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ASSESSMENT OF FLOOD HAZARD ZONATION IN A MOUNTAINOUS AREA BASED ON GIS AND ANALYTICAL HIERARCHY PROCESS

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Abstract: In this study, flood hazard areas were evaluated in the Lighvan catchment as a mountainous area. So after preparing seven criteria such as slope, flow accumulation, distance from drainage network, lithology, runoff depth, land use and vegetation cover, the relative importance of criteria and sub-criteria for occurrence of the flood were weighted using the Analytic Hierarchy Process (AHP) method and then flood hazard map was extracted by Flood Hazard Index in GIS. The results of weights showed that flow accumulation, distance from drainage network and slope are the most and vegetation cover and lithology are the less importance factors in flood risk of the Lighvan catchment. Flood hazard zonation map divided to five classes; very low, low, moderate, high and very high. According to this, 3.35% of the catchment area in the range of very high risk and 5.97% in the range of high risk. Also weak pasture, rainfed farming, barren land, garden and dense pasture have high distribution in high and very high flood hazard classes. Finally regarding to priority for management and mitigation of flood hazard, the sub-catchment 4, 13 and 19 of the study area is facing serious problem of flood hazard, spatially Lighvan village is located in sub-catchment 4 and Beyragh villages is located in sub-catchment 3. So flood hazard mitigation and flood control in these sub-catchments should be implemented immediately. The results of this study act as guidelines for managers and planners to determine rational management of catchment for mitigation of flood hazard.

Keywords: flood hazard zonation, Analytical Hierarchy Process, remote sensing, GIS analysis, Lighvan catchment.

1. INTRODUCTION

The population in hazardous areas and the vulnerability of human settlements has grown over the past half century. One of the most common hazards among all environmental hazards is flooding that endanger the lives of millions people around the world each year. Flood is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems, which not only damages the lives, natural resources and environment, but also causes the loss of economy and health (Thilagavathi et al., 2011).

Flood zonation is to identify and describe the areas that have potential of surface runoff. This is based on the similarity of hydrological and hydrogeological characteristics of the areas that have been studied and in this way possibility of using the potential of each zone can be identified and evaluated. Actually with localization of the zones that have a high potential can be achieve an overall assessment of the region flood because a high potential for flooding the region is the introduction to the increased risk of flooding in that region.

The first step in management of flood and flood plains is preparing the map of flood zonation. There are different methods used to create the flood hazard zonation maps, which one of the newest is use of geographical information systems and remote sensing (Dewan et al., 2007, Abou El-Magd et al., 2010; Haq et al., 2012; Kumar & Mohan, 2014; Elkhrachy, 2015).

Flood occurrence depends on some factors such as physical, hydrological, meteorological and geomorphologic characters of the catchments. Each of these factors influencing the flood risk has different contributions in occurrence the event of catchment floods. So that it could be prioritize these factors according to the impact of each in flood occurrence. In this regards, decision making is one of the approaches to obtain the degree of importance of each factor. Also Geographical Information System (GIS) may provide more and better information about decision making situations. The multi criteria decision analysis within GIS may be used to develop and evaluate alternative plans that may facilitate compromise among interested parties.

The application of GIS-based multi-criteria analysis in the context of flood risk assessment was rare until 2000 (Kazakis et al., 2015). After 2000, regarding to zonation and identification of flood prone areas using Geographical Information System (GIS) along with decision making has been done many studies in the world (e.g. Sinha et al., 2008; Wu et al., 2015, Rahmati et al., 2015). Also researchers were used different factors to calculate flood hazard according to their aims (e.g. Ghanavati (2014) used slope, profile curvature, plan curvature, precipitation, drainage density, distance to river, geology, geomorphology, land use and soil for evaluating flood risk zonation in Karaj city by fuzzy logic; Ebrahimi (2014) investigated effect of land use on flood zonation; Shafapour Tehrany et al., (2015) evaluated flood susceptibility using altitude, slope, curvature, stream power index, topographic wetness index, distance from the river, geology, land use/cover, soil, and surface runoff in GIS-based support vector machine (SVM) model in Kuala Terengganu catchment of Malaysia; Kazakis et al. (2015) investigated flood hazard areas in Rhodope–Evros region of Greece using flow accumulation, distance from the drainage network, elevation, land use, rainfall intensity and geology by index-based approach and Analytical Hierarchy Process; Rahmati et al., (2015) assessed the efficiency of Analytical Hierarchical Process (AHP) to identify potential flood hazard zones by comparing with the results of a hydraulic model (HEC-RAS). They used four parameters via distance to river, land use, elevation and land slope in some part of the Yasooj River of Iran. The results showed that the AHP technique is promising of making accurate and reliable prediction for flood extent).

The semi-arid mountainous catchments have potential to flooding due to low vegetation cover, high slope, flashy flood rainfall and land use changes. So the overall objective of the present article is definition of flood hazard zones and understanding the effects of important parameters in flooding of Lighvan catchment (North-western of Iran), where mitigation flood efforts should be taken because this area has experienced different natural and human impacts that increase flood hazard.

2. STUDY AREA

The Lighvan catchment (Fig. 1) is located in the northern slope of Sahand Mountain (North-western Iran) and it has an area of 142 km^2. According to topographical characteristics, the study area can be divided into two unites: High Mountain and high plateau. The mean slope of the study area is 31%. Igneous rocks, Quaternary in age, and alluvium tuff with the relatively large thickness outcrop in the catchment. Soils are young and relatively undeveloped and consist of two categories, entisol and inceptisol. There are two hydrological stations within the catchment. The Lighvan station is located in the upper part while the Hervi station at the outlet of the catchment (Khaleghi et al., 2015). The average annual precipitation was 333 mm and 250 mm respectively at Lighvan and Hervi station. Average annual temperature of the Lighvan catchment is 6.4°C and average temperatures in August (the warmest month) and February (the coldest month) are 18.2°C and -5.1°C respectively. The climate, according to classification categories of Bull (1991) and available statistical data, is cold semi-arid, shifting to cold semi-humid in the highest portions of the catchment (Karami & Bayati Khatibi, 2005).

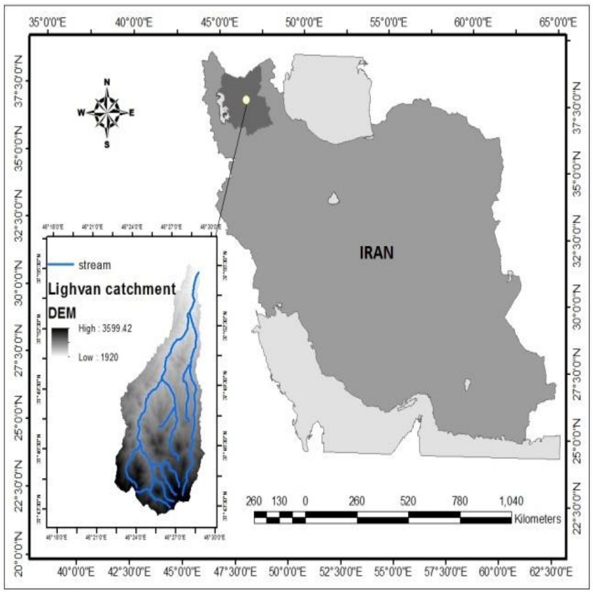


Figure 1. Location of the study area

The length of the Lighvan River is 28.5 km. The average annual discharge is 6.6 m^3/s at the outlet of the catchment (Hervi station). There are four villages (Beiragh, Lighvan and SefidKhan) in the study area. Also Lighvan catchment as a semi-arid mountainous region is influenced by natural and human factors that are sensitive to environmental changes and is always at the risk of flooding. According to the Regional Water Authority of East Azarbaijan province, flood damages have increased during the last 10 years so flood hazard zonation in this area seems necessary.

3. MATERIALS AND METHODS

3.1. Flood Hazard Zonation

Figure 2 shows flowchart of methodology for flood hazard zonation. According to this, some variables were prepared that are important in flood hazard zonation in study area such as slope, runoff depth, flow accumulation, distance from drainage network, lithology, land use and vegetation cover.

3.1.1. Slope

For slope layer, first DEM of study area extract from 1:25000 topographic map and then the slope layer was created by the spatial analyst> surface> slope function in ArcGIS software.

3.1.2. Runoff depth

SCS method estimates the runoff according to rainfall and characteristics of catchments. So it is appropriate for estimating runoff where there aren't enough stations for the flow measurement in the catchments. The Soil Conservation Service (SCS) empirical method proposed by the U.S. Soil Conservation Service is widely used for estimating direct runoff.

The Soil Conservation Service (SCS) empirical method proposed by the U.S. Soil Conservation Service is widely used for estimating direct runoff. The SCS method that is also well known as curve number method is based on water balance:

$$P = I_a + F + Q \qquad (1)$$

Where P is rainfall (mm), I_a is Initial abstraction (mm), F is cumulative infiltration other than I_a (mm), Q is direct runoff (mm). Initial abstraction (I_a) is function of the maximum potential abstraction (S).

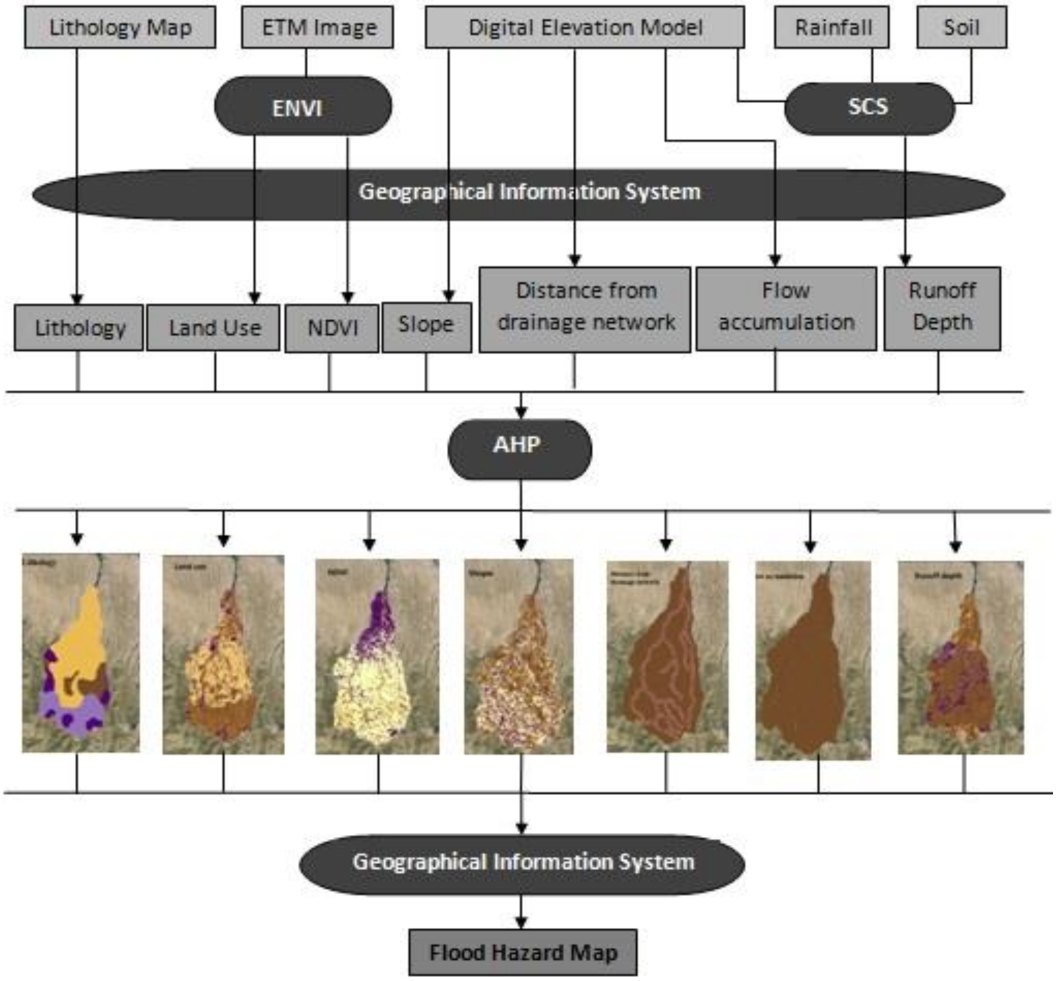


Figure 2. Methodology flowchart used in flood hazard zonation

The following equation is using for estimating runoff:

$$Q = \frac{(P-I_a)^2}{P+S+I_a} \qquad (2)$$

Equation (2) is true for P> I_a , otherwise the estimated runoff to be zero. Initial retention (I_a) is in fact part of the precipitation that does not participate in the runoff and is considered equal to I_a = 0.2S in SCS:

$$R = \frac{(P-0.2S)^2}{P+0.8S} \qquad (3)$$

The potential maximum retention (S) is determined based on curve number (CN) from the following equation (USDA, 1986):

$$S = \left(\frac{2450}{CN}\right) - 25.4 \quad \text{(mm)} \qquad (4)$$

In this case CN is a function of land use, vegetation and hydrologic soil group (HSG) (Chow, et al., 1988). In this regards, Curve Number method (SCS-CN) is one of the most widely used approaches for fast and accurate calculation of the catchment surface runoff and also is used to determine hydrological parameters (Zhan & Huang, 2004; Kopp & Noman 2008). SCS method based on GIS was used in many studies for estimating runoff (Ramakrishnan et al., 2009; Amutha & Porchelvan, 2009; Domnita et al., 2010, Dhawale, 2013). This method can incorporate the land use for computation of runoff from rainfall (Shadeed & Almasri, 2010). A high curve number means high runoff and low infiltration; whereas a low curve number means low runoff and high infiltration. So by using hydrologic soil groups, land use and maximum 24 hourly rainfalls (40.7mm), CN and runoff depth of Lighvan catchment are calculated.

3.1.3. Flow accumulation

Flow accumulation is one of the most important parameter in defining flood hazard. The accumulated flow is based on the number of cells flowing into each cell in the output raster. High values of accumulated flow indicate areas of concentrated flow and consequently higher flood hazard. For calculating the flow accumulation, first the flow direction (direction of flow is determined by the direction of steepest descent, or maximum drop, from each cell) was extracted using DEM and Hydro extension in ArcGIS, then the flow accumulation was created by the flow direction and Hydrology> Flow accumulation> in ArcGIS software.

3.1.4. Distance from drainage network

In addition to areas of concentrated surface water, river-overflows are important for the initiation of a flood event. Often the inundation is due to riverbeds and expands in the surroundings. The role of riverbed decreases as the distance increases. That explains why distance from the drainage network has been assigned a high weight in the methodology (Kazakis et al., 2015). Distance from drainage network is calculated by imposing buffer zones around the drainage network.

3.1.5. Geology

The geology map (Geological Organization and Mineral Exploration of Iran [GOMEI], 1996) shows that lithology of Lighvan catchment formations is related to Sahand volcanic activity. Pyroclastics, dacitic to andesitic volcanic rocks, dacitic subvolcanic rocks and ash flows cover the catchment area.

3.1.6. Land use

Landsat ETM+ image (date 2010/08/11) was used to analyze land use at Lighvan catchment. Such images have a spatial resolution of 30*30 m. The analysis was carried out using ENVI 4.7 and a supervised classification. The following land use classes were defined: garden, irrigated farming, rainfed farming, barren land, residential areas, dense pasture and weak pasture. Training data were acquired by field survey (using GPS), Google Earth images and previous land use maps. Supervised classification was obtained using the maximum likelihood algorithm.

3.1.7. Vegetation cover

In this study, vegetation cover map was extracted by NDVI index and using Landsat ETM+ image of 2010 year in ENVI 4.7 software. The Normalized Difference Vegetation Index (NDVI) is an index of plant greenness or photosynthetic activity, and is one of the most commonly used vegetation indices. By taking the ratio of red and near infrared bands from a remotely-sensed image, an index of vegetation, greenness can be defined. The Normalized Difference Vegetation Index (NDVI) is probably the most common of these ratio indices for vegetation:

$$NDVI = \frac{NIR-RED}{NIR+RED} \qquad (5)$$

Where NIR is the near infrared band value for a cell and RED is the red band value for the cell. NDVI can be calculated for any image that has a red and a near infrared band. The biophysical interpretation of NDVI is the fraction of absorbed photosynthetically active radiation. The fact that sums and differences of bands are used in the NDVI rather than absolute values may make the NDVI more appropriate for use in studies where comparisons over time for a single area are involved, since the NDVI might be expected to be influenced to a lesser extent by variation in atmospheric conditions (Mather & Koch, 2011). Digital Number (DN) values of NDVI images are between -1 to +1, whereas -1 belongs to very deep water and +1 belongs to completely dense vegetation cover. Therefore, investigation of vegetation cover density needs to study only positive values (Myneni et al., 1995).

3.1.8. Analytical Hierarchy Process

First step, after preparing data layers, all variables were weighted using the Analytical Hierarchical Process (AHP) method which is a multi-criteria decision making technique based on a 9-point scale (Table 1) (Saaty, 1980). This method involved a pair-wise comparison of the relative preferences of a small number of decision factors for flood risk assessment after constructing a decision hierarchy. Pair-wise comparison matrix is created by assigning weights by experts (Saaty, 2008). These weights computed automatically in Expert Choice software called Multi-Criteria Decision Analysis (MCDA) tool (Siddayao et al., 2015). In the AHP method, the pairwise comparisons of all the criteria were taken as the inputs while the relative weights of the criteria were the outputs. Moreover, the final weightings for the criteria are the normalized values of the eigenvectors that is associated with the maximum eigen values of the ratio (reciprocal) matrix (Razandi et al., 2015).

Table 1. Saaty's nine-point weighting scale (Saaty, 1992)

Intensity of importance	Description
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to Extremely strong importance
9	Extremely importance

Following the creation of the eigenvector matrix of the AHP, its consistency needs to be evaluated. Examining the consistency of the comparisons based on consistency ratio (CR) was considered. The consistency ratio (CR) must be less than 0.1. Therefore, CR is a numerical index to examine the consistency of the pair wise comparison matrix and is defined as:

$$CR = \frac{CI}{RI} \qquad (6)$$

Where CI is the consistency index and RI is the random index (Table 2) whose value depends on the number (n).

Table 2. Random Consistency Index (RI) (Saaty, 1992)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

In Table 2 the values of RI are tabulated. In this study the criteria are seven and as a result the RI = 1.32. The CI was calculated using the following formula:

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (7)$$

Where n is number of criteria and λ_{max} is average value of the consistency vector (Saaty, 1992).

Second step, each criterion was classified as sub-criterion and then classified layers were weighted. Weight gives the ranges of flood susceptibility within each criterion. The normalized weight was calculated based on the sum of the weights assigned on each criterion.

Third step, for estimating Flood Hazard Index (FHI), all data layers were aggregated in the GIS environment. The acquired values are processed in order to calculate the relative significance of each criterion and the corresponding weighting criterion factor (w). So following the calculation of the weights, the FHI can be calculated using equation10.

$$FHI = \sum_{i=1}^{n} r_i . w_i = S.w_S + R.w_R + F.w_F + D.w_D + U.w_U + NDVI.w_{NDVI} + L.w_L \qquad (8)$$

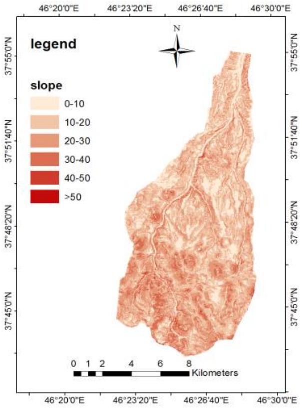
Where, r_i is the rating of the parameter in each point, w_i is the weight of each parameter and n is the number of the criteria. Finally, Flood Hazard Index (FHI) was computed using overlay analysis in Spatial Analyst of ArcGIS software.

Finally for accuracy of the flood hazard map, historical flood records are used that were measured in two points of the study area.

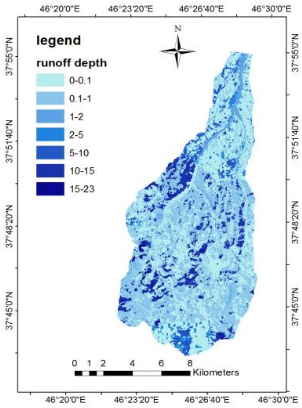
4. RESULTS AND DISCUSSION

All of data layers prepared (Fig. 3). The slope of catchment is in six categories from 0 to more than 50 percent. By increasing the slope of the catchment, infiltration decreases and runoff increases. The slope between 1 to 20% and then 20 to 30 percent is allocated maximum area of the catchment which reflects the steep catchment. So with increasing the slope, the time for infiltration decreases and also concentration time decreases.

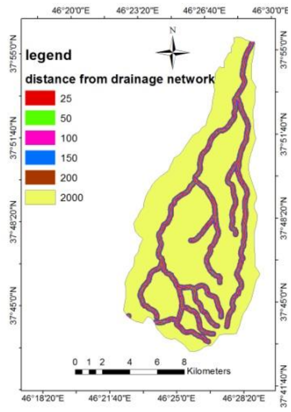
The flow accumulation values vary in a range between 0–327396, with the highest values occurring in the outflow of Lighvan and main tributaries. Lower values of this factor occur in streams of lower order. The classes of distance from drainage network have been defined by historical floods in the study area so that areas near the river network (25, 50 and 100 m) are high and 150, 200 and 2000 are low flood hazard potential so that the effect of this parameter decreases in distances.



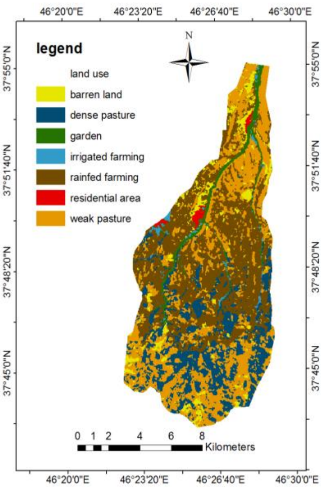
Slope



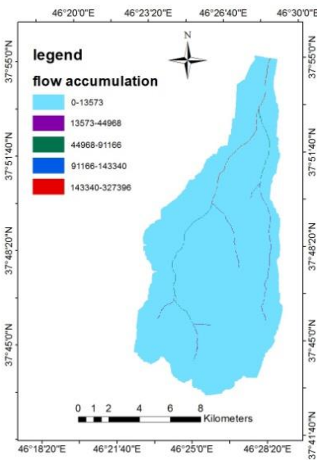
Runoff depth



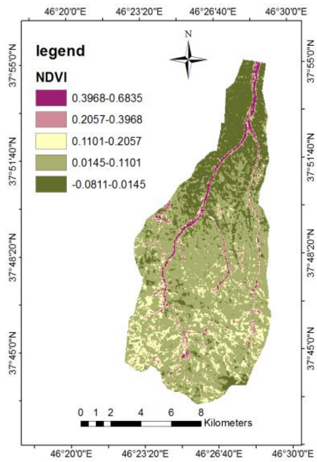
Distance from drainage network



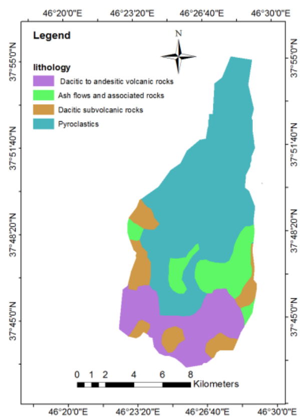
Land use



Flow accumulation



Vegetation cover



Lithology

Figure 3. Data layers used in proposed analysis

Runoff depth layer was prepared by SCS method. Runoff was obtained for the catchment that was in seven classes from 0 to 23 cm. The greater runoff depth has a more effective role in flood risk. The class 0.1 - 1 cm is allocated the largest area of the catchment.

The lithology of the flood hazard areas is an important criterion because permeable formations favour water infiltration. In Lighvan catchment, pyroclastics covers around 58% of the catchment area. Also dacitic to andesitic volcanic rocks, dacitic subvolcanic rocks and ash flows and associated rocks cover the catchment area around 19, 11 and 12 percent respectively. The Lighvan catchment lithology formations have different permeability. Dacitic subvolcanic rocks, dacitic to andesitic volcanic rocks, ash flows and pyroclastics have low to high permeability respectively.

Land use has a major influence on runoff and infiltration rate. Land use map shows that the largest catchment area is for rainfed farming and weak pasture so potential retention of soil is less.

Vegetation index values fluctuate between +1 and -1 values and proved that the closer to +1 number, the amount of vegetation cover increases. For the Lighvan catchment, the amount of vegetation cover is between -0.08 to 0.68 that shows the vegetation cover of catchment is weak. 57.88 percent of catchment area has low vegetation cover and only amount of vegetation cover is more in the Lighvan river valley that dedicated to agriculture and gardens. Whatever less amount of vegetation cover index, more valuable in flooding because it reduces the permeability and increases runoff.

Table 4. Normalized weights for sub-criteria.

Criteria	Sub-criteria				
F (pixels)	0-13573	13573-44968	44968- 91166	91166- 143340	143340-327396
Weight	0.032	0.060	0.120	0.228	0.560
Consistency ratio (CR) =0.08					

D	25	50	100	150	200	2000
Weight	0.515	0.244	0.100	0.070	0.044	0.027
Consistency ratio (CR) =0.09						

S	0-10	10-20	20-30	30-40	40-50	>50
Weight	0.026	0.046	0.087	0.155	0.252	0.435
Consistency ratio (CR) = 0.07						

R	0-0.1	0.1-1	1-2	2-5	5-10	10-15	15-23
Weight	0.022	0.035	0.054	0.087	0.143	0.268	0.391
Consistency ratio (CR) = 0.08							

U	G	Dp	Wp	If	Rf	B	Ra
Weight	0.021	0.033	0.050	0.078	0.099	0.329	0.391
Consistency ratio (CR) = 0.09							

NDVI	0.3968 - 0.6835	0.2057 - 0.3968	0.1101 - 0.2057	0.0145 - 0.1101	-0.0811- 0.0145
Weight	0.037	0.067	0.133	0.268	0.494
Consistency ratio (CR) = 0.07					

L	P	Af	D&A	Ds
Weight	0.054	0.109	0.281	0.556
Consistency ratio (CR) = 0.06				

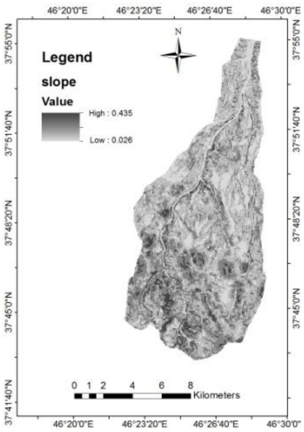
G=Garden; Dp= Dense Pasture; Wp= Weak Pasture; If= Irrigated Farming; Rf= Rainfed Farming; B= Barren Land; Ra= Residential Area; Af= Ash flows and associated rocks; Ds= Dacitic Subvolcanic rocks; D&A= Dacitic to Andesitic volcanic rocks; P= Pyroclastics

Table 3. Pair-wise comparison matrix and normalized weights for the criteria

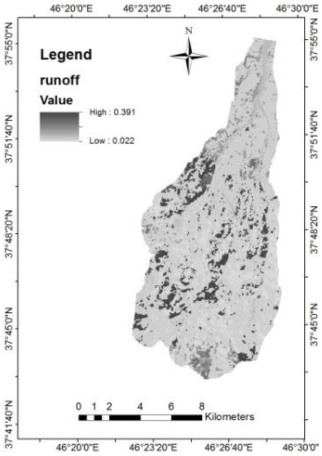
Criteria	**F**	**D**	**S**	**R**	**U**	**NDVI**	**L**	**Normalized weight**
F	1	2	3	3	5	5	7	0.331
D	1/2	1	3	3	4	4	6	0.254
S	1/3	1/3	1	2	3	3	6	0.150
R	1/3	1/3	1/2	1	3	3	5	0.120
U	1/5	1/4	1/3	1/3	1	2	3	0.064
NDVI	1/5	1/4	1/3	1/3	1/2	1	3	0.053
L	1/7	1/6	1/6	1/5	1/3	1/3	1	0.028
Consistency ratio (CR) = 0.04								

F= Flow accumulation; D= Distance from drainage network; S=Slope; R=Runoff depth; U=Land use; L= Lithology

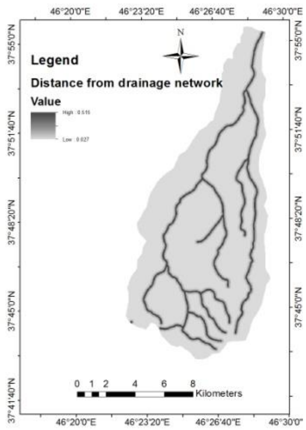
After preparing criteria (data layers) and sub-criteria (classes within data layers), pair-wise comparison matrix and normalized weights for criteria (Table 3) and sub-criteria (Table 4) were calculated according to AHP. The values of each row characterize the importance between two criteria.



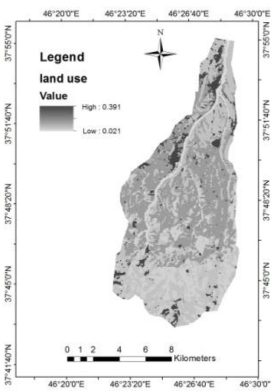
Slope



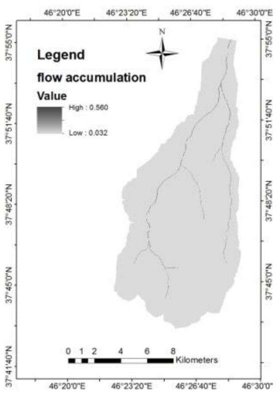
Runoff depth



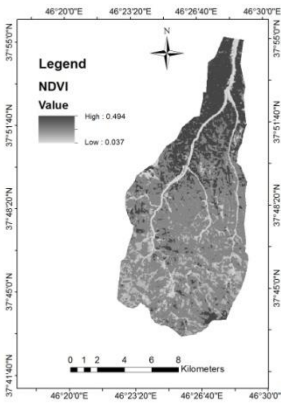
Distance from drainage network



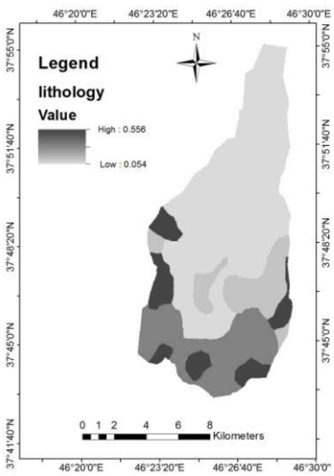
Land use



Flow accumulation



Vegetation cover



Lithology

Figure 4. Weighted data layers. Darker areas indicate higher values

The first row of the table illustrates the importance of flow accumulation in regard to the other criteria which are placed in the columns so that flow accumulation is significantly more important from lithology and therefore is assigned the value 7 and the row has the inverse values of the pairwise comparison (e.g. 1/7 for lithology).

Since according to Tables 3 and 4, Consistency Ratio (CR) value is lower than the threshold (0.1), so the weights' consistency is confirmed then weighting criteria and sub-criteria layers were extracted (Fig. 4).

After weighting criteria and sub-criteria (Fig. 4), Flood Hazard Index (FHI) map was created in GIS. FHI map (Fig. 5) shows that flood hazard divided to five classes; very low, low, moderate, high and very high so that 3.35% of the catchment area in the range of very high risk and 6.97 % in the range of high risk (Fig. 8). Historic flood records (Fig. 5) justified the flood hazard map accuracy so that the historical flood events have occurred in the high and very high flood hazard areas.

Flood hazard potential map in the Lighvan sub-catchments (Fig. 6) were classified into different types and their final priorities were estimated. Out of 19 sub-catchments, sub-catchment 4, 13 and 19 fall under high, sub-catchments 3, 6, 9, 15, 17 and 18 under moderate and sub-catchments 1, 2, 10, 11, 12, 14 and 16 under low, and sub-catchments 5, 7 and 8 under low flood hazard, therefore the sub-catchments 4, 13 and 19 of the study area is facing serious problem of flood hazard (these sub-catchment located in the confluence of the two stream tributaries).

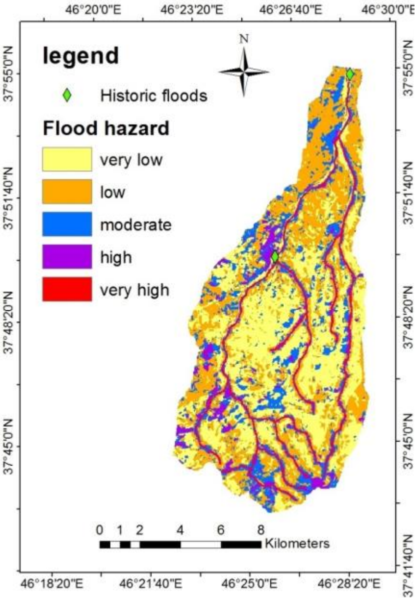


Figure 5. Flood hazard zonation map

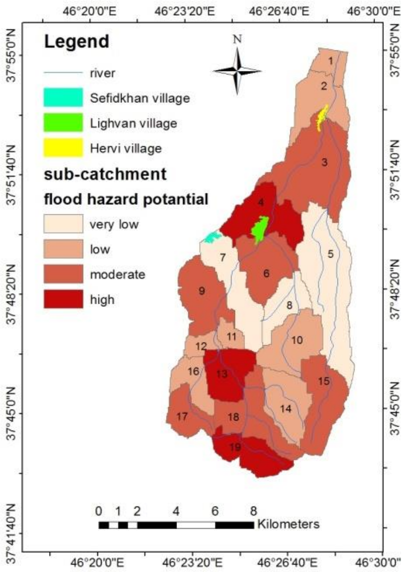


Figure 6. Flood hazard potential map of the sub-catchments

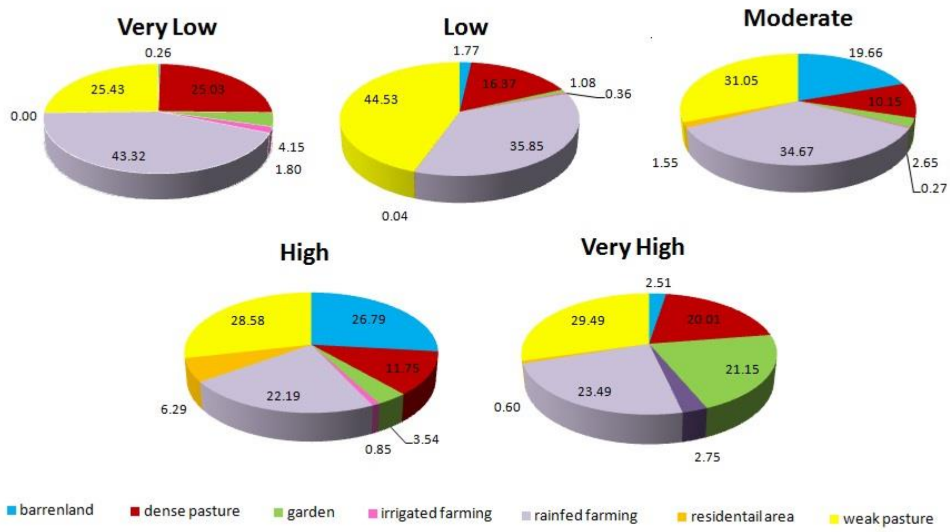


Figure 7. Distribution of land use in flood hazard areas

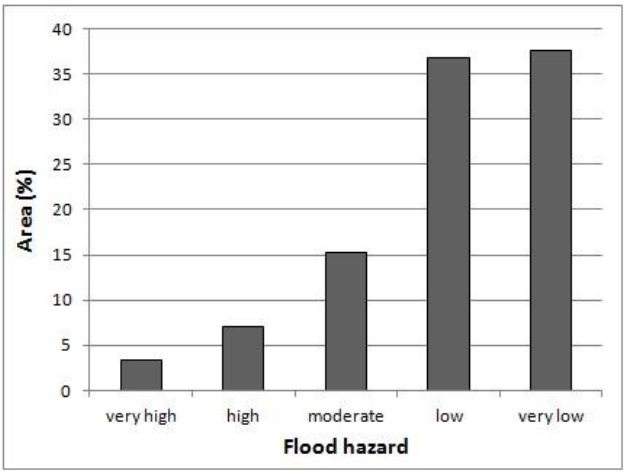


Figure 8. Percentage area of the flood hazard zones

One the other hand Lighvan village is located in sub-catchment 4 and Beyragh villages is located in sub-catchment 3 so flood hazard mitigation and flood control in these sub-catchments should be implemented immediately based on principles of the integrated catchment management. Other sub-catchments are under low or moderate flood hazard category.

The distribution of the land use in the susceptible zones to the flood in the study area is illustrated in figure 7. Accordingly, the 29.49%, 23.49%, 21.15% and 20.01% of the very high flood hazard zones are weak pasture, rainfed farming, garden and dense pasture respectively. Also 6.29 percent of high flood was included in residential area where the Lighvan village located. Also flood plain of Lighvan River (very high flood hazard potential) has been occupied by garden, agricultural land and residential area so that these areas are inundated by flood in heavy rainfall events.

5. CONCLUSION

In this study, AHP is combined with GIS and RS as a tool for evaluating flood hazard in Lighvan catchment. Flood hazard zonation map was created for Lighvan catchment based on different criteria which all of criteria such as slope, flow accumulation, distance from drainage network, lithology, runoff depth, land use and NDVI were prepared with GIS and RS. After preparing all of data layers, criteria and sub-criteria were weighted by Analytical Hierarchy Process based on expert judgments. Results show that in this mountainous catchment, flow accumulation, distance from drainage network and slope are the most importance factors in flood risk of Lighvan catchment. Resulted flood hazard index map divided to five classes; very low, low, moderate, high and very high. The accuracy of the flood hazard map verified by historical flood events in study area that have occurred in the high and very high flood hazard areas.

According to flood hazard zonation, 3.35% (located in the riverside) and 6.97 percent of the catchment area are in the range of very high and high risk. This is result of some important criteria combination in flooding and internal relationship between the criteria. The distribution of the land use in the susceptible zones to the flood in the catchment showed that most percent of the very high flood hazard zones was included in weak pasture, barren land, garden and rainfed farming respectively. Also rainfed farming, weak pasture and dense pasture are very low and low to moderate prone areas. Therefore rainfed farming and weak pasture have high distribution in flood hazard classes because most percent of catchment have rainfed farming and weak pasture land uses.

This study indicate that Lighvan catchment has potential to flooding in river flood plain and in sub-catchment 4, 13 and 19 because of natural (slope, drainage network, land cover, lithology etc). and human (agricultural activities in riverside, over grazing and land use changes) factors so the integrated catchment management for flood hazard mitigation and flood control should be done. In this regards, using GIS and remote sensing along with a multi-criteria decision making technique (AHP) for the estimation of the flood hazard areas can be a useful for the mitigation of the devastating impact of flood in this mountainous catchment. Finally the decision-makers and planners can use the results of flood hazard map as guidelines for identifying the sub-catchments priority and effective catchment management.

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