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Detection of Flood Hazard in Urban Areas Using GIS: Izmir Case

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Abstract

The aim of this study is to predict the potential flood-hazard areas using Shuttle Radar Topography Mission - Digital Elevation Model (SRTM-DEM). The study area is the province of Izmir. SRTM-DEM of the Izmir Province has 90 m of grid size resolution; 45 m of horizontal accuracy; and 15 m of vertical accuracy. Within this study, obtaining spatial information on flood-hazard by using Izmir digital terrain models and by 3D analysis that will help to achieve the regional flood hazard management scheme is aimed. Flood-hazard areas have been identified by the use of digital elevation model covering the study area. The main rivers in the study area are Gediz, Kucuk Menderes and Bakircay that creates the coastal flood plains. In order to estimate the spatial distribution of flood-hazard areas in İzmir, five factors are used: flow accumulation, land use, slope, rainfall intensity, and elevation. The classic hydrological modelling approach was applied to determine the rainfall intensity; rainfall intensity of study region is created with the average amount of total rainfall intensity of fifteen stations in the two basins per minute using the interpolation method (spline interpolation). By the digitizing rivers, topography, flow direction and flow accumulation, as well as the flood detention areas are determined. These factors were combined with the weighted overlay method to determine categorized flood-hazard areas. As a result, possible flood-hazard areas have been determined in the case of Izmir Province.

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Keywords: weighted overlay; GIS; Izmir; flood hazard map; SRTM.

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1. Introduction

There has seen an increase in flood hazard events worldwide, especially in the last thirty years. Climate changes and human-induced land-use interventions are defined as important factors causing the flood hazard [1]. There is a mutual trigger situation that the urban areas are the most influenced areas from the flood and also the urbanization is the most important reason of the formation of flood. Flood is also an important risk factor for our country. According to the flood hazard statistics in Turkey, Izmir has the greatest flood risk within the largest three cities (Istanbul, Ankara and Izmir). Besides, the Gediz and Kücük Menderes basins, locating within the border of Izmir urban area, are one of the priority flood hazard basins through the 25 basins in Turkey [1], [10]. Due to the dense unplanned urbanization, locating at the shores of the Izmir bay that is the catchment area surrounded by high mountains devoid of vegetation, locating in the Mediterranean basin with high atmospheric activity, Izmir could be claimed that it is highly possible to occur flood hazard in the city [1], [10].

To prevent flood hazard, flood hazard maps has become one of the important tools providing flood control and so reducing the damages. With the aim of mapping Flood hazard areas of Izmir, in our study area of Izmir, potential flood hazard areas have been estimated and evaluated. Within this estimation process; flow accumulation, stream drainage patterns, slope, rainfall intensity and elevation factors are used. This study is based on the approach used by [2] which is the hydrological model of flood areas detection with different hazard levels [2].

Geographic Information System (GIS) based spatial analysis and visual elements are used frequently in recent years for detection of flood hazard areas and for preparation of maps. GIS applications are based on database and which analysis tools have logical and mathematical relationships between the layers [3], [4], [5], [6]. Geographical Information System applications mapping are varied as flood hazard mapping, flood hazard management, hydrological data storing and management. GIS is a data management system that shows different data sets on the same map such as land use, construction, environmental, groundwater and topography [3], [7], [8], [9].

In this study, Izmir Province has been handled in order to evaluate its flood hazard areas and to create its potential hazard area maps. The study area locates in the western part of Turkey, on the shores of the Aegean Sea, between the $37^o45^'$and $39^o15^'$ north latitude and $26^o15^'$and $28^o20^'$ east longitudes and covers an area of 12,012 km^2 [10].

In the study area, there are Gediz, Kucuk Menderes and Bakircay rivers. These rivers and their stream beds constitute delta plains and the flood areas on the shores of the Aegean Sea. Figure 1 shows the main plains of the study area which are Menemen Plain between Yamanlar and (1075 m.) and Dumanlı (1090 m.) Mountains, by the Gediz River (also is called Menemen Delta), Menderes Plain, Torbalı Plain extending between Bozdag (2160 m.) and Aydin Mountains (1650 m.) by the Kucuk Menderes River, Kemalpasa Plain which is located in the north side of Kemalpaşa (1465 m.) Mountain.

According to the data obtained from the General Directorate of Meteorology, in the Aegean Region the average cumulative rainfall of the 2013-2014 is 563.9 mm. The normal rainfall in the area is 598.1mm and the average in the same period of last year is 707.7 mm. Table 1 shows the assessment of the cumulative rainfall of Gediz and Kucuk Menderes Basins [11].

Table 1. Cumulative rainfall (mm).

Basins	October 2012- August 2013	1 October 2013-30 June 2014	changes (%)
Gediz	714.7	493.2	-9.2
Kucuk Menderes	731.4	566.5	-4.6

The natural and/or man-made interventions inducing the flood hazard are mentioned as urban growth, coastal delta plains, stream beds in the invalid regulations, inappropriate land use decisions in slopped areas, so the deforestation and soil erosion, constructions on waterlines and waterways deviations. Thus, it is not possible to overcome flood hazards without future flood simulations, evaluations and management [4], [12], [13], [14], [15] and [16]. For this reason, in this study, we propose a kind of simulation method consisting of rainfall averages (minimum and maximum) ,the flow accumulation, stream drainage patterns, slope, rainfall intensity, elevation in the study area and land use thematic maps. These inputs have been handled via GIS-based weighted superposition (weighted overlay) method by considering potential flood hazard areas.

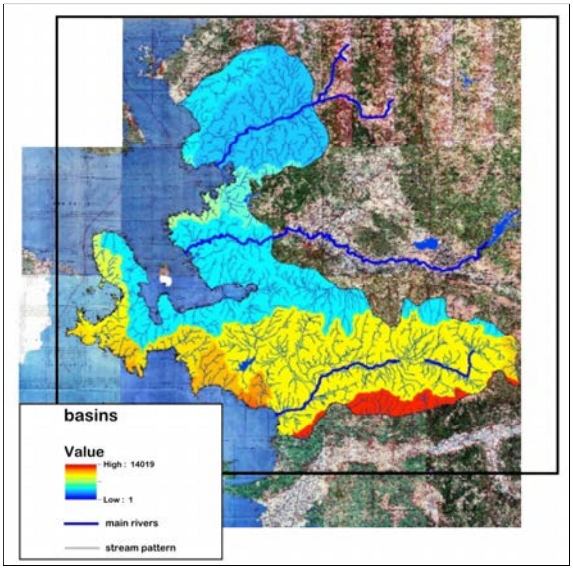

Fig. 1. Elevation of basins in Izmir City-Region.

2. Determination of Flood Hazard Areas in Izmir

The method used for composing the flood hazard area maps is shown in Fig. 2. First of all the factors that cause flood are determined and the mutual interaction ratios are calculated. These factors are determined as flow accumulation, stream drainage patterns, slope, rainfall intensity, elevation and land use. Besides, using Digital Elevation Model (DEM) files, their GIS-based maps were created. In the study, ArcGIS 10.2.1 modules are used as GIS software.

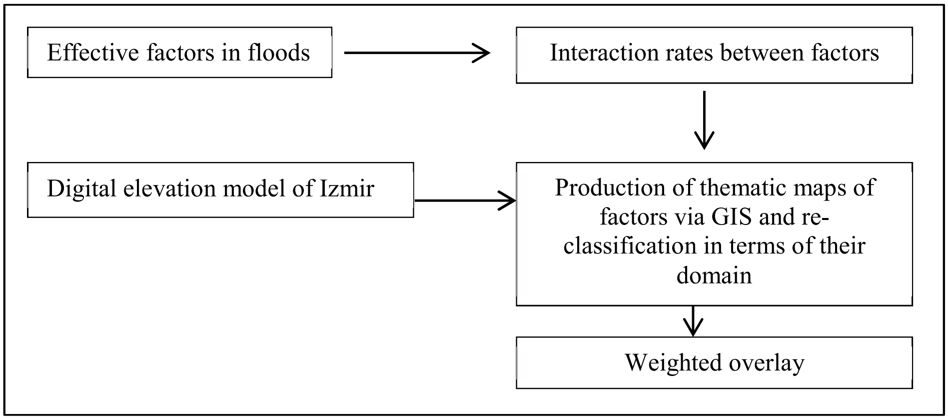

Fig. 2. Methodology.

In the second phase, DEM data was converted from the WRS geographic coordinates (k, u degrees) to UTM projection system (x, y meters cords) which is the 35N zones and Datum WGS84 ellipsoid. Primary and secondary mutual effects of factors have been determined in [4] and [13]. As shown in Fig. 3, a straight line between two factors indicates that it has a fundamental impact on the other. The dotted line between the two factors indicates that it has a secondary effect on the other. For example, while flow accumulation has fundamental impact on land use, it has secondary effect on the slope. In order to measure two different effects, one (1) point is assigned for the main effects and a half (0.5) points are assigned for secondary effects. In the next phase, a factor rate is calculated as the sum of the impacts on others.

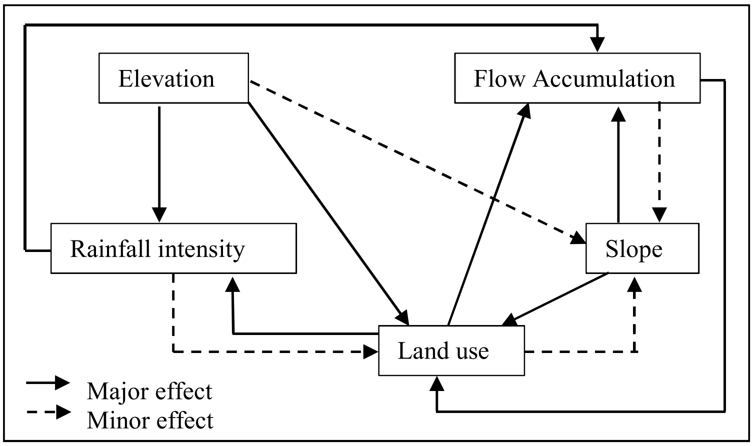

Fig. 3. Methodology.

Weighting approach has been applied by giving different weight value to each factor, due to each factors have different impact on flood hazard. Factor weights are determined using the methodology provided by [13]. The ratios determined for the factors are shown in Table 2.

Table 2. Mutual Effects of Factors.

	Interactions Btw Factors	Rates	Outcome
Flow Accumulation	1 major +1 minor	(1 x 1) + (1 x 0.5) =	1.5 points
Slope	2 major +0 minor	(2 x 1) + (0 x 0.5) =	2.0 points
Land Use	1 major +1 minor	(1 x 1) + (1 x 0.5) =	1.5 points
Rainfall Intensity	1 major +1 minor	(1 x 1) + (1 x 0.5) =	1.5 points
Elevation	3 major +1 minor	(3 x 1) + (1 x 0.5) =	3.5 points

In the study area, maximum rainfall data falling within an hour recorded in fifteen stations of the three basins are used to determine the rainfall intensity, as shown in Table 3. Spline interpolation method is selected within various methods of interpolation, because this method is defined as the most appropriate method for studies involving a small number of cases, same as in the study area, in the literature [16] and [17].

Within these factors land use is the descriptive factor; while flow accumulation, slope, elevation and rainfall intensity has numerical values. The basic rule to estimate flood hazard areas is a classification based on the degree of risk of disaster of the field. The effect of each factor has been mapped in the form of five different risk levels; as very high, high, medium, low and very low. Classification is performed with GIS environment and for each factor, thematic maps are generated (Fig. 4.).

Factor maps including numerical values have been labeled into five classes on the basis of Jenk's Natural Breaks method [18] and [19]. Non-numerical values of factors are labeled on the basis of the classes impacts on flood hazard for mapping. For example, in the map of land use the least ratio of land use types has been identified as the most dangerous area.

Linear combination of thematic maps and the choice of their weights create the map of potential risk areas. In the study, topographic (height) data is used to calculate the direction of flow and accumulation, and also to determine the borders of the flow. Flow accumulation, is an indirect way to measure the drainage areas (raster units) and it continuously increases with drainage of the stream channels [17]. Topographic slope and elevation parameters are inversely proportional to flood [5]. The factors used in this study are selected through literature and overall approach to flood hazards [12], [15] and [20].

In the next step, all layers are combined in the ArcMap environment and reclassified by dividing into determined classes. To make a comprehensive assessment of risk, the weight and ratios of each are combined by associating with each other. This approach contains multiplying the calculated ratio and its determined weight to calculate the total weight for each factor. As mentioned before, the five different label levels and their representing numbers are used. Proposed assessment of hazard level (expert judgment), as scores, as shown: Very high - 10; High - 8; Medium - 5; Low - 2 and Very low - 1.

Gross weight of the total weight of all the factors are shown in Table 4. The ratios of factors according to their impacts on flood hazard are determined for flow accumulation by 15%, for the slope by 20%, for land use by 15%, for the rainfall intensity by 15% and elevation by 35% and thematic maps shown in Fig. 7. are combine based on these proportions .

Synthesis map showing risky areas contains combination of these five variables which are directly related to the flood that may occur in the study area. The thematic labelled maps have been combined with the approach of weighting methods and the final flood hazard map showing risky areas is produced (Fig. 5.).

Table 3. Maximum rainfall data falling within an hour (min./mm).

Station / mn.	10	15	30	60	120	180	240	300	360	480	720	1080	1440	Average
Aydın	9.9	14	17.5	30	36.3	47.7	48.5	48.5	48.5	48.5	51.2	58.1	59.3	40
Dikili	11.7	13.9	19	23.4	32	41.9	42.7	43	47.7	52.3	60.1	69.8	90.8	42
Ayvalık	6.4	9.1	10.3	10.6	12.7	16.1	21.4	24.3	24.3	25.3	25.4	25.4	68.4	22
Bergama	15.1	17.9	27.3	39.3	41.1	43	43.2	52.1	55.1	57.3	62.2	94.2	100.5	50
Çeşme	16.8	20.4	37	59.5	73.2	77.6	80.8	81.9	87.7	93.6	131.3	158.2	165.6	83
İzmir	12	15.1	19.7	35.4	39.9	54.8	66.9	74.9	82.5	92.7	118.3	133.1	143.2	68
Kuşadası	15.5	18.8	22.9	26.2	30.2	35.4	38	39.8	42.8	50.8	55.9	58.5	58.8	38
Nazilli	12.1	12.8	14.6	22.3	33.9	42.9	44.1	46.2	49.3	50.7	52.4	52.5	58.3	38
Ödemiş	11.3	14.2	18.2	28	44.5	44.5	44.5	44.5	44.5	47.9	47.9	48	48	37
Selçuk	7.1	12	16.3	19.4	21.2	27.6	30.9	32.4	37.9	49.8	62.2	68.1	68.1	35
Seferihisar	10.4	17.6	29.8	50.2	75	81.6	87.8	90.9	93.3	94.5	117.1	175.9	194.5	86
Manisa	18.4	27.1	36.3	46.8	47.3	51.4	53.7	55.8	59.4	77.3	79.6	98	100.2	58
Salihli	20.4	30.6	44.2	51.1	57.3	57.4	57.5	57.5	57.6	57.6	68.9	69	69	54
Akhisar	7.9	8.9	12.8	16.6	25.6	32.3	37.1	40.8	41.9	47.5	53.6	55.1	57.5	34
Didim	13.5	18.6	30.1	55.8	76.7	105.9	108.2	108.2	108.2	108.2	108.2	108.3	110.1	82

3. Results and Evaluation

Unplanned part of cities with inadequate infrastructure and global climate change especially observed in the last thirty years has led to loss of life and property in our country. It is necessary to determine risk areas in our cities by the help of meteorological, hydrological, topographical factors and rainfall intensity in different time periods of the region for possible future flood. By this end, our work focused on Kucuk Menderes and Gediz basin which had flood events in previous years in Izmir Province. These basins have flood hazard potential affecting residential areas, industrial areas and fertile farmlands.

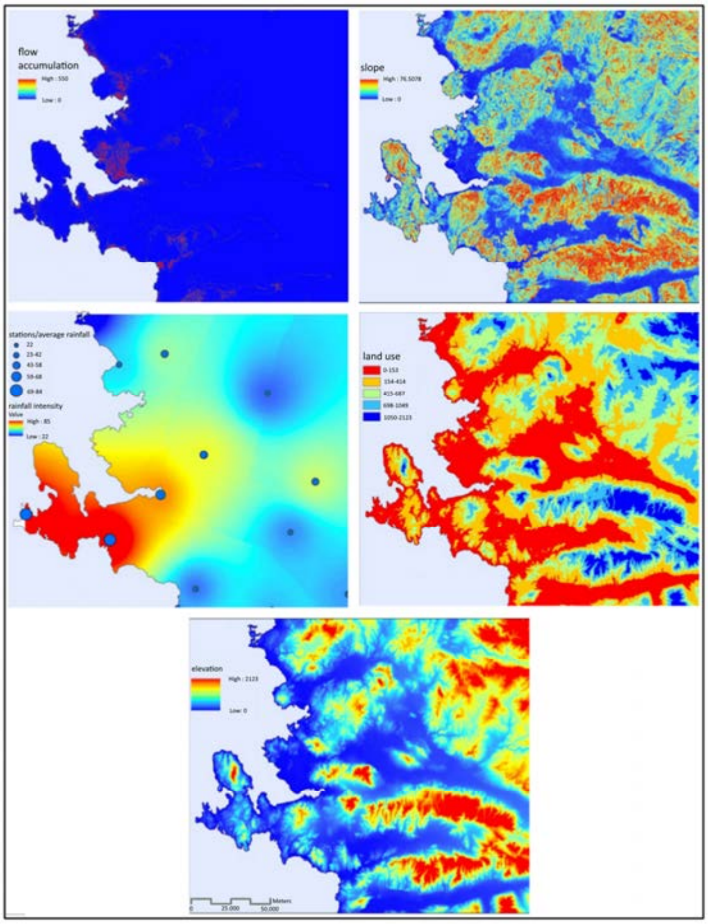

Fig. 4. Thematic maps of flow accumulation, slope, land use, rainfall intensity and elevation.

Potential flood area map is created by method specified using flow accumulation, slope, land use, rainfall intensity and elevation factors and the result the weighted interaction rate of each factors. The line of Torbali-Odemis at the south and east, Sasali-Foca and Dikili-Bergama line at the north and some part of the line of Cesme-Ovacik at the west has been observed as the areas with high flood hazard potential. These areas contain agricultural land and industry in the north, tourism land in the west and huge agricultural land in the south and east. In order to prevent possible adverse consequences, growing number of settlements at basins, newly opening roads and facilities, inadequate agricultural methods, new settlements in stream beds should be avoided.

GIS-based modelling methods to identify flood areas, which are part of the synthesis of threshold, should be used as an efficient tool within the comprehensive planning process. Besides, it is essential to mention that the accuracy of DEM, sampling errors and quality of measurements depend on the resolution of the grid size. The interpolation techniques are enhanced in terms of determining risk areas. Use of high resolution DEMs could strengthen the accuracy of regional analysis of flood hazards.

Table 4. Classification and weighting of factors.

Factor	Domain	Descriptive Level	Proposed Weight (a)	Rate(b)	Weighted Rate(a*b)	Total Weight	Percentage (%)
Flow Accumulation (m.)	200.59-550	Very high	10	1.5	15	39	15
	60.39-200.59	High	8		12		
	15.1-60.39	Medium	5		7.5		
	2.16-15.1	Low	2		3		
	0-2.16	Very low	1		1.5		
Slope (%)	0-3.6	Very high	10	2	20	52	20
	3.6-9.6	High	8		16		
	9.6-16.2	Medium	5		10		
	16.2-24.6	Low	2		4		
	24.6-76.2	Very low	1		2		
Land Use	Seaside/ Settlement	Very high	10	1.5	15	39	15
	Settlement	High	8		12		
	Agriculture / Settlement	Medium	5		7.5		
	Argiculture / Forest	Low	2		3		
	Forest	Very low	1		1.5		
Rainfall Intensity (min./mm)	68-85	Very high	10	1.5	15	39	15
	56-68	High	8		12		
	47-56	Medium	5		7.5		
	39-47	Low	2		3		
	22-39	Very low	1		1.5		
Elevation (m.)	0-153	Very high	10	3.5	35	91	35
	153-414	High	8		28		
	414-697	Medium	5		17.5		
	697-1049	Low	2		7		
	1049-2123	Very low	1		3.5		
Total						260	100 %

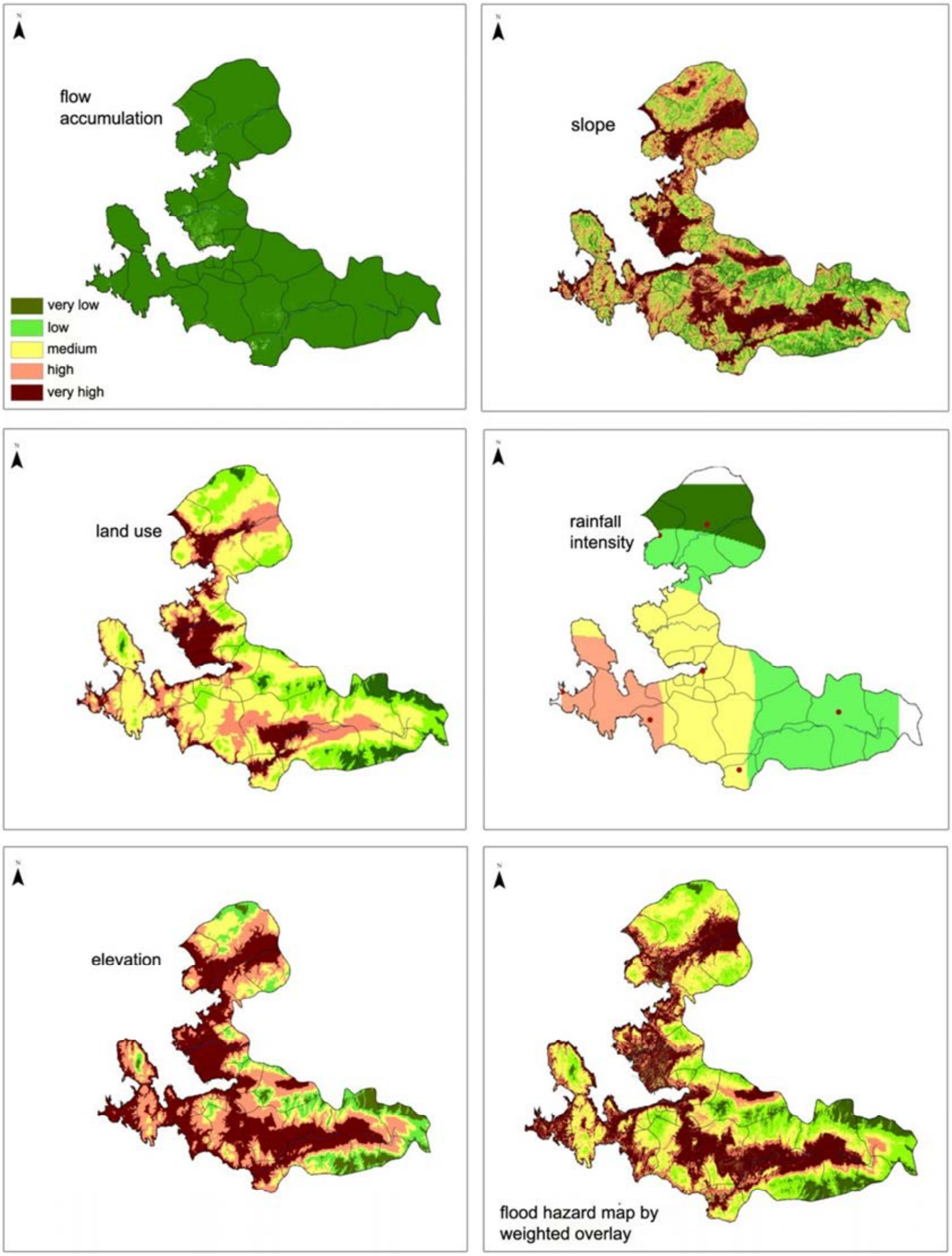

Fig. 5. Weighted factor maps and combined flood hazard map.

References

[1] Atay H, Tuvan A, Demir O, and Balta I. Iklim degisikliginin saglik uzerine etkileri. T.C. Orman ve Su Isleri Bakanligi Meteoroloji Genel Mudurlugu, Ankara; 2012.
[2] Manfreda S, Sole A and Fiorentino M. Can the basin morphology alone provide an Insight into floodplain delineation? WIT Transactions of the Ecol. Environ. 2008; 118, 47-56.
[3] Correia F, Saraiva M, Nunes F and Ramos I. Coupling GIS with hydrologic and hydraulic flood modelling, water resources management 1998; 12, 229-249.
[4] Kourgiala N and Karatzas G. Flood management and a GIS modelling method to assess flood-hazard areas - a case study. Hydrological Sciences Journal 2011; 56(2), 212-224.
[5] Kwak Y and Kondoh A. A study on the extraction of multifactor influencing floods from rs image and gis data; a case study in nackdong basins. korea. beijing. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences 2008; 421–426.
[6] Sanyal J and Lu X. Application of remote sensing in flood management with special reference to monsoon asia. Natural Hazards 2004; 33, 283-301.
[7] Burrough P. Principles of geographical information system for land resources assessment, Monographs on Soil and Resources Survey no 12. Oxford university press, Oxford; 1986.
[8] Demirci A and Karakuyu M. Afet yonetiminde cografi bilgi teknolojilerinin rolu. Dogu Cografya Dergisi 2004; 12(9), 67-100.
[9] Ozcan O, Musaoglu N and Seker D. Taşkın alanlarının cbs ve uzaktan algılama yardımıyla belirlenmesi ve risk yonetimi; sakarya havzasi ornegi. Turkiye Harita Bilimsel ve Teknik Kurultayi; 2009. TMMOB Harita ve Kadastro Muhendisleri Odasi, Ankara.
[10] Izmir Valiligi. www.izmir.gov.tr, 24.11.2014.
[11] Meteoroloji Genel Mudurlugu. www.mgm.gov.tr, 24.11.2014.
[12] Eimers J, Weaver J, Terziotti S and Midgette R. Methods of rating unsaturated zone and watershed characteristics of public water supplies in north Carolina; 2000. Water Resources Investment Report, Raleigh, NC, 99–4283.
[13] Shaban A, Khawlie M, Abdallah C. Use of remote sensing and GIS to determine recharge potential zones: the case of occidental Lebanon. Hydrogeology Journal 2006; 14(4), 433-443.
[14] Seker D and Kabdasli S. Kıyılardaki dogal felaketler icin risklerin cbs ile analizi ve risk haritalarıinin uretilmesi, Selcuk Universitesi Jeodezi ve Fotogrametri Muhendisligi Ogretiminde 30. yil Sempozyumu, Konya, 16-18 October 2002, Selcuk University, pp. 322-332.
[15] Yahaya S, Ahmad N and Abdalla R. Multicriteria analysis for flood vulnerable areas in hadejia-jama'are river basin, nigeria. European Journal Scientific Research 2010; 42(1), 71-83.
[16] Hutchinson M. Interpolation of rainfall data with thin plate smoothing splines. II. Analysis of Topographic Dependence Describing or Pertaining to Special Regions, Journal of Geographical Information and Decision Analysis 1998; 2(2), 152–167.
[17] Schäuble H, Marinoni O and Hinderer M. A gis-based method to calculate flow accumulation by considering dams and their specific operation time, Computer Geoscience 2008; 34(6), 635-646.
[18] Skelton S and Panda S. Geo-spatial technology use to model flooding potential in chestatee river watershed, Carroll, G. D., Georgia Water Resources Conference, Athens, Georgia, 27-29 April 2009, Warnell School of Forestry and Natural Resources, The University of Georgia, pp. 410-417.
[19] Smith R. Comparing traditional methods for selecting class intervals on choropleth maps, The Profess. Geogr., Wiley, 38(1):62–67; 1986
[20] Zerger A. and Wealands S. Beyond Modelling: Linking Models with GIS for Flood Risk Management, Natural Hazards 2004; 33:191-208.