JOURNAL OF FLOOD ENGINEERING
Vol. 8 No. 1 (January-June, 2017)

Received: 13th June 2016   Revised: 14th August 2017   Accepted: 01st November 2017

ASSESSING FLOOD HAZARD USING GIS BASED MULTI-CRITERIA DECISION MAKING APPROACH; STUDY AREA: EAST-AZERBAIJAN PROVINCE (KALEYBAR CHAY BASIN)

Mojtaba Pirnazar[1], Arash Zand Karimi[2], Bakhtiar Feizizadeh[2]
Kaveh Ostad-Ali-Askari[3*], Saeid Eslamian[4], Hafez Hasheminasab[1],
Omid Ghorbanzadeh[1] and Majedeh Haeri Hamedani[4]

[1]*Department of Remote Sensing and GIS, Faculty of Geography and Planning, Tabriz University, Iran*
[2]*Department of Remote Sensing and GIS, Faculty of Geography and Planning, Tabriz university, Iran*
[3]*Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran*
Corresponding author E-mail: Koa.askari@khuisf.ac.ir
[4] *Water Engineering Department, Isfahan University of Technology, Isfahan, Iran*

Abstract: Floods are one of the most common and widely distributed natural risks to life and property. Due to such hazards associated with flooding as disruption of services, health impacts, famine and disease, flood protection must be taken into account in almost all development projects. Feasibility study of flood and evaluating the sensitive places prone to flood is the main step for controlling and managing the flood and utilizing it. Kaleybar Chay basin, that is located in East Azerbaijan province, is one of the areas which has experienced several floods during the last years and because of mismanagement, it has caused several life and property losses to the residents of this area. In this study, the effective factors which impact on flooding, from physical, hydrological and environmental factors were explored through executing the ANP model. Through the present research, the ETM^+ image of the Landsat satellite and the ANP model were used considering their abilities in analyzing the criteria and coefficient of their results with their real world. The results of the study showed that in ANP method, 20 percent of the area which is in the north areas of the basin has the high risk from flooding aspect; the results of the study were supplied for recognizing the area with high possibility of flooding in Kaleybar Chay basin and the provided maps will be used in executive organizations (such as governorate, natural resources) for logistics planning and controlling the flood.

Key words: hazard, flooding, ANP, Kaleybar Chay basin, East Azerbaijan

1. INTRODUCTION

Natural disasters and their economic impact are increasing worldwide at an alarming rate. People, property, society, and the environment are suffering more and more from natural hazards (Dang *et al.* 2011). Flood is considered to be the most common natural disaster worldwide during the past decades, producing many environmental and socio-economic consequences within the affected flood plain (Marchand *et al.* 2009; Taylor *et al.* 2011; Dawod *et al.* 2012; Heidari 2014; Rahmati *et al.* 2015).

Moreover, The Fourth Assessment Report of the Intergovernmental Panel on Climate Change reveals that flood disaster and the losses generated by them will continue to grow in frequency and severity in the future (IPCC, 2007).

The floodwater susceptibility mapping has the more application in studying the management studies of flood and planning the future direction of city growth (Barkhordar and Chavoshian, 2011; Buchele *et al.* 2006; Vahidniaa *et al.* 2008; Tehrany *et al.* 2014. Nowadays, these maps are regarded as the basic and important data in studying the development projects throughout the world and it has been studied by the related organizations before each investment or executing the development plans (Barkhordar and Chavoshian, 2011).

Many studies have been done on flood susceptibility mapping and flood analysis using GIS and MCDM (Yang *et al.* 2013, Chen *et al.* 2015, Rahmati *et al.* 2015, Khosravi *et al.* 2016, Fernandez *et al.* 2016). MCDM provides a powerful tool for flood management and has received a great deal of attention in solving such problems, not only from researchers but also decision makers and practitioners outside the scientific community (Brito and Evers, 2016).

Flood risk management can benefit from the use of MCDM tools. MCDM is an umbrella term used to describe a set of methods for structuring and evaluating alternatives on the basis of multiple criteria and objectives. These methods provide targeted decisions, as they can handle the inherent complexity and uncertainty of such problems as well as the knowledge arising from the participation of several actors (Yan *et al.*, 2011; Zagonari and Rossi, 2013, Brito and Evers, 2016).

MCDM can enhance the quality of decisions, by making the process more explicit, rational, and efficient, leading to justifiable and explainable choices (Mateo, 2012). Among the different methods of MCDM, ANP has higher accuracy specially in decision making with several criterias because of hierarchy system and taking into account the complex interactions (correlation and feedback) among the elements. Furthermore, it has attributes like flexibility, applying qualitative and quantitative criterias coincidently and assessing the compatibility in judges (Zebardast, 2010).

The ANP is a useful tool for prediction and for representing a variety of competitors with their explicitly known and implicitly assumed interactions and the relative strengths with which they wield their influence in making a decision. It is also useful in conflict resolution where there can be many opposing influences. The combination of these characteristics enables the development of real participatory processes, which are crucial for the implementation of successful and long-lasting flood management programs (Affeletranger, 2001).

The extent and frequency of floodwater event in each area depends on different factors. The physical characteristics of basin, hydrological characteristics, applications which are resulted from humanistic activities are involved to intense the floodwater or reduce and extent of the damages resulted from it. Recognizing these factors and classifying them in each area are the primary principals of controlling floodwater and decreasing it (Razavi, 2009). The main objective of this research is assesment flood hazard potential zones using ANP[3] with the physical, environmental and hydrological criteria in 10 sub-criteria included (*CN)*[4], (*Q*)[5], (*S*)[6], Drainage, land use, Lithology, height, slope and vegetation in Kaleybar Chay basin's.

2. STUDY AREA

Central Kaleybar Chay basin which is a part of north Arasbaran is located in East Azerbaijan. The basin has a total area of approximately 28173 hectares. This mountain area is in 500 to 2500 meters height of sea level and Kaleybar with 48837 population is located in this basin. Average precipitation is 313 millimeters per year and because of special hydro morphological conditions, flood was happened several times in this area (Figure 1). The present study was done for recognizing the areas with high risk for controlling and managing this event.

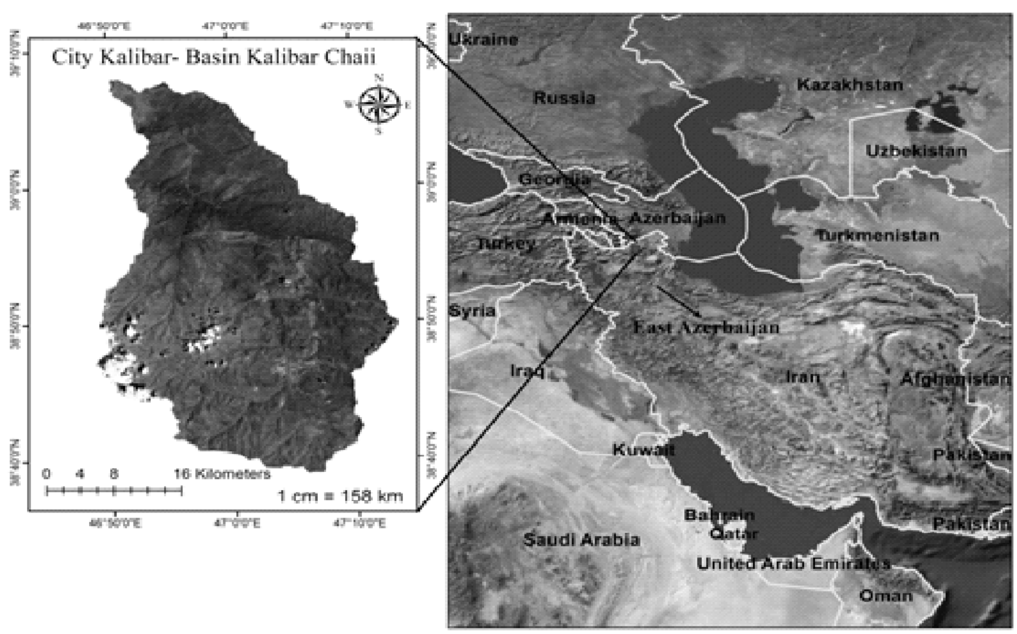

Figure 1: Location of the study area

3. MATERIALS AND METHODOLOGY

3.1. Data

The present paper considered the Assessing flood hazard of the flooding in central Kaleybar Chay basin. Through the present study, the ETM+ satellite images of the Landsat were used. These images were taken with 30-meter spatial resolution in 7 bands in 2014. The Landsat satellite images were used for extracting the vegetation cover. The other data include the DEM taken by SRTM with 30-meter spatial resolution for extracting the height level and slope, digital geology map 1:100000, precipitation data and Debi of precipitation-gauge station. Moreover, GPS data of the Garmin model were used for training samples and ground control points. For doing the present research, the processing functions of ENVI 5.1 software, analysis functions of ArcGIS10.2.2 and the decision functions of super decision 5 software were used.

3.2. Methodology

Totally, this research includes three parts; the first part is related to processing the image, the second part is related to running the model and the last part is integrating the previous parts to find the high risk area from flood point of view. Figure 2 shows the flowchart of the study. Through this flowchart, three steps were shown for executing the research.

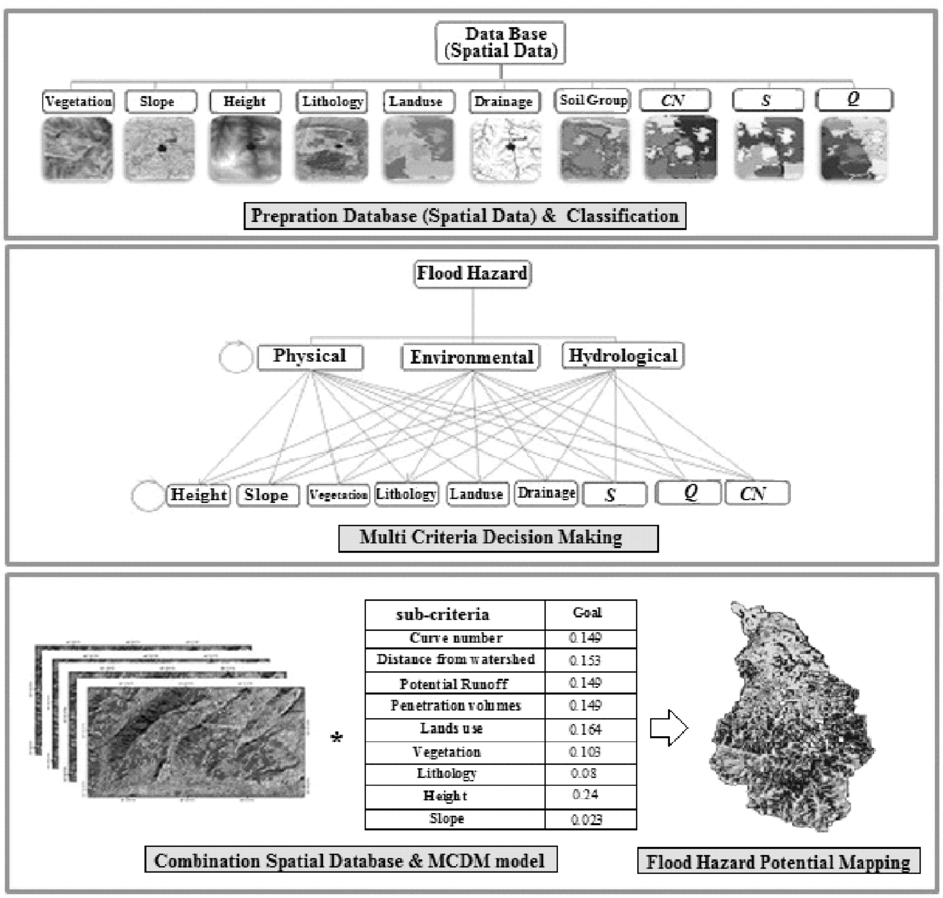

Figure 2: Stages of the Study

In the first level, the layers (slope, elevation, vegetation and …) were supplied by attention to their importance in runoff and flood forming. In the second level, the model was executed by forming the network among the criteria and sub-criteria. One of the capabilities of ANP method is that it provides a possibility to be handled according to the conditions of each region. In this study 20 experts and stakeholders including the experts in charge of regional water and soil matters, regional planners, construct consultants etc. that have complete information about the condition of the study region and effective factors in flood occurance, have said their views on the factors affecting the flood occurance in the region. Taking into account the opinions of experts and stakeholders and reviews on the preceding studies in this field, desired network was designed.

After designing the network, questionnaires were designed and compled by experts and stakeholders. Finally, by averaging the given values and entering them into the superdecision software, final value of every criteria was defined.

The application of ANP process involves the following steps:

1. Making the model and transferring the problem to a network structure,
2. Forming the pairwise comparison matrix and determining the primary factors,
3. Forming the super-matrix and converting it to limitation super-matrix.

Finally, by applying the coefficients on the layers which were supplied in the first level, the final output which shows the areas in the high risk of flooding in Kaleybar Chay basin would be generated.

4. RESULTS

In this study by according to the literature review and experts ideas, The effective factors on the flood potential, such as slope, distance from rivers, land use and etc were selected and all the mentioned factors were converted to a raster grid with 30*30 m cells for application of the ANP method. Following, the effects of each of the factors that is involved in causing flood have been illustrated.

4.1. Physical factors

By increasing the slope of the basin's level, the chance for penetrating would be decreased and it can be resulted that by increasing the slope of the basin, the time of concentration would be decreased (Najmaei, 2008). high slopes causing high picks in hydrograph (Zahedi and Baiati Khatibi, 2009). So the height is the important factor in the hydrologic study.

In Kaleybar Chay basin, the slope condition is that 10-20% slope appropriated the 46% of the most redundancy (Figure 3), and the redundancy of intense slopes is less; therefore, it can be resulted that the slope of studying basin is moderate.

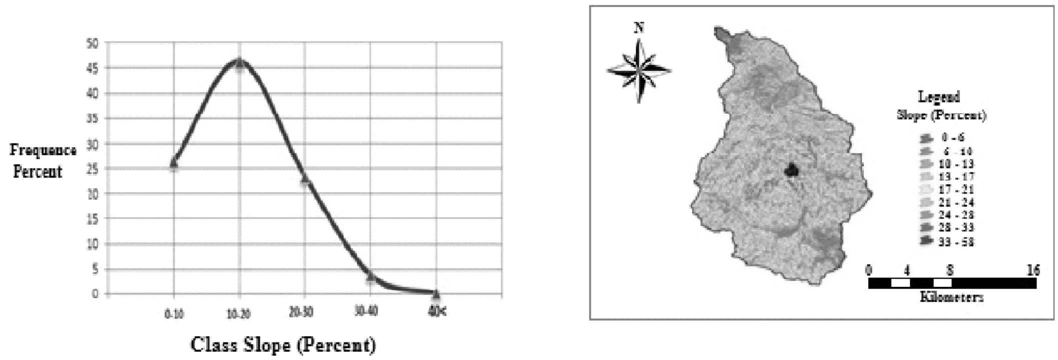

Figure 3: Slope distribution in the study area

The evaluation in Kaleybar Chay basin ranges from 269 to 2923 meters which 39.72% of the height is in 1500 to 2000 meters which allocated the most part of the height levels. Based on the Figure 4, it is concluded that, the height of the basin in the upper side is high and intensify the flood.

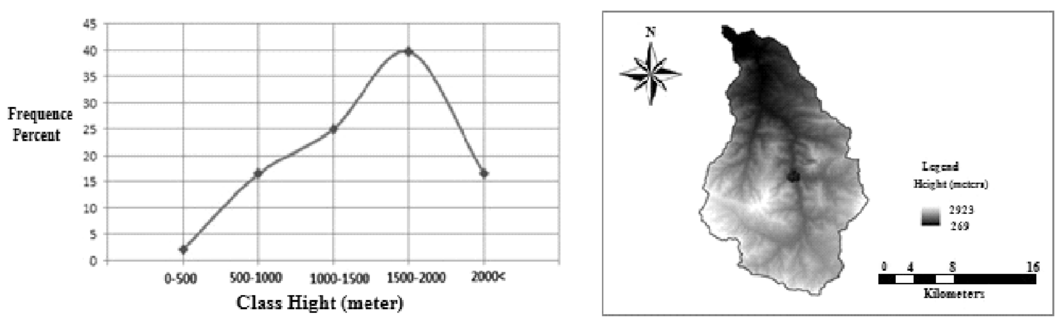

Figure 4: Distributing the height in the study area

4.2. Environmental factors

The type of stone and soil cover impact on the penetrating capacity (Table 1). The penetrable soil or stone supply the conditions for penetrating the water to ground and delay the discharging of it to the main stream; Basins with relatively impenetrable bed rock or soil, create high volumes of runoff (Garde, 2006).

The amount of water and the load of sediment, the picks of water flood and its happening time, and the transmission speed of the current pick is influenced by Identity and covering of the vegetation (Garde, 2006; Kheirizade *et al.*, 2013). Type of land use and its location, influence on intensity of flooding, for example the land uses like forest in contrast to urban land uses, absorb much water and produce less runoff.

In relation to lithology, the penetrable condition of the basin is mentioned. In the study area, sandstone with 16.21%, volcanic rock with 14.63%, and Conglomerate-sandstone with 12.88% allocated the largest area, and totally most part of the area is covered by stone with low penetration (Figure 5).

Table 1
The stone type and permeability (Lewis *et al.* 2006)

Resistance	*Stone type*	*Permeability*	*Type of stone*	*Permeability*	*Type of stone*
Low	Basalt	Low	Marn- Limon	Moderate	Silt- clay
Low	Volcanic	Moderate	Marn-sandstone	Moderate	Silt-conglomerate
Moderate	Transformation	Low	Granit-Manzanita	high	Konglomera-sandstone
high	Sandstone	Moderately-high	Gabbros Pirocsinit	Moderately high	Silt
		Moderate	Schist	Moderate	Schist

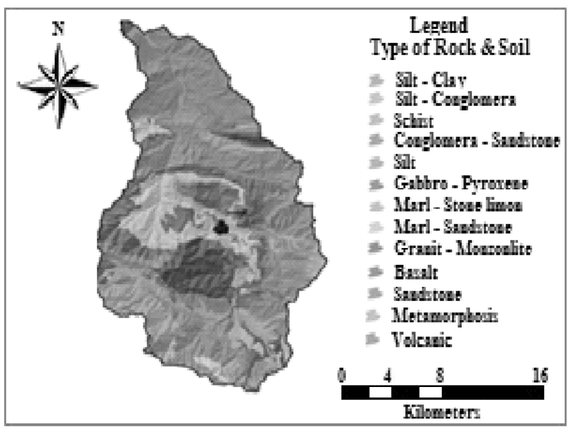

Figure 5: Stone type in the study area

Studying the area's vegetation shows that the central and east parts of the area have the suitable condition, but southern, northern and eastern parts don't have the suitable conditions. The vegetation index of the area is among -0.315 to 0.745 which is mostly located in the range of 0.315 to 0.471 (Figure 6).

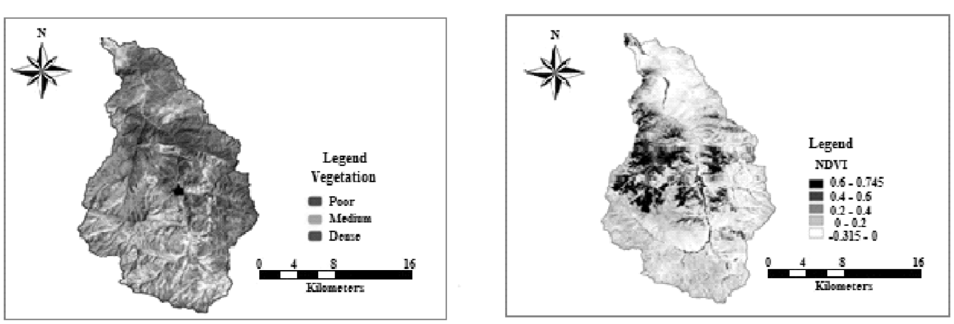

Figure 6: Vegetation distribution and NDVI of the study area

Studying the existed land uses in the area shows that the grassland, woodlands and forest have been allocated the largest area and these land uses absorb the water and cause to produce the less runoff. Of course, in land use discussion, distribution of them are so important (Figure 7).

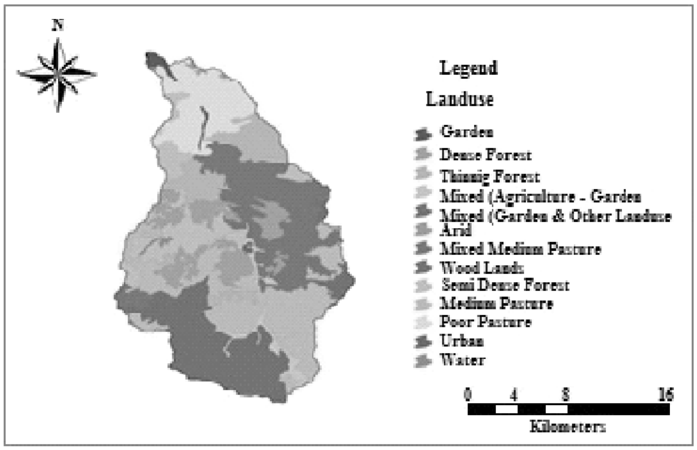

Figure 7: Land use and its distribution in there areas

4.3. Hydrological factors

Distance from stream is one of the parameters that impacts on flood prevention, while distance from stream decrease in the basin, the risking of flooding increases (Figure 8). The layer of distance from the streams of the basin was supplied in 5 classifications with 150 meter interval and as it was mentioned above, by increasing the distance from streams, the risk of flooding is decreased.

The other important parameter is the *CN* which determines how much rainfall infiltrates into soil or an aquifer and how much rainfall becomes surface runoff. A high curve number

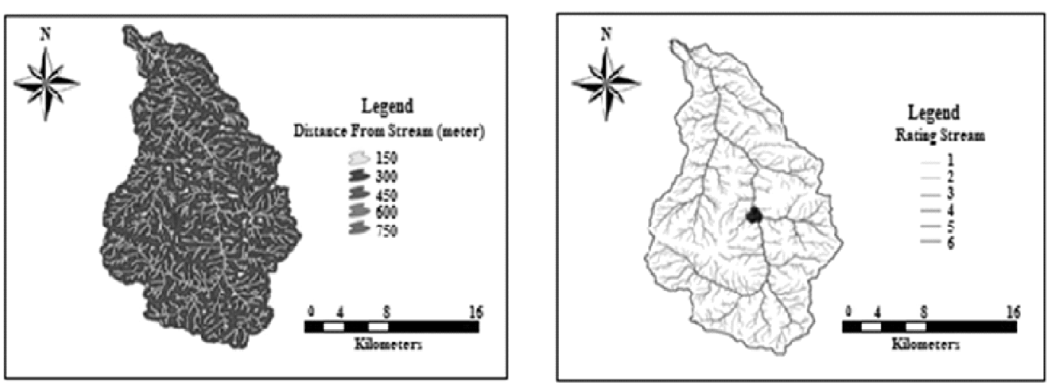

Figure 8: Grading the streams and distance from stream

means high runoff and low infiltration, where as a low curve number means low runoff and high infiltration (Kheirizade *et al.*, 2013; Zhan and Huang, 2004). Obtaining the height factor of the runoff in relation to the risking of flooding in watershed is so important. In SCS[7] method, in total condition the runoff height would be obtained from equation1.

$$\text{Equation 1} \quad Q = \frac{(P - 0.2\ S)^2}{(P + 0.8S)^2}$$

Where, Q is the height of runoff in the watershed; *P* is the volume of rainfall (cm), *S* is the potential maximum soil retention (cm) which its value depends on curve number and it volume in metric system is accessed from equation 2.

$$\text{Equation 2} \quad S = \frac{25400}{CN} - 254$$

For calculating the curve number, the soil's hydrologic layer is supplied by using the basin soil map and land use layer of the basin (Figure 9). Then by using these layers and rainfall layer, the curve number's layer, ability to retention rainfall in soil (*S*) and potential runoff producing (*Q*) were supplied.

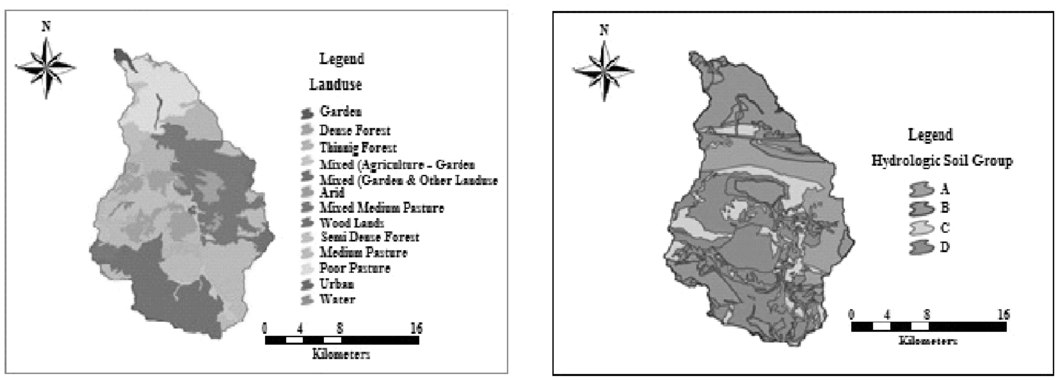

Figure 9: The effective parameters in obtaining curve number (hydrologic groups land use)

As it was mentioned above a high *CN* means high runoff and low infiltration; checking the condition of the number of the basin shows the range of *CN* from 40 to 89 which most part of the basin was covered by *CN* 70 (Figure 10).

The volume of the penetration of the basin is effected by curve number and as it can be found through the Figure 11, its range was from 31.39 to 381 millimeters which include the most redundancy in the area which had 50-60 millimeters and the high penetration volume in the basin covered the less part of the area which this issue shows the runoff's intense of the area.

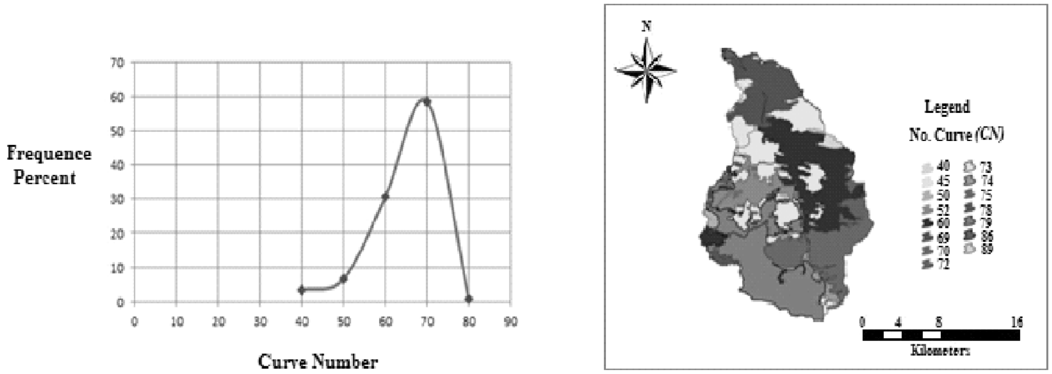

Figure 10: the curve number and its transmittal in the area

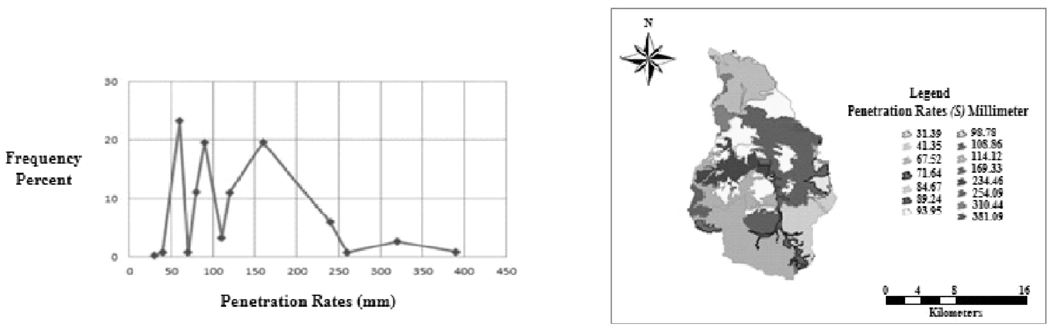

Figure 11: The penetration's volume and exploring its density in the area

According to equation 1, the potential runoff producing depends on the rainfall volume and; in Kaleybar Chay basin the potential runoff producing is between 166.07 to 359.24 millimeter which the most redundancy is 290 to 310 millimeters (Figure 12) and this shows that the potential runoff producing in the area is more than infiltration volume.

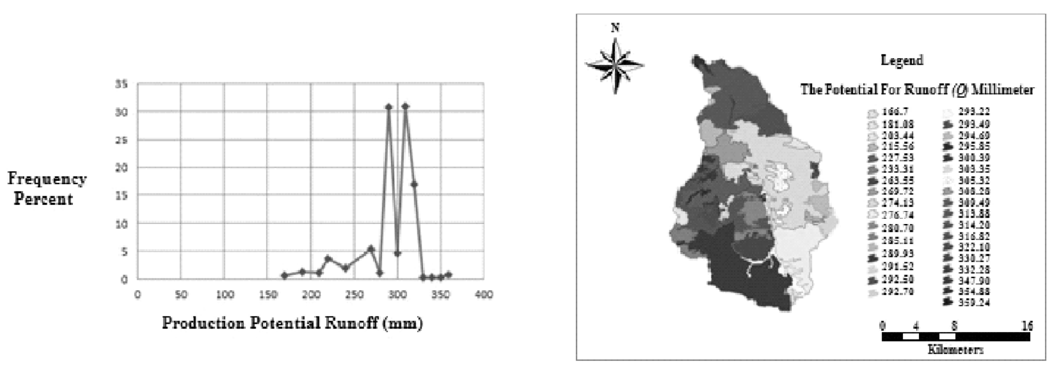

Figure 12: The potential runoff producing and exploring its density in the area

4.4. Executing the Analytical Network Process Model (ANP)

For understanding the mutual dependency among the main criteria, the binary comparing among the main criteria is done based on Satty's evaluation (Figure 13).

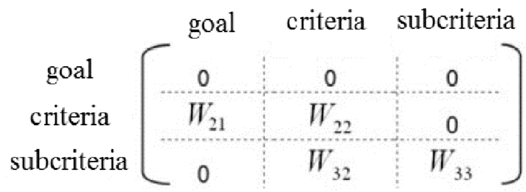

Figure 13: Show relationship between goal, criteria, subcriteria

Pair-wise comparing of main criteria and the accessed matrix from binary comparing of the main criteria to the goal (W21) shows in Tables 2 and 3.

Table 2
The binary comparing of main criteria

Special vector	*Environmental*	*Physical*	*Hydrological*	*Title of cluster*
(W)	2	4	1	Hydrological
0.571	0.5	1		Physical factors
0.142	1			Environmental factors
0.285				

CR = 0.00

Table 3
The accessed matrix from binary comparing of the main criteria to the goal (W21)

W	*Main criteria*
0.285	Environmental
0.142	Physical
0.518	Hydrological

For calculating the importance of each main criterion (by attention to mutual dependency among them), the binary comparing of sub-criteria of each criteria has been done and presented in the below Table (W22).

Table 4
Binary comparing of main criteria by attention to their inner dependency with hydrological factor

Special vector	*Physical*	*Environmental*	*Criterion*
(W)	2	1	Environmental
0.666	1	0.5	Physical
0.333			

CR = 0.00

Table 5
Matrix accessed from main criteria's binary comparing (W22)

Physical	*Environmental*	*Hydrological*	
0.666	0.8	0	Hydrological
0.333	0	0.666	Environmental
0	0.2	0.333	Physical

By attention to this fact that some elements which are in the clusters may be depended on the other elements of the other clusters, in this case by attention to the matrix controlling criterion, couple comparing was formed and the binary matrix elements were compared and the weight of matrix is calculated and the conclusion enters the primary super-matrix (W32).

Table 6
Binary comparing of the sub-criteria related to environmental criteria

Special vector (W)	*Landuse*	*Vegetation*	*Lithology*	*Title*
0.571	2	4	1	Lithology
0.142	0.5	1		Vegetation
0.285	1			Landuse

CI: 0.00

Table 7
Matrix accessed from the binary comparing criteria with sub-criteria (W32)

Physical	*Environmental*	*Hydrological*	
0	0	0.304	Curve Number (CN)
0	0	0.293	Distance from watershed
0	0	0.2	potential Runoffproducing (Q)
0	0	0.2	Penetration volumes (S)
0	0.285	0	Land use
0	0.142	0	Vegetation
0	0.571	0	Lithology
0.333	0	0	Height
0.666	0	0	Slope

As it was mentioned in the last section, 9-sub-criterion which shows the characteristics of the main 3-criteria was selected for studying the present study. The mutual dependency of these sub-criteria in Table 8 has been shown. Usually, for obtaining this Table and determining the mutual dependency of sub-criterion and criteria, the opinion of the experts have been used (W33).

After exploring the equations of the sub-criteria, binary comparing among the sub-criteria was done. The matrix for comparing the sub-criteria has been come in W33 matrix.

Table 8
Inner dependency of sub-criteria to each other

Potential runoff producing *(Q)*	**Penetration volumes *(S)***	**Curve Number *(CN)***	**Distance from watershed**	**Slope**	**Height**	**Land use**	**Vegetation**	**Lithology**	**Sub-criterion**
				*	*	*	*		**Lithology**
*	*	*	*	*	*	*		*	**Vegetation**
*	*	*	*	*	*		*	*	**Land use**
						*	*	*	**elevation**
						*	*	*	**Slope**
*	*	*		*	*	*	*	*	**Distance from watershed**
*	*		*	*	*	*	*		**Curve Number *(CN)***
*		*	*			*	*		**Penetration volumes (*S*)**
	*	*	*	*	*	*	*	*	**Potential runoff producing *(Q)***

Table 9: Matrix accessed from comparing the binary comparison of the sub-criteria (W33)

Curve Number (CN)	*Distance from watershed*	*Potential runoff producing (Q)*	*Penetration volumes (S)*	*Height*	*Slope*	*Lithology*	*Vegetation*	*Lands use*	*Sub-criterion*
0	0.197	0.222	0.222	0.136	0.133	0.153	0.117	0.133	**Curve Number *(CN)***
0.226	0	0.222	0.222	0.136	0.133	0.153	0.117	0.133	**Distance from watershed**
0.196	0223	0	0.222	0.123	0.133	0.153	0.117	0.133	**Potential runoff producing *(Q)***
0.196	0.223	0.222	0	0.123	0.133	0.153	0.117	0.133	**Penetration volumes (*S*)**
0	0	0	0	0	0	0.076	0.075	0.066	**Height**
0	0	0	0	0	0	0.076	0.058	0.066	**Slope**
0	0	0	0	0.247	0.266	0	0.234	0.266	**Lithology**
0.152	0.131	0.111	0.111	0.094	0.066	0.076	0	0.066	**Vegetation**
0.226	0.223	0.222	0.222	0.136	0.133	0.153	0.104	0	**Lands use**

After calculating the W33, the inharmonious, harmonic and limited super-matrix would be accessed for calculating the W_{ANP} (the weight of importance of each one of these sub-criteria to the goal) (Table 10).

In the next step W_{ANP} multiply on the cluster's weight to access the coefficient of each sub-criterion, these values were multiplied on layers and the final maps would be obtained. Finally, each of the layers were divided to 5 classes and for each one of 5- classes (sub-layers)the related coefficients in the Super decision software would be accessed. Totally, for layers of distance from stream, the potential runoff producing, penetration volume, curve number, vegetation index and slope of the high volume caused to increase the flood

Table 10
Matrix accessed from comparing the binary comparison of sub-criteria with goal (W_{ANP})

Goal (W)	*Sub-criteria*
0.149	Curve number *(CN)*
0.153	Distance from watershed
0.149	Potential runoffproducing *(Q)*
0.149	Penetration volumes *(S)*
0.164	Lands use
0.103	Vegetation
0.08	Lithology
0.24	Height
0.023	Slope

and height caused to decrease the flood, and from class 1 (low height) to 5 (high height) the effect of coefficient would be decreased. For lithology and land use layers based on the volume of the penetration the classification and the high penetration volume would be in the primary classes.

Table 11
Calculating the final weight of the indices

Final weight	*Clusters' weight*	W_{ANP}	*Informative layers*
0.077	0.518	0.149	Curve number (CN)
0.079	0.518	0.153	Distance from watershed
0.077	0.518	0.149	Potential runoff producing (Q)
0.077	0.518	0.149	Penetration volume
0.046	0.285	0.164	Land use
0.029	0.285	0.103	Vegetation
0.022	0.285	0.08	Lithology
0.003	0.142	0.024	Height
0.004	0.142	0.033	Slope

In the final step, by multiplying the coefficients accessed from the model and integrating the informative layers, the final feasibility map of flood in Kaleybar Chay basin would be generated (Figure 14).

5. CONCLUSIONS

In this research, susceptibility mapping of flood in Kaleybar Chay basin was studied. In previous studies, flood potential was assessed by taking just one factor (Hydrology, morphology etc.) but in this research for a high accuracy we tried to use a variety of factors. Also in assessing the potentials of flood the homogenous area is watershed area and basic studies are done in this level, This point was neglected in previous studies.

For comparing the results, the Analytic Network Process method was used; the final weight of each main variable and also sub categories were done. Analyzing the weights

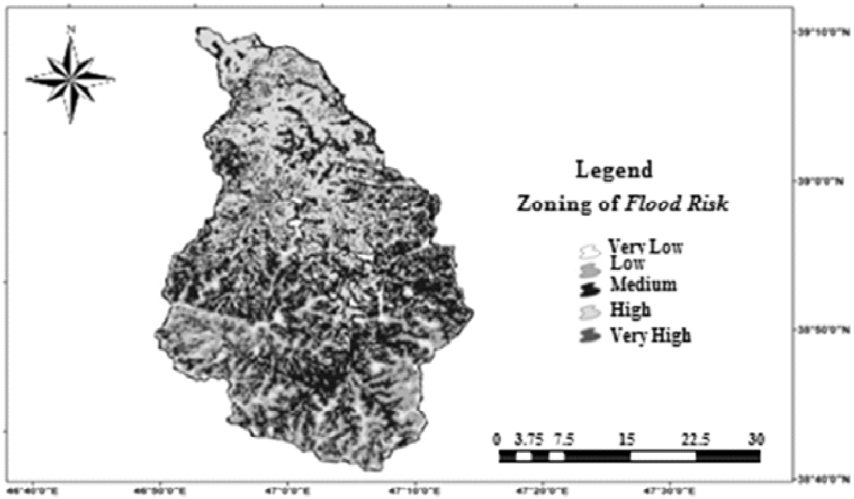

Figure 14: Susceptibility mapping of flood in Kaleybar Chay basin

shows that in relation to flooding danger, curve number factor, distance from stream, potential runoff producing and penetration volumes had the highest impact on controlling the flood in Kaleybar Chay basin, and this issue shows that the mentioned factors are effected by hydrological characteristics of the basin which this factor is effected by the geomorphologic factors of the basin. The results obtained from the present study showed that %73.20 of the basin included the medium ranking to high ranking from flooding point of view which showed the high potential of area for flooding. Through this research's results and by attention to the sever flood damage in southern parts of the Iran in 2017, future research will be based on using the fuzzy operators for reaching to high accuracy in susceptibility mapping of flood in the watersheds of southern and western areas of Iran. Due to the fact that in this research it has been tried to assess the important factors effecting the flood according to the literature review and experts ideas, therefore the overall framework of study can be used in another studies but taking to the account the features of study area, number of factors can be ignored or lesser degree of importance can be implied to them .therefore Based on the accessed results of this study, it is suggested that researchers use the images with higher spatial resolution and also more layers for reaching to high accuracy in exploring the flooding in other areas. The results of the present study will be applicable for executive organizations (East Azerbaijan Agriculture Organization, Natural Resources Office of Kaleybar and …) for planning and managing the water and soil sources and decreasing the damages resulted from flood.

References

[1] Affeletranger, B. (2001). Public participation in the design of local strategies for flood mitigation and control, International Hydrological Programme, Technical Documents in Hydrology, No. 48, UNESCO, Paris.

[2] Barkhordar, M. and Chavoshian, S.A., (2011). Flood zoning. Publisher: IR pdf - Civil Engineering, pp. 1-19.

[3] Brito, M.M., and Evers, M., (2016). Multi-criteria decision-making for flood risk management: a survey of the current state of the art. Nat. Hazards Earth Syst. Sci., No. 16, pp. 1019–1033. doi:10.5194/nhess-16-1019-2016.

[4] Buchele, B., Kreibich, H., Kron, A., Thieken, A., Ihringer A, Oberle P, Merz B, Nestmann F., (2006). Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks. Nat Hazard Earth Syst. Vol. 6., pp. 485-503.

[5] Dang, N. Mukand, M., Babel, S. H and T. Luong., (2011). Evaluation of flood risk parameters in the Day River Flood Diversion Area, Red River Delta, Vietnam. Nat Hazards., No. 56, pp.169–194, doi: 10.1007/s11069-010-9558-x.

[6] Dawod, G.M., Mirza, M.N and Al-Ghamdi, K.A., (2012). GIS-based estimation of flood hazard impacts on road network in Makkah city, Saudi Arabia. Environ Earth Sci. Vol. 67, pp. 2205-2215.

[7] Fernandez, P., Mourato, S and Moreira, M., (2016). Social vulnerability assessment of flood risk using GIS-based multicriteria decision analysis. A case study of Vila Nova de Gaia (Portugal). Geomatics, Natural Hazards and Risk. Vol. 7, doi: http://dx.doi.org/10.1080/19475705.2015.1052021.

[8] Garde, R. J., (2006). River Morphology, Published by New Age International (P) Ltd., Publishers, New Delhi, India.

[9] Heidari, A,. (2014). Flood vulnerability of the Karun river system and short-term mitigation measures. Flood Risk Manag. Vol. 7, pp. 65-80.

[10] Huali, Ch., Yuka, I., Marie, S and Tomochika, T., (2015). Flood hazard assessment in the Kujukuri Plain of Chiba Prefecture, Japan, based on GIS and multicriteria decision analysis. Natural Hazards,Vol. 78, pp. 105–120. doi: 10.1007/s11069-015-1699-5.

[11] International Plant Protection Convention Report (2007). Contribution of Working Group II (WGII): Climate Change 2007: Impacts, Adaptation and Vulnerability.

[12] Kheirizade, A. M., Maleki, J and Amoonia, H., (2013). Zoning the torrent danger potential in watershed scope of Mardagh Chaii by using the ANP model. The Quantitative Geomorphological Researchs. No. 3, pp. 39-56.

[13] Khosravi, Kh., Nohani, E., Maroufinia, E and Pourghasemi, H. R., (2016). A GIS-based flood susceptibility assessment and its mapping in Iran: a comparison between frequency ratio and weights-of-evidence bivariate statistical models with multi-criteria decision-making technique. Natural Hazards. Vol. 83, pp. 947–987, doi. 10.1007/s11069-016-2357-2.

[14] Lewis, M. A., Cheney, C. S and Dochartaigh, B., (2006). Guide to Permeability Indices. Information Products Programme Open Report CR/06/160 N. Licence No.100017897/2007, pp. 1-20.

[15] Marchand, M., Buurman, J., Pribadi, A and Kurniawan A., (2009). Damage and casualties modelling as part of a vulnerability assessment for tsunami hazards: a case study from Aceh, Indonesia. Flood Risk Manag. No. 2, pp.120-131.

[16] Mateo, J. R., (2012). Multi Criteria Analysis in the Renewable Energy Industry, Springer London, London, pp. 105, doi:10.1007/978-1-4471-2346-0.

[17] Najmaei, M., (2008). Engineering hydrology, 2nd Volume, 2nd Pub., Science and Industry of Iran University, Tehran, Iran.

[18] Rahmati, O., Zeinivand,. H and Besharat, M., (2015). Flood hazard zoning in Yasooj region, Iran, using GIS and multi-criteria decision analysis. Geomatics, Natural Hazards and Risk. No. 3, pp. 1000-1017, doi: http//: dx.doi.org/10.1080/19475705.2015.1045043.

[19] Razavi, A., (2009). Principals of determining the water resources, first Pub. Water and Electricity University Pub., Tehran.

[20] Taylor, J., Davies, M., Clifton, D., Ridley, I., Biddulph P., (2011). Flood management: prediction of microbial contamination in largescale floods in urban environments. Environ Int. No. 37, pp. 1019-1029.

[21] Tehrany, M.S., Lee, M.J., Pradhan, B., Jebur, M.N and Lee, S., (2014). Flood susceptibility mapping using integrated bivariate and multivariate statistical models. Environ Earth Sci. No. 72, pp. 4001-4015.

[22] Vahidniaa, M.H., Alesheikh, A., Alimohammadi, A and Bassirid A., (2008). Fuzzy analytical hierarchy process in GIS application. The international archives of the photogrammetry. Remote Sens Spatial Inform Sci. Vol. 37, pp: 593-596.

[23] Yan, H. Bin, Huynh, V. N., and Nakamori, Y., (2011). A probabilistic model for linguistic multi-expert decision making involving semantic overlapping, Expert Syst. Appl., 38, pp. 8901–8912, doi:10.1016/j.eswa.2011.01.105.

[24] Yang, X. l., Ding, J.h., and Hui, H,. (2013). Application of a triangular fuzzy AHP approach for flood risk evaluation and response measures analysis. Natural hazards Vol. 68, No. 2, pp. 657-674.

[25] Zahedi, M. and Baiati Khatibi, M., (2009). Hydrology, 1ST Pub., Samt Pub. Tehran, Iran.

[26] Zhan, X. and Huang, M. L., (2004). ArcCN- Runoff: an ArcGIS Tool for Generating Curve Number and Runoff Maps, Environmental Modeling and Software, Vol. 19, No. 10, pp. 875–879.

[27] Zagonari, F. and Rossi, C., (2013). A heterogeneous multi-criteria multiexpert decision-support system for scoring combinations of flood mitigation and recovery options, Environ. Model. Softw., 49, pp. 152–165, doi:10.1016/j.envsoft.2013.08.004.

[28] Zebardasr, E., (2010). Application of ANP In urban and regional planning. Journal of Fine Arts, Architecture, No. 41, pp. 90-79.

[29] Ostad-Ali-Askari, K., Shayannejad, M. 2015, Study of sensitivity of Autumnal wheat to under irrigation in Shahrekord, Shahrekord City, Iran. International Journal of Agriculture and Crop Sciences, 8 (4), 602-605.

[30] Shayannejad, M., Akbari, N., Ostad-Ali-Askari, K. 2015, Study of modifications of the river physical specifications on muskingum coefficients, through employment of genetic algorithm. International Journal of Development Research, 5(3), 3782-3785.

[31] Ostad-Ali-Askari, K., Shayannejad, M. 2015, The Reviews of Einstein's Equation of Logarithmic Distribution Platform and the Process of Changes in the Speed Range of the Karkheh River, Khuzestan province, Iran. International Journal of Development Research, 5(3), 3786-3790.

[32] Ostad-Ali-Askari, K., Shayannejad, M., Ghorbanizadee-Kharazi, H. 2015, Assessment of artificial neural network performance and exponential regression in prediction of effective rainfall, International Journal of Development Research, 5(3),3791-3794.

[33] Shayannejad, M. Akbari, N. and Ostad-Ali-Askari, K. 2015, Determination of the nonlinear Muskingum model coefficients using genetic algorithm and numerical solution of the continuity. Int. J. of Science: Basic and Applied Research, 21(1), 1-14.

[34] Ostad-Ali-Askari, K., Shayannejad, M. 2015, The Study of Mixture Design for Foam Bitumen and the Polymeric and Oil Materials Function in Loose Soils Consolidation. Journal of Civil Engineering Research, 5(2), 39-44. DOI: 10.5923/j.jce.20150502.04

[35] Sayedipour, M., Ostad-Ali-Askari, K., Shayannejad, M. 2015, Recovery of Run off of the Sewage Refinery, a Factor for Balancing the Isfahan-Borkhar Plain Water Table in Drought Crisis Situation

in Isfahan Province-Iran. American Journal of Environmental Engineering, 5(2): 43-46. DOI: 10.5923/j.ajee.20150502.02.

[36] Ostad-Ali-Askari, K., Shayannejad, M. 2015, Developing an Optimal Design Model of Furrow Irrigation Based on the Minimum Cost and Maximum Irrigation Efficiency. International Bulletin of Water Resources & Development, 3(2), 18-23.

[37] Ostad-Ali-Askari, K., Shayannejad, M. 2015, Presenting a Mathematical Model for Estimating the Deep Percolation Due to Irrigation. International Journal of Hydraulic Engineering, 4(1), 17-21. DOI: 10.5923/j.ijhe.20150401.03.

[38] Ostad-Ali-Askari, K., Shayannejad, M. 2015, Usage of rockfill dams in the HEC-RAS software for the purpose of controlling floods. American Journal of Fluid Dynamics, 5(1), 23-29. DOI: 10.5923/j.ajfd.20150501.03.

[39] Ostad-Ali- Askari, K., Shayannejad, M. 2015, The effect of heterogeneity due to inappropriate tillage on water advance and recession in furrow irrigation. Journal of Agricultural Science, 7(6), 127-136.

[40] Shayannejad, M., Ostad-Ali-Askari, K. 2015, Effects of magnetized municipal effluent on some chemical properties of soil in furrow irrigation. International Journal of Agriculture and Crop Sciences, 8(3), 482-489.

[41] Ostad-Ali-Askari, K., Shayannejad, M. 2015, Optimal design of pressurized irrigation laterals installed on sloping land. International Journal of Agriculture and Crop Sciences, ISSN 2227-670X. 8(5), 792-797.

[42] Ostad-Ali-Askari K, Shayannejad M, Eslamian S, Navab-Pour B. 2016, Comparison of solution of Saint-Venant equations by characteristics and finite difference methods for unsteady flow analyzing in open channel. International Journal of Hydrology Science and Technology, 6(3), 9-18.

[43] Ostad-Ali-Askari K, Shayannejad M, Eslamian S, et al. 2017, Deficit Irrigation: Optimization Models. Management of Drought and Water Scarcity. Handbook of Drought and Water Scarcity, Taylor & Francis Publisher, USA. Vol. 3. 1th Edition, pp: 373-389.

[44] Eskandari S, Hoodaji M, Tahmourespour A, Abdollahi A, Mohammadian-Baghi T, Eslamian S, Ostad-Ali-Askari K. 2017, Bioremediation of Polycyclic Aromatic Hydrocarbons by Bacillus Licheniformis ATHE9 and Bacillus Mojavensis ATHE13 as Newly Strains Isolated from Oil-Contaminated Soil. Journal of Geography, Environment and Earth Science International, 11(2): 1-11.

[45] Shayannejad M, Ostad-Ali-Askari K, Eslamian S, et al. 2017, Development of a new method for determination of infiltration coefficients in furrow irrigation with natural non-uniformity of slope. Sustain. Water Resour. Manag., 3(2): 163-169.

[46] Shafaei-Bejestan M, Eslamian S, Marani-Barzani M, P. Singh V, Kazemi M, Ostad-Ali-Askari K. 2017, Assessment of Drainage Slope on the Manning Coarseness Coefficient in Mountain Area. International Journal of Constructive Research in Civil Engineering (IJCRCE), 3(1): 33-40.

[47] Bahmanpour H, Awhadi S, Enjili J, Eslamian S, Ostad-Ali-Askari K. 2017, Optimizing Absorbent Bentonite and Evaluation of Contaminants Removal from Petrochemical Industries Wastewater. International Journal of Constructive Research in Civil Engineering (IJCRCE), 3(2): 34-42.

[48] Shayannejad M, Eslamian S, Gandomkar A, Marani-Barzani M, Amoushahi-Khouzani M, Majidifar Z, Rajaei-Rizi F, Kazemi M, P. Singh V, Dehghan SH, Shirvani-Dastgerdi H.R, Norouzi H, Ostad-Ali-Askari K. 2017, A Proper Way to Install Trapezoidal Flumes for Measurements in Furrow Irrigation Systems. International Journal of Research Studies in Agricultural Sciences (IJRSAS), 3(7): 1-5.

[49] Dehghan Sh, Kamaneh S.A.A., Eslamian S, Gandomkar A, Marani-Barzani M, Amoushahi-Khouzani M, Singh V.P., Ostad-Ali-Askari K. 2017, Changes in Temperature and Precipitation with the Analysis of Geomorphic Basin Chaos in Shiraz, Iran. International Journal of Constructive Research in Civil Engineering (IJCRCE), 3(2): 50-57.

[50] Ostad-Ali-Askari K, Shayannejad M. 2016, Flood Routing in Rivers By Muskingum's Method With New Adjusted Coefficients. International Water Technology Journal, IWTJ, 6(3): 189-194.

[51] Ostad-Ali-Askari K, Shayannejad M, Ghorbanizadeh-Kharazi H. 2017, Artificial Neural Network for Modeling Nitrate Pollution of Groundwater in Marginal Area of Zayandeh-rood River, Isfahan, Iran. KSCE Journal of Civil Engineering, 21(1):134-140. Korean Society of Civil Engineers. DOI 10.1007/s12205-016-0572-8.

[52] Soltani-Toudeshki A.R, Shayannejad M, Ostad-Ali-Askari K, Ramesh A, Singh V.P., Eslamian S. 2017, Wastewater and Magnetized Wastewater Effects on Soil Erosion in Furrow Irrigation. International Journal of Research Studies in Agricultural Sciences (IJRSAS), 3(8): 1-14. http://dx.doi.org/10.20431/2454-6224.0308001.

[53] Eslamian, S. S. and S. Soltani, 2002, Flood Frequency Analysis, Arkan Publishing, Isfahan, Iran, 332 p.

[54] Eslamian, S. S., 1995, Regional Flood Frequency Analysis Using a New Region of Influence Approach, Ph.D. Thesis, Univ. of New South Wales, School of Civil Engineering, Dept. of Water Engineering, Sydney, NSW, Australia, 1995, Supervised by: Professor David H. Pilgrim, 380 P.

[55] KaBu|a, T. and Eslamian, S. 2014, Impact of the Development of Vegetation on Flow Conditions and Flood Hazards, in Handbook of Engineering Hydrology, Ch. 21, Vol. 2: Modeling, Climate Changes and Variability, Ed. By Eslamian, S., Francis and Taylor, CRC Group, USA, 415-449.

[56] Rahman, A., Haddad, Kh. and Eslamian, S. , 2014, Regional Flood Frequency Analysis, 2014, in Handbook of Engineering Hydrology, Ch. 22, Vol. 2: Modeling, Climate Changes and Variability, Ed. By Eslamian, S., Francis and Taylor, CRC Group, USA, 451-469.

[57] Deiminiat, A., and Eslamian, S., 2014, River Managed System for Flood Defense, in Handbook of Engineering Hydrology, Ch. 14, Vol. 3: Environmental Hydrology and Water Management, Ed. By Eslamian, S., Francis and Taylor, CRC Group, USA, 299-314.

[58] Dalezios, N. R. and Eslamian, S, 2016, Regional design storm of Greece within the flood risk management framework, Int. J. Hydrology Science and Technology, Vol. 6, No. 1, 82–102.

[59] Talchabhadel , R., Shakya, N. M. Dahal , V., and Eslamian, S., 2015, Rainfall Runoff Modelling for Flood Forecasting (A Case Study on West Rapti Watershed), Journal of Flood Engineering, Vol. 6, No. 1, 53-61.

[60] Yousefi, N., Safaee, A., Eslamian, S., 2015, The Optimum Design of Flood Control System Using Multivariate Decision Making Methods (Case Study: Kan River Catchment Basin, Iran), Journal of Flood Engineering, Vol. 6, No. 1, 63-82.

[61] Galoie, M., Eslamian, S., and A. Motamedi, 2014, An Investigation of the Influence of a Retention Dam on Flood Control In a Small Catchment Area in Austria, Journal of Flood Engineering, Vol. 5, No. 1/2, 1–15.

[62] Deiminiat, A. and S. Eslamian, 2014, A Telemetry And Tele Control System For Local Flood Warning, A Case Study, Journal of Flood Engineering, Vol. 5, No. 1/2, 87–100.

[63] Ajigoh, E. and Eslamian, S., 2013, Nyando catchment GIS modeling of flood in undated areas, Journal of Flood Engineering, Vol. 4, No. (1-2), 77–86.

[64] Galoie, M., Zenz, G. and Eslamian, S., 2013, Determining the high flood risk regions using a rainfall-runoff modeling in a small basin in catchment area in Austria, Journal of Flood Engineering, Vol. 4, No. (1-2), 9–27.

[65] Bazrkar, M. H., Fathian, F., and Eslamian, S., 2013, Runoff modeling in order to investigate the most effective factors in flood events using system dynamic approach (Case study: Tehran Watershed, Iran), Journal of Flood Engineering, Vol. 4, No. 1-2, 39–59.

[66] Alaghmand, S., Bin Abdullah, R., Abustan, I. and S. Eslamian, 2012, Comparison between capabilities of HEC-RAS and MIKE11 hydraulic models in river flood risk modeling (a case study of Sungai Kayu Ara River basin, Malaysia), International Journal of Environmental Science and Technology, Vol. 2, No. 3, 270-291.

[67] Galoie, M., Zenz, G., S. Eslamian and A. Motamedi., 2012, Numerical simulation of flood due to dam-break flow using an implicit method, International Journal of Environmental Science and Technology, Vol. 2, No. 2, 117-137.

[68] Gholami. A., Mahdavi, M. and S. Eslamian, 2012, Probability Distribution Choices for Minimum, Mean and Maximum Discharges, by L-Moments in Mazandaran Province, IRAN, Journal of Flood Engineering, Vol. 3, No. 1, 83-92.

[69] Alipour, M. H., Shamsai, A., Eslamian, S. S. and R. Ghasemizadeh, 2011, A new fuzzy technique to find the optimal solution in flood management, Journal of Flood Engineering, Vol. 2, No. 1, 1-9.

[70] Ghasemizade, M., Mohammadi K., and S. S. Eslamian, 2011, Estimation of design flood hydrograph for an ungauged watershed, Journal of Flood Engineering, Vol. 2, No. 1/2, 27-36.

[71] Dhital, Y. P., Kayastha, R. B. and S. S. Eslamian, 2011, Precipitation and discharge pattern analysis: a case study of Bagmati River basin, Nepal, Journal of Flood Engineering, Vol. 2, No. 1, 49-60.

[72] Eslamian, S. S., 2010, The Physically-Statistically Based Region of Influence Approach For Flood Regionalization, Journal of Flood Engineering, Vol. 1, No. 2, 149-158.

[73] Eslamian, S. S., 2010, Flood Regionalization Using a Modified Region of Influence Approach, Journal of Flood Engineering, Vol. 1, No. 1, 51-66.

[74] Eslamian, S. S., 2010, Flood Regionalization Using a Modified Region of Influence Approach, Journal of Flood Engineering, Vol. 1, No. 1, 51-66.

[75] Ghazavi, R., Vali, A. B. and S. S. Eslamian, 2010, Impact of flood spreading on infiltration rate and soil properties in an arid environment, Water Resources Management, Vol. 24, No. 11, 2781-2793.