X4 +$$

Where X1, X2, X3, X4 are ratings for each factor (Esmali A, and Ahmadi H, 2003; Domakinis, 2005; Nikolaidou, 2009).

Based on the above methodology and using the ArcGIS 9.3 software and more particularly the Raster Calculator tool, the flood susceptibility map was created.

The susceptibility map classifies the area into 7 categories, which categorize the areas in more or less susceptible to flooding as shown in the table below:

Table 11 Distribution of flood susceptibility in Kassandra

Susceptibility	Area (km^2)	Percentage (%)
Very Low	2	0,64
Low	107	34,19
Low - Medium	104	33,23
Medium	74	23,64
Medium - High	20	6,39
High	5	1,60
Very High	1	0,32

The susceptibility map was constructed using the method presented in detail above, contains subjective judgments, and this is because, the factors taken into account but also the relevance of these were selected empirically, because there is no specific methodology for this purpose.

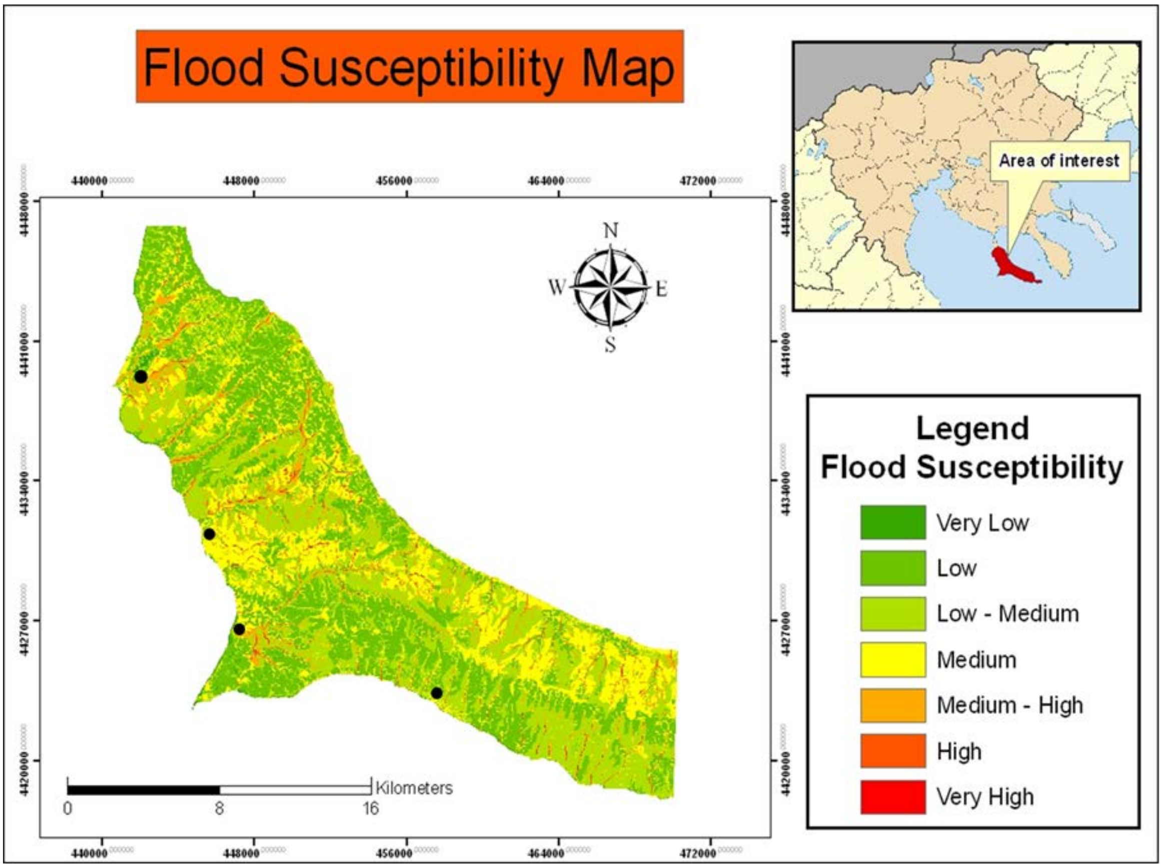

Figure 12 Flood susceptibility map of the area

The map shows that: in general, areas with high rates of susceptibility detected scattered mainly in the western part of the study area.

4. CONCLUSIONS AND DISCUSSION

The purpose of this study was an attempt to evaluate the contribution of Remote Sensing and GIS in assessing the vulnerability of an area to flooding by constructing susceptibility maps.

This resulted in the following conclusions below:

• According to the data of CORINE LAND COVER 2000, the land cover map of the study area was created. From the map, it seems that most of the study area consists of farmland about 70%, while 12% of forests.

• From the map heights according to the classification by Dikau, 1989, shows that the extent of the study area divided into two types of terrain. Flat with 84.38% and 15.63% with hilly terrain.

• Regarding the hydrographic network in the study area, according to the classification by Strahler, consisting of branches to 5th grade, but mainly the network reaches 3rd class.

• The slope map, following the classification of the IGU (Demek, 1972), showed that in the study area slopes range from 0 ° -43 ° degrees. Areas with slopes of 5 ° to 15 ° degrees cover45.57% of the total area of the study area, correspondingly areas with slopes between 2 ° and 5 ° degrees account for 27.06%, while the slopes from 0 ° to 2 ° degrees cover 16.23% of the total area. Finally, slopes from 15^o to 35^o cover only 11%. It should be mentioned at this point that the slopes in the settlements where there were floods are range from 0 ° to 2 ° (slightly sloping terrain)

• From the Topographic wetness index, which shows the distribution of moisture based on the topography of the region, it appears that 81.48% of the region has low index values , while 17.09% moderate values, only a small percentage of order of 1.42% gives high values. Increased wetness index shows that the region is more prone to floods and reduced-price index shows reduced susceptibility for flood events

• From the lithological permeability map turns out that 35.61% of the area consists of high permeability rocks, the 32.19% of moderate permeability and also 32.19% from permeable rock.

• According to the map of land cover roughness, roughness values, which are based on the Strickler’s rate, and prevail in the region, are the “5” with 38.17% percentage, the “8” with 28.70% and the “7” with 27.51%. The value of 5 corresponds to high surface roughness, the more the numbers increase the less the degree of roughness gets.

• From the digital processing and analysis of the satellite image Landsat-7 occurred the "Normalized Difference Vegetation Index» (NDVI). The picture was given four classifications of vegetation (absence, sparse, moderate, and dense) and incorporated into a GIS environment, where the vegetation map of the area was created. In the study is noted that the highest percentage corresponds to sparse vegetation with 44,03%, moderate vegetation have a percentage 30.19%, dense in proportion 13.52% and absence of vegetation found in percentage 12,26%. This translates to the fact that the lack of vegetation favors movement of the water downstream, after the water is not retained by the root system of the plants, leading to flow at a higher speed and thus increases the risk for flooding.

• From the co-evaluation of the parameters of the topographic wetness index, the permeability of the rock, the roughness of land cover and the vegetation cover the final flood susceptibility map was constructed, which classifies the area into 7 categories. These categories show which areas are more or less vulnerable to flooding. According to the final map the largest portion of the study area corresponds to:

- Low susceptibility areas which occupy 107km^2 or 34.19% of the total area and appears extensively on the S and NE part of the peninsula.
- Medium-Low susceptibility zones covering 104km^2 or 33.23% of the total, and appear on the SE and NW
- Areas with high susceptibility reach only 1.6%, and are located along the main branches of the drainage system throughout the peninsula. Although in these areas there is a large residential development combined with low slopes and sparse vegetation, where major floods have occurred in the past (W and SW). This outlines the necessity for further quantification of the urban fabric in these areas, in order to develop a flood protection planning for affected areas.

REFERENCES

Alexakis, D., 2003: Continuous monitoring of Mount Camel and the wider region, with the help of Remote Sensing and Geographical Information Systems. An environmental approach, Thesis, Aristotle University of Thessaloniki, School of Geology, Thessaloniki. (In Greek)

Balafoutis C., 1977. Contribution to the study of the climate of Macedonia and Western Thrace. PhD thesis. Thessalonica

Beven, K.J., Kirkby, M.J., 1979: A physically based variable contribution area model of basin hydrology. Hydrological Science Bulletin pp. 24, 43 – 69.

Dalezios, N. F., Environmental Remote Sensing, University Teaching, University of Thessaly, Volos, 2002. (In Greek)

Demek, J., 1972: Manual of detailed geomorphological mapping. Academia, Prague, 344 p.

Domakinis, C., 2005: The use of Remote Sensing and GIS in mapping landslides in the coastal region Strymonikos - Kavala, Thesis, Aristotle University of Thessaloniki, School of Geology, Thessaloniki. (In Greek)

Donati, L. and Turrini, M. C.: An objective method to rank the importance of the factors pre-20 disposing to landslides with the GIS methodology: application to an area of the Apennines (Valnerina; Perugia, Italy), Eng. Geol., 63, 277–289, 2002.

e-EcoRisk, 2004. District business website support system and decision-making to address the environmental risk and disaster management of large-scale industrial waste ", funded by" European Commission-Research Directorate-General" (EVG1-2001 - 00,087). (2004 / / Principal Investigator A. Filippides).Maidment, David R., Oscar Robayo, Watershed and Stream Network Delineation, Center for Research in Water Resources, University of Texas at Austin, September, 2002.

Esmali A, Ahmadi H, 2003. Using GIS & RS in mass movements hazard zonation—a case study in Germichay Watershed, Ardebil, Iran. Map India Conference 2003. At http://www.gisdevelopment.net/application/natural_hazards/landslides/ma03004.htm [Accessed December 15, 2010]

Fourniadis, J., Economides, M. & Astaras, T., 2002: Identify areas susceptible to erosion, with the help of Geographic Information Systems (GIS) and Remote Sensing. An example of the drainage basin Anthemountas, Proceedings of the 6th Panhellenic Geographical Conference of Greek Geographical Society, Thessaloniki October 3-6, 2002, Volume II (In Greek)

Moyssiadou, P., 2010: Development of space-time predictive model of risk of natural hazards - implementation in areas of Halkidiki, Thesis, Aristotle University of Thessaloniki, Department of Civil Engineering, Thessaloniki. (In Greek)

Nikolaidou, M., 2009: Use of Remote Sensing and GIS in the record flood of mountainous areas south of the lake bulbs. An environmental approach, Thesis, Aristotle University of Thessaloniki, School of Geology, Thessaloniki. (In Greek)

Paraschou, I., 2005: The geomorphological evolution of the valley of the river Inachus Fthiotida, a tributary of river Sperchios, Thesis, Aristotle University of Thessaloniki, School of Geology, Thessaloniki. (In Greek)
Quinn, P. F., K. J. Beven, P. Chevallier, and O. Planchon (1991), The prediction of hillslope flowpaths for distributed modelling using digital terrain models, Hydrol. Processes, 5, 59 – 80.
Rodhe, A. and Seibert, J., 1999, Wetland occurrence in relation to topography - a test of topographic indices as moisture indicators, Agricultural and Forest Meteorology 98-99: 325-340.
Saaty, T.L., 1980: The Analytical Hierarchy Process, NY, McGraw Hill.
Seibert, J., K.Bishop and L.Nyberg, 1997, A test of TOPMODEL's ability to predict spatially distributed groundwater levels, Hydrological Processes 11: 1131-1144.
Sørensen, R. , Zinko, U. and Seibert, J., 2006. On the calculation of the topographic wetness index: evaluation of different methods based on field observations, Hydrology and Earth System Sciences, 10, 101-112.
Soulakellis, P., 1994: Contribution to the analysis of satellite images Landsat-5/TM and GIS in Tectonic Geomorphology regions of Northern Greece, PhD Thesis, Department of Geology, Aristotle University of Thessaloniki. (In Greek)
Soulios, G.Ch., 1996: General Hydrogeology, Aristotle University of Thessaloniki, University Studio Press, Thessaloniki. (In Greek)
Syllaios, P., 2000: Introduction to Remote Sensing and Geographic Information Systems, Volume I, Introduction to Remote Sensing, Giachoudi-Giapouli, Thessaloniki. (In Greek)
The SI Metric System of Units and SPE Metric Standard (2nd ed.). Society of Petroleum Engineers. June 1984 [First published 1982].
Tsiros E., 2006: The Normalized Difference Vegetation Index (NDVI) and Other Indicators in Monitoring Hydrological Drought Thesis, University of Thessaly, Department of Agriculture Animal Production and Aquatic Environment, Volos.(In Greek)
Zinko, U., Seibert, J., Dynesius, M., and Nilsson, C.: Plant species numberspredicted by a topography based groundwater-flow in-dex, Ecosystems, 8, 430-441, 2005.
URL1: https://www.youtube.com/watch?v=2lvRZlVeju4 [Accessed July,16th, 2014]
URL2: http://www.pestaola.gr/xalkidiki-rain-in-kassandra-and-sibiri/ [Accessed July,16th, 2014]