ORIGINAL PAPER

Flood risk zoning based on the hydro-climatic characteristics of basins in Hamedan Province, Iran

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Date of submission: 13 Nov 2018, ***Date of acceptance:*** 29 Apr 2020

ABSTRACT

Recently, floods have become a severe environmental issue in the Iran due to climate change. Several studies have indicated that ensemble flood forecasting based on numerical weather predictions could provide an early warning with extended lead time. The floods during 1992-2013 showed that Hamedan Province is a high-risk area in Iran due to various causes, such as the harvesting and uncovering of farms, high intensity of precipitation, land and soil quality, and land slope. The present study aimed to identify the infleuntial factors in flood based on their scoring in terms of the influence intensity in recognized flooded areas. According to the results, the north (Kabudar Ahang), northeast (Razan), and south and southwest of the studied area (Nahavand) were high-risk regions in Hamedan Province. In addition, the causes of floods varied in different regions of the province, and Hamadan province is flooded in different areas due to various causes.

Keywords: Flood, Hydro-climatic properties, Basin, Zoning, Hamedan

Introduction

Flood is an exceptionally extreme water flow from natural river beds.[1] Flooding affects an average of 520 million people each year and is a deadly natural phenomenon, which occurs frequently.[1-4] Flood warning is an efficient approach for the reduction of flood damage. However, numerous flood forecasting systems in the world rely on the observed rainfall, and the lead time of these systems is often short for small basins.[5, 6]

The investigations in Iran have indicated that in the 1950s, 3,700 flood cases occurred.[7] Furthermore, studies have shown that over 80% of the cities in Iran are at the risk of flooding.[8] In the snowy-rainy regimes that are affected by continental climate, the maximum flow occurs in spring when snow melts rapidly, often leading to severe flooding.[6] Hamadan Province is located in the west of Iran, and the climate is associated with substantial snow fall; therefore, maximum flows are expected to occur in the region in spring. However, there is a historical peak flood flow in this area, which occurs in autumn, indicating that in addition to melting snow and rainfall regimes, other factors also contribute to flooding in this province.

According to the recent study of the European Environment Agency, annual flood losses are expected to increase fivefold by 2050 and up to 17-fold by 2080.[9, 10] Several studies have been conducted in this regard; for instance, Stephen has assessed the zoning of Ylstun river floods in Montana (USA).[11] In addition, Tate and Maidment have examined river zoning using the HEC-RAS model and ArcView GIS,[12] while Quinn *et al.*[13] and Melesse *et al*.[9] have investigated the modeling and mapping of the surface flows in catchment

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Citation: Maryanaji Z, Merrikhpour H, Vejdani Nozar A. Flood risk zoning based on the hydro-climatic characteristics of basins in Hamedan Province, Iran. J Adv Environ Health Res 2020; 8(2): 111-123

areas. On the other hand, Sahoo *et al*. have used artificial neural networks for the assessment of the river basins characterized by the mountainous region of Ohio (USA) to predict water quality parameters such as temperature, turbidity, and dissolved oxygen, as well as the sudden floods in the region.[14]

In another study, Kerh and Lee estimated the flood discharge in the downstream of the Coping River basin in Taiwan using artificial neural networks.[15] The results of the mentioned study indicated the significant effects of soil physiographic properties on the forecast accuracy of the upstream flood rate, recommending the method for the prediction of the flood discharge in the basin without the use of statistical data. Furthermore, Dawson *et al.* conducted a study in Ireland catchment to estimate the flood discharge and index flood of various return periods of 10, 20, and 30 years.[16]

In the past decade, basin flood zoning capabilities have been evaluated by Jalilvahabi,[17] Mosavi,[18] Motiei *et al*.[19] in Iran. The study by Ghanavati aimed to identify the effects of physiographic and hydro-geomorphologic factors on the risk of flooding in Gamasyab basin analyzed 12 geomorphologic and physiographic variables using the regression multivariate analysis.[20] In another research, Yamani and Enayati assessed the flood hazard zonation of Behjatabad (Ghazvin) and Fashand (Tehran) based on geomorphologic watersheds using weighting methods in the geographic information system (GIS).[21] The results of the mentioned study suggested that the basins with steep and lower compactness coefficient had higher flooding coefficient.

The hydrological models that are suitable for implementation in the automated mode should be[22] easily, rapidly, and efficiently calibrated and recalibrated if necessary, inexpensive in terms of the computational/ processor resources,[23] forced by commonly available data (e.g., precipitation and evaporation/evapotranspiration), and sufficiently reliable even when forced by unsuitable data.

Rarely, hydro-meteorological forecasts are correlated with quantitative potential impact estimates (e.g., economic losses and involved population) since hydro-meteorological forecasts are generally devoted to the prediction of possible flood magnitudes.[24, 25] Numerous studies have been focused on flood forecasting in various regions in Hamadan Province, while no integrated studies have been conducted in this regard to date. In a research, Maryanji and Maroofi examined the basin flood capability of Gharechay Basin based on the catchment runoff, and the findings indicated the significant correlation between the digital model map and flow depth, so that with movement from the highlands to the lowland basin, the region with lower runoff depth would increase.[26]

The present study aimed to investigate flood hazard using a flood forecasting model based on the basin runoff coefficient variables, gravelius coefficient, average height, vegetative, slope, and basin area, and river basin throughout Hamadan Province.

Materials and Methods

Studied area

Hamadan Province is located in the west of Iran and has long been at the risk of flooding due to the factors related to the region, climate, and weather. The precipitation distribution of this area is erratic, and the 24 h maximum precipitation occurs between the 20th of March and 20th of April. The large amount of rainfall increases the probability of perilous flood in the province. The area has snowy winters, and the snow melting time is simultaneous with the high rains in spring when the flooding of rivers increases. In the other months of year, floods occur due to land harvesting and uncovering.

Hamadan Province has an area of 19,546 km^2 and is located in an elevated region, with Alvand Mountains running from the northwest to the southwest as part of Zagros Mountain Range in Iran. The geographical coordinates are 33°33´-35°38´ north latitude and 47°45´-49°36´ east longitude (Fig. 1). The central basin (Gharechay River), which is considered to be the largest basin in Hamadan Province, is located in Markazi and Hamadan provinces. In addition, the Gamasyab Basin is located in the south of the province and is the second main area. In the present study, the intensity of floods in the mentioned basins has been discussed.

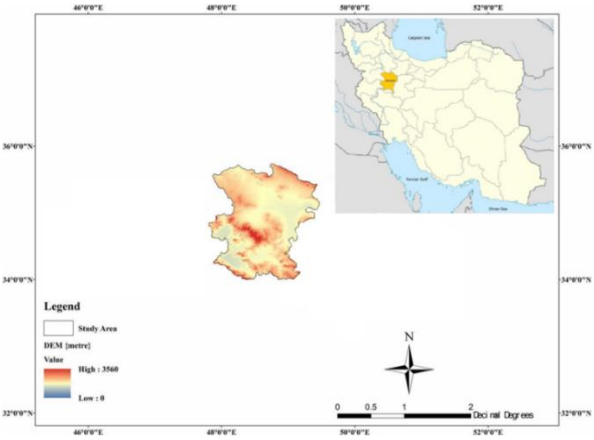

Fig. 1. The geographical location of Hamadan Province

Research methodology

The influential factors in the flooding intensity of the Gharechay and Gamasyab basins were evaluated. Each parameter was scored within the range of 1-4 (1 and 4 showing the least and most important factors, respectively). The numerical value of each parameter was multiplied by a coefficient, which depended on the involvement of these parameters in flooding. Finally, the obtained values for the parameters were added to each hydrologic unit to determine the flood intensity of the unit.[27]

The variography technique (calculation of variogram/semi-variogram) could be used to measure the spatial variability and dependency of a regionalized variable. Variography provides the input parameters for the spatial interpolation of Kriging.[28] The variogram function is expressed, as Eq. 1:

$$\gamma(h) = \frac{1}{2N\,(h)} \sum_{i=1}^{N(h)} [Z\,(x_i) - Z\,(x_i + h)] \qquad (1)$$

where, $\gamma(h)$ is the semivariance (variogram), $Z(x_i)$ shows the value of the variable Z at the location of x_i, and $N(h)$ represents the number of the pairs of the sample points as separated by the lag distance of h.

In order to evaluate the possible anisotropic spatial variability, the surface variogram was calculated based on the symmetrical property of the variogram function for all the variables.[28] The variogram plots (experimental variograms) were also obtained by calculating the variogram at various lags. Spherical, exponential, and Gaussian models were selected in order to model the experimental variograms and obtain the data regarding the spatial structure, as well as the input parameters for the Kriging estimation. The data collected by the variography step were used to calculate the sample weighting factors for spatial interpolation through an ordinary block Kriging procedure.

In this study, the basins were assessed independently and only compared based on their physical characteristics and precipitation regime. The flooding intensity of the studied basins was determined based on six influential factors in floods, including the precipitation depth and time, accumulated snow depth, basin slope and shape, type of land and vegetation, and quantitative values. Since the examined factors did not have similar effects on the increasing or decreasing of the runoff in the basins, the weight of these factors was considered independent in order of importance, so that the results regarding the flooding intensity would be comparable as hydrological units.

A set of goodness of fit tests (e.g., Kolmogorov-Smirnov test and Chi-square) were used in order to determine the degree of fitness of the probability distribution models with the observed data.[29] If the fit was acceptable, the distribution would be selected for further analyses. In addition, the acceptable distributions were ranked based on the two statistics of the mean relative deviation (MRD) and mean square relative deviation (MSRD), which are explained in Eqs. 2 and 3. The distribution with the smallest MRD and MSRD was considered to have the best fit on the observed data.[29]

$$MRD = \frac{\sum_{i=1}^{n}|X_i - \acute{X}_i|}{(N-m)} \quad (2)$$

$$MSRD = \frac{\sum_{i=1}^{n}(X_i - \acute{X}_i)^2}{(N-m)} \quad (3)$$

where, x_i represents the *ith* observed data, denoting the estimated value of x_i, N shows the number of the data, and m denotes the number of the distribution parameters.[30]

After determining the flood hydrograph output in all the sub-basins, the considered factors in each sub-basin varied to assess the impact of the factor on the peak output flow.

Results and Discussion

Maximum 24 h precipitation and precipitation isotherms

The variations of the maximum 24 h precipitation were investigated at different periods in different years in order to be converted into a common time base. Following that, the incomplete statistics were completed. The present study was focused on a 22-year period (1992-2013). After the reconstruction and completion of the station data to estimate the maximum 24 h precipitation in the selected stations, the maximum annual 24 h precipitation stations during the study period were extracted initially. Afterwards, variable statistical distributions were fitted to the data using graphical and statistical software (GIS and SPSS). Based on the MRD, MSRD, and three-parameter log-normal distribution with the maximum likelihood parameter estimation, the most appropriate statistical distribution was diagnosed based on the maximum 24 h precipitation.

According to the evaluation of the maximum 24 h precipitation in Hamadan Province meteorological stations, most of the maximum 24 h precipitations had the maximum frequency in March and April. The available data of Ekbatan and Nahavand stations also indicated that the maximum 24 h precipitation frequencies were in March. In Nojeh station, the maximum 24 h precipitation frequency was observed in March and April, while the maximum 24 h precipitation of Dargazin station was in March. Evidently, the mean maximum 24 h precipitations in these stations had the highest frequency in March and April. However, the maximum cumulative mean maximum 24 h precipitations in these two months was observed in Dargazin station (44.12 mm), while the minimum cumulative mean maximum 24 h precipitation was observed in Ekbatan station (30.97 mm).

Regarding the range of the variations in the cumulative mean maximum 24 h precipitation between February 20th and April 20th in Hamedan Province, the classification was as follows: 1) < 32 mm, 2) 32 - 37 mm, 3) 37-42 mm, and 4) > 42 mm. Table 1 shows the cumulative mean maximum 24 h precipitation between February 20th and April 20th (mm) in Gamasyab and Gharechay sub-basins, and the zoning is shown in Fig. 2.

Classification of the effects of snow repletion

Due to the lack of snow measurement systems for the sub-basins, the amount of snow was estimated based on the data on temperature and precipitation during 22-year period. In this period, the study was performed based on the environment temperature during precipitation. In addition, the daily mean temperature was assumed to be zero during precipitation. In such case, precipitation cumulated in the form of snow. Notably, when the mean minimum day temperature was zero, it would be expected that snow melted quicker and would not accumulate. Based on the mentioned data and monthly precipitation, the effects of snow repletion were classified. Regarding the variation range of the total precipitation in the form of snow (mm) during October 20-February 20 in the hydrologic units, scoring was performed, as follows: 1) <45 mm, 2) 45-60 mm, 3) 60-75 mm, and 4) >75 mm. Eq. 4 was used to calculate the actual snow coefficient (P_a).[31]

$$P_a = \frac{W_s}{P} \quad (4)$$

where, W_s is the water resulting from the melted snow, and P shows the sum of precipitation per month (mm).

Eq. 5 shows the calculation of the

Chandra snow coefficient, in which P_c is the snow coefficient, T_{max} shows the maximum mean temperature, T_{min} represents the mean minimum temperature (°C), and T_s is the coefficient expressing the specific temperature of snowfall. The range of the used coefficients was 1.66-2.2.[31]

$$P_c = 100\frac{(T_s - T_{min})}{(T_{max} - T_{min})} \quad (5)$$

In the present study, we attempted to assess the temperature range over the region temperature to determine the accuracy of the proposed method to obtain the optimal coefficient for Hamedan region. Table 2 shows the amount of snow in Gamasyab and Garechay sub-basins with the total coefficients, and the zoning is depicted in Fig. 3.

Table 1. Cumulative mean maximum 24 h precipitation of Gamasyab and Gharechay sub-basins

Main basin	Sub-basin	Amount of snow (mm)	Quantitative value	Applying affecting coefficient*
Gharechay	Simineh Rud in Koshk abad	81.82	4	8.8
	Abshineh in Yalfan	63.6	3	6.6
	Zehtaran	49.26	2	4.4
	Khamingah in road bridge	49.26	2	4.4
	Bhador beyg	63.6	3	6.6
	Saleh Abad	63.6	3	6.6
	Maryanaj	63.6	3	6.6
	Abbas Abad	63.6	3	6.6
	Alomjerd in Dareh Morad beyg	63.6	3	6.6
	Omar abad	49.26	2	4.4
Gamasyab	Ghamasyab in Sang Surakh	45.33	2	4.4
	Nahavand Dargusheh	45.33	2	4.4
	Ab Malayer in Vesej	32.16	1	2.2
	Ghel Ghel Rud in Firuzabad	45.33	2	4.4
	Khoram Rud in Aran	45.3	2	4.4
	Shahab in Aghajan Balaghi	63.6	3	6.6
	Gamasyab in Do Ab	45.3	2	4.4

*Effective coefficient of 24 h precipitation: 3

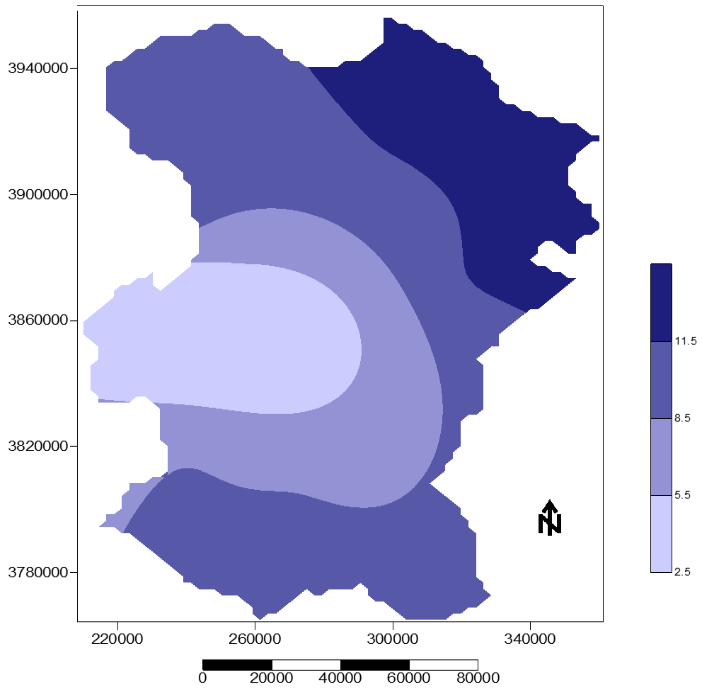

Fig. 2. Zoning mean maximum 24- hour precipitation of Gamasyab and Gharechay sub-basins

Table 2. Amount of snow in Gamasyab and Gharechay sub-basins with quantitative value

Main basin	Sub-basin	Cumulative of mean maximum 24 h precipitation	Quantitative value	Applying affecting coefficient*
Gharechay	Simineh Rud in Koshk abad	32.35	2	6
	Abshineh in Yalfan	30.97	1	3
	Zehtaran	44.12	4	12
	Khamingah in road bridge	44.12	4	12
	Bhador beyg	30.97	1	3
	Saleh Abad	30.97	1	3
	Maryanaj	30.97	1	3
	Abbas Abad	30.97	1	3
	Alomjerd in Dareh Morad beyg	30.97	1	3
	Omar abad	44.12	4	12
Gamasyab	Ghamasyab in Sang Surakh	40.9	3	9
	Nahavand Dargusheh	40.9	3	9
	Ab Malayer in Vesej	40.9	3	9
	Ghel Ghel Rud in Firuzabad	40.9	3	9
	Khoram Rud in Aran	40.9	3	9
	Shahab in Aghajan Balaghi	30.97	1	3
	Gamasyab in Do Ab	40.9	3	9

*Effective coefficient of snow: 2

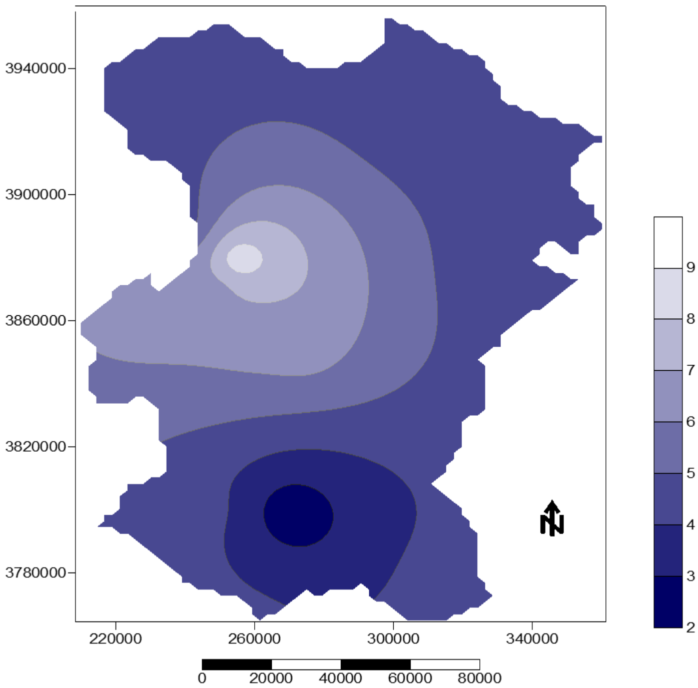

Fig. 3. Zoning of snow in Gamasyab and Gharechay sub-basins

Classification of the effects of watershed slope on flood

The effects of the sub-basin slope were classified based on the physiography studies performed by the Consultancy Engineering Company in Tehran (Iran). Regarding the mean slope of the basins (%), scoring was performed, as follows: 1) <6%, 2) 6-12%, 3) 12-18%, and 4) >18%. Table 3 shows the slope value in Gamasyab and Garechay sub-basins with the quantitative coefficients, and the zoning is depicted in Fig. 4.

Table 3. Slope of Gamasyab and Gharechay sub-basins with quantitative coefficients

Main basin	Sub-basin	Average watershed slop (%)	Quantitative value	Applying affecting coefficient*
Gharechay	Simineh Rud in Koshk abad	1.88	1	2
	Abshineh in Yalfan	6.20	2	4
	Zehtaran	2.92	1	2
	Khamingah in road bridge	3.10	1	2
	Bhador beyg	4.4	1	2
	Saleh Abad	7.91	1	4
	Maryanaj	14.6	3	6
	Abbas Abad	16.97	3	6
	Alomjerd in Dareh Morad beyg	15.50	3	6
	Omar abad	0.62	1	2
Gamasyab	Ghamasyab in Sang Surakh	19.92	4	8
	Nahavand Dargusheh	3.16	1	2
	Ab Malayer in Vesej	1.35	1	2
	Ghel Ghel Rud in Firuzabad	3.83	1	2
	Khoram Rud in Aran	2.06	1	2
	Shahab in Aghajan Balaghi	7.67	2	4
	Gamasyab in Do Ab	1.07	1	2

*Effective coefficient of basin slope: 2

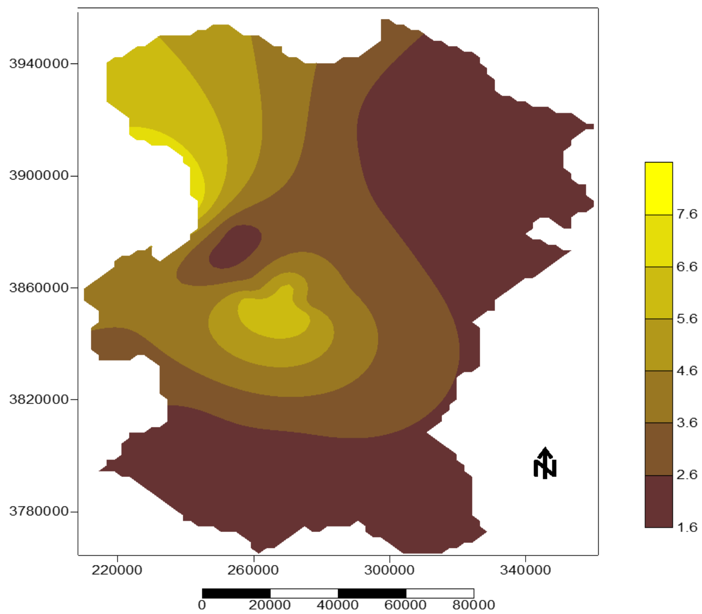

Fig. 4. Zoning of sub-basin slope in Gamasyab and Gharechay sub-basins

Classification of the effects of watershed shape on flood

In this study, the gravelius coefficient was used for the comparison of the effects of basin shape on flood. The coefficient was obtained based on the studies conducted by Consultancy Engineering Company. To evaluate the effects of the watershed shape on flood, the gravelius coefficient of the sub-basins was classified, as follows: 1) 1.7-2, 2) 1.5-1.7, 3) 1.2-1.5, and 4) 1-1.2. Table 4 shows the gravelius coefficients of Gamasyab and Gharechay sub-basins, and the zoning is depicted in Fig. 5.

According to the previous studies in this regard, the gravelius coefficient of Shahab sub-basin in Aghajan Balaghi is 1.14, which is most similar to the circle in Gamasyab watershed. Moreover, the gravelius coefficient of Amr Abad sub-watershed has been estimated at 1.95, which is the most similar sub-watershed to the rectangular shape.

Table 4. Gravelius coefficients of Gamasyab and Gharechay sub-basins

Main basin	Sub-basin	Gravelius coefficient	Quantitative value	Applying affecting coefficient*
Gharechay	Simineh Rud in Koshk abad	1.52	2	3
	Abshineh in Yalfan	1.30	3	4.5
	Zehtaran	1.29	3	4.5
	Khamingah in road bridge	1.44	3	4.5
	Bhador beyg	1.53	2	3
	Saleh Abad	1.23	3	4.5
	Maryanaj	1.29	3	4.5
	Abbas Abad	1.23	3	4.5
	Alomjerd in Dareh Morad beyg	1.28	3	4.5
	Omar abad	1.90	1	1.5
Gamasyab	Ghamasyab in Sang Surakh	1.16	4	6
	Nahavand Dargusheh	1.53	2	3
	Ab Malayer in Vesej	1.63	2	3
	Ghel Ghel Rud in Firuzabad	1.44	3	4.5
	Khoram Rud in Aran	1.53	2	3
	Shahab in Aghajan Balaghi	1.14	4	6
	Gamasyab in Do Ab	1.69	2	3

*Effective coefficient of gravelius coefficient: 1.5

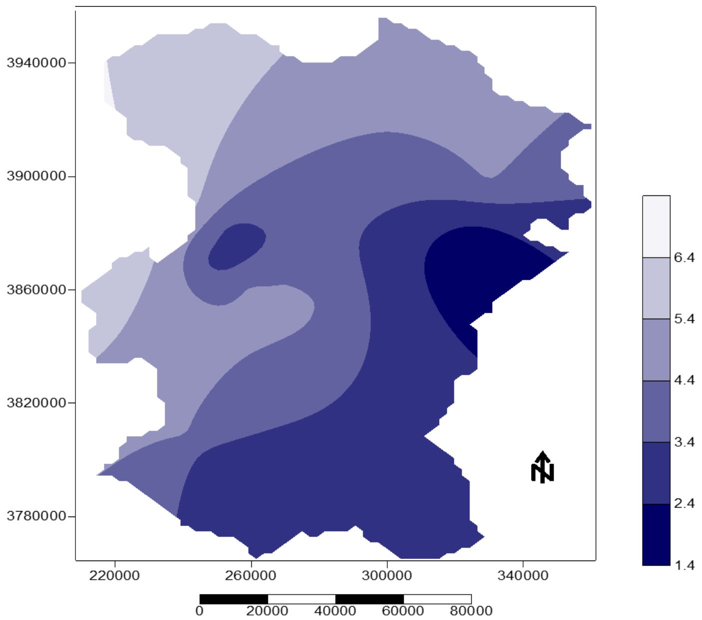

Fig. 5. Zoning of gravelius coefficients of Gamasyab and Gharechay sub-basins

Classification of the effects of soil quality on flood

The intensity and amount of water infiltration in soil has a significant impact on runoff formation. As such, the SCS curve number method was used in the present study to determine the runoff as an influential factor in runoff formation. To evaluate the effects of this parameter, the basin flood intensity was classified using the curve number method (A-D). In order to prepare the map of the potential areas with flood risk, the SCS method was used (Eqs. 6 and 7):

$$S = \frac{1000}{CN} - 10 \quad (6)$$

$$R = \frac{(P - 0.25)^2}{P + 0.8S} \quad (7)$$

In the equations above, R, P, S, and CN were the height of the runoff (mm), rainfall height in each period (mm), retention ratio of the surface area (mm), and curve number, respectively. In this method, although the six-hour precipitation was proposed, the 24-hour precipitation data could be used in the absence of the six-hour precipitation.[32] Furthermore, the use of the fixed coefficients to convert the daily precipitation into the six-hour precipitation for large areas such as Gharechay basin causes an error.

Due to the lack of precipitation graphs in all the stations in the present study, the 24-hour precipitation of the stations was assessed. In order to use the SCS method, the index map area or number of the characteristic curves was obtained. Based on the permeability of the soils, hydrologic soil groups and land use maps were prepared using Landsat satellite images (thematic mapper). Following that, the discontinuity between the land use map and soil hydrologic group was determined using the ArcView GIS software, and the curve number maps of the region were prepared.

To evaluate soil quality based on the infiltration rate (mm/h), the sub-basins were classified, as follows: 1) A: 7.5-11.5 mm/h, 2) B: 3.5-7.5 mm/h, 3) C: 1.5-3.5 mm/h, and 4) D: 0.5-1.5 mm/h. Table 5 shows the soil infiltration classification of Gamasyab and Gharechay sub-basins, and the zoning is depicted in Fig. 6.

Table 5. Soil infiltration classification of Gamasyab and Gharechay sub-basins based on SCS classification with quantitative coefficients

Main basin	Sub-basin	Soil class	Quantitative value	Applying affecting coefficient*
Gharechay	Simineh Rud in Koshk abad	C	3	5.1
	Abshineh in Yalfan	B	2	3.4
	Zehtaran	D	4	6.8
	Khamingah in road bridge	B	2	3.4
	Bhador beyg	B	2	3.4
	Saleh Abad	C	3	5.1
	Maryanaj	C	3	5.1
	Abbas Abad	B	2	3.4
	Alomjerd in Dareh Morad beyg	C	3	5.1
	Omar abad	C	3	5.1
Gamasyab	Ghamasyab in Sang Surakh	B	2	3.4
	Nahavand Dargusheh	D	4	6.8
	Ab Malayer in Vesej	B	2	3.4
	Ghel Ghel Rud in Firuzabad	C	3	5.1
	Khoram Rud in Aran	D	4	6.8
	Shahab in Aghajan Balaghi	C	3	5.1
	Gamasyab in Do Ab	B	2	3.4

*Effective coefficient of soil quality: 1.7

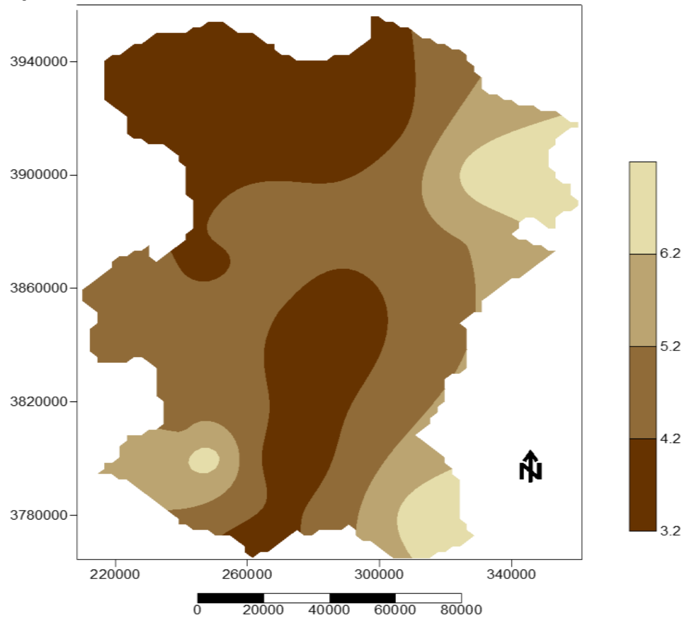

Fig. 6. Zoning of soil quality of Gamasyab and Gharechay sub-basins

Classification of the effects of vegetation on flood

In the current research, no condensing was observed on vegetation in Hamedan Province. To evaluate the vegetation quality, the sub-basins were classified as condense, semi-condense, semi-thinly scattered, and thinly scattered. The data on vegetation were extracted from the vegetation, pasture, and land use management maps of Hamedan Province. Table 6 shows the classification of the vegetation of Gamasyab and Gharechay sub-basins, and the zoning is depicted in Fig. 7.

Table 6. Vegetation classification of Gamasyab and Gharechay sub-basins with quantitative coefficients

Main basin	Sub-basin	Vegetation covering quality	Quantitative value	Applying affecting coefficient*
Gharechay	Simineh Rud in Koshk abad	Thinly scattered	4	8
	Abshineh in Yalfan	Semi-condence	2	4
	Zehtaran	Semi-thinly scattered	3	6
	Khamingah in road bridge	Semi-condence	2	4
	Bhador beyg	Semi-thinly scattered	3	6
	Saleh Abad	Semi-thinly scattered	3	6
	Maryanaj	Semi-condence	2	4
	Abbas Abad	Semi-condence	2	4
	Alomjerd in Dareh Morad beyg	Semi-condence	2	4
	Omar abad	Semi-thinly scattered	3	6
Gamasyab	Ghamasyab in Sang Surakh	Semi-condence	2	4
	Nahavand Dargusheh	Semi-thinly scattered	3	6
	Ab Malayer in Vesej	Semi-condence	2	4
	Ghel Ghel Rud in Firuzabad	Semi-thinly scattered	3	6
	Khoram Rud in Aran	Semi-thinly scattered	3	6
	Shahab in Aghajan Balaghi	Semi-condence	2	4
	Gamasyab in Do Ab	Semi-thinly scattered	3	6

*Effective vegetation quality coefficient: 2

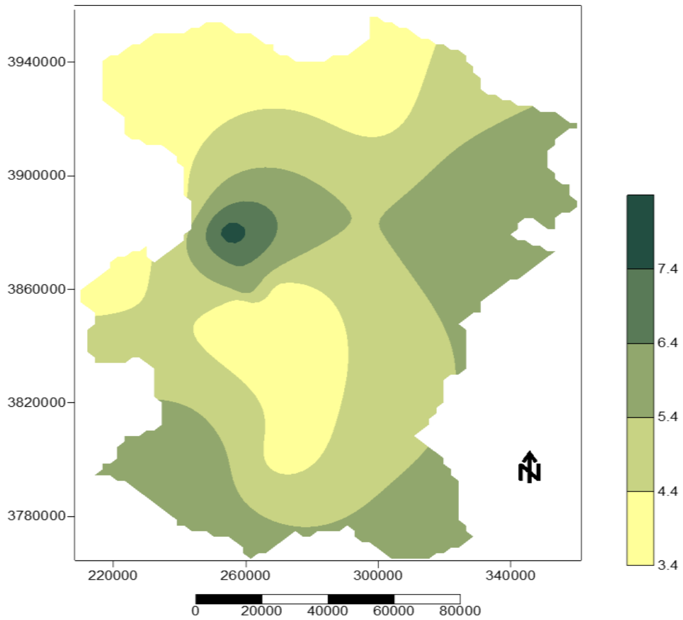

Fig. 7. Zoning of vegetation classification of Gamasyab and Gharechay sub-basins

Evaluation of the effective parameter coefficients in flood

In total, six parameters were considered in the present study, each of which was an independent coefficient.[27] The basin shape coefficient was 1.5, soil quality coefficient was

1.7, vegetation coefficient was 2, basin slope coefficient was 2, snow repletion coefficient was 2.2, and maximum 24-hour precipitation coefficient was 3. Therefore, the numerical value of the flood intensity of the sub-basins was calculated independently. In this calculation, the cumulative credits were determined based on the coefficient effects, and their sensitivity to flood was also compared. Table 7 shows the flood intensity of Gamasyab and Gharechay sub-basins, and the flood risk zoning is depicted in Fig. 8.

Table 7. Output of flood intensity of Gamasyab and Gharechay sub-basins

Main basin	Sub-basin	Maximum 24- hour precipitation between February 20th and April 20th (mm)	Amount of snow	Basin slope	Basin shape	Soil quality	Basin vegetation	Total
Gharechay	Simineh Rud in Koshk abad	6	8.8	2	3	5.1	8	32.9
	Abshineh in Yalfan	3	6.6	4	4.5	3.4	4	25.5
	Zehtaran	12	4.4	2	4.5	6.8	6	35.7
	Khamingah in road bridge	12	4.4	2	4.5	3.4	4	30.3
	Bhador beyg	3	6.6	2	3	3.4	6	24.0
	Saleh Abad	3	6.6	4	4.5	5.1	6	29.2
	Maryanaj	3	6.6	6	4.5	5.1	4	29.2
	Abbas Abad	3	6.6	6	4.5	3.4	4	27.5
	Alomjerd in Mareh Morad beyg	3	6.6	6	4.5	5.1	4	29.2
	Omar abad	12	4.4	2	1.5	5.1	6	31.0
Gamasyab	Ghamasyab in Sang Surakh	9	4.4	8	6	3.4	4	34.8
	Nahavand Dargusheh	9	4.4	2	3	6.8	6	31.2
	Ab Malayer in Vesej	9	2.2	2	3	3.4	4	23.6
	Ghel Ghel Rud in Firuzabad	9	4.4	2	4.5	5.1	6	31.0
	Khoram Rud in Aran	9	4.4	2	3	6.8	6	31.2
	Shahab in Aghajan Balaghi	3	6.6	4	6	5.1	4	28.7
	Gamasyab in Do Ab	9	4.4	2	3	3.4	6	27.8
Average in province		6.88	5.44	3.41	3.97	4.7	5.14	29.5

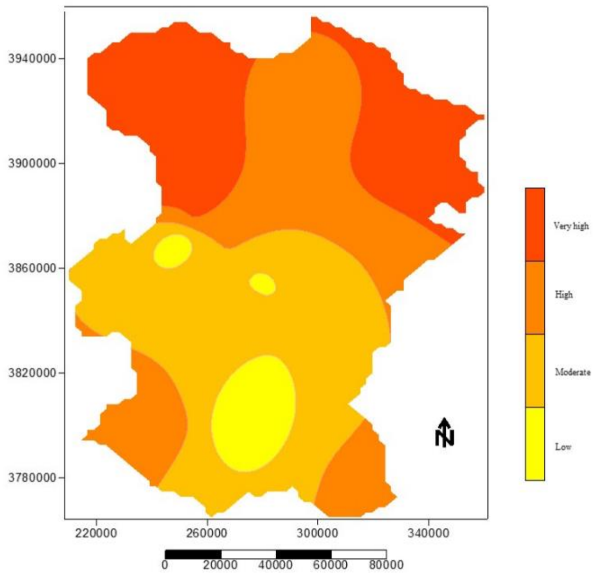

Fig. 8. Classification of flood intensity in Hamedan province

Conclusion

In this study, graphical software (GIS) and statistical software (SPSS) were used, and the combination of the graphical and statistical data of the geographical areas of Hamedan Province were distinguished in terms of flood characteristics, as follows:

1. The northern and northeastern plains (Kaboudrahang, Razan, and Ghahavand plains) were those with the highest predicted risk of flooding due to the concentration of winter precipitation in the

form of snow. Snow melting in spring and association with severe spring precipitation may lead to river flooding. In addition, the surroundings of the plain by mountains, as well as the slope and shape of the basins, exacerbate the risk of flooding.

2. The central and southern mountain regions (Alvand Highlands) were predicted to be at the medium risk of flooding. Although the rainfall in this area is snowy, the slope and topographic conditions may be associated with fewer destructive floods in this area compared to the northeastern regions. Due to the high altitude, the time of snow melting in this area does not coincide with the maximum daily and monthly rainfall occurring in mid-March continuing until early spring. Therefore, the snowmelt in these areas only leads to floods in the rivers in late May and early June.
3. Nahavand plain has several destructive flooding, the main cause of which is heavy and short-term rainfalls. Unlike the northeastern plains where hydrology is the main cause of flooding, the floods in this area are mostly meteorological. Furthermore, the proximity of this area to the main focal point of Zagros Mountain Range and Mediterranean Sea is the primary cause of this issue.

In general, the causes of floods vary in different regions of the province, and various areas of Hamedan Province may be flooded due to different causes.

References

1. James B, Rouhban B, Papa H, Tovmasyan K. Disaster preparedness and Mitigation. Paris, France: United Nations Educational, Scientific and Cultural Organization. 2007.
2. Henonin J, Russo B, Roqueta D S, Sanchez-Diezma R, Domingo Sto N, Thomsen F, *et al*. Urban flood real-time forecasting and modelling: A state-of-the-art review. MIKE by DHI conference, Copenhagen, Denmark, 2010, P028.
3. WMO & GWP. Flood Forecasting and Early Warning. World Meteorological Organization & Global Water Partnership, p. 19, 2013.
4. Pappenberger F, Cloke H L, Parker D J, Wetterhall F, Richardson D S, Thielen J. The monetary benefit of early flood warnings in Europe. Environ Sci Policy 2015; 51: 278–91.
5. Banihabib M E, Arabi A. The impact of catchment management on emergency management of flash-flood. Inter J Emerg Manag 2016; 12(2): 185-95.
6. Goodarzi L, Banihabib M E, Roozbahani A, Dietrich J. Bayesian network model for flood forecasting based on atmospheric ensemble forecasts. Nat Hazards Earth Syst Sci 2019; 19(11): 2513–24.
7. Khosroshahi M. An overview to identification and prioritization of flood prone areas using SSSE method in sub-watersheds (Case study: Shamsabad basin). Iran-Watershed Manag Sci Engin 2016; 10(33): 59-73. [In Persian]
8. Chitsaz N, Banihabib M E. Comparison of different multi criteria decision-making models in prioritizing flood management alternatives. Water Resour Manag 2015; 29(8): 2503-25.
9. Melesse A M, Graham W D, Jordan J D. Spatially distributed watershed mapping and modeling: GIS-Bassed strom runoff response and hydrograph analysis: Part 2. J Spatial Hydrol 2003; 3: 2-28.
10. European Environment Agency (EEA). Floodplain management: reducing flood risks and restoring healthy ecosystems. Available at https://www.eea.europa.eu/highlights/floodplain-management-reducing-flood-risks. 2016.
11. Slagle S E. Hydrology of area 49, Northern Great plains and Rocky Mountain coal province, Montana and Wyoming. U.S geological survey, Water-Resources investigations. Open file report. 1983: 82-682.
12. Tate E, Maidment D. Floodplain Mapping Using HEC-RAS and Arcview GIS. Center for Research in Water Resources (CRWR), 1999 Report No. 99-1, 223 pp.
13. Quinn P, Beven K, Chevallier P, Planchon O. The predection of hillslope flow paths for distributed hydrological modelling using digital terrain models. Hydol Process 1991; 5(1): 59-79.
14. Sahoo G B, Ray C, De Carlo E H. Use of neural network to predict flash flood and attendant water qualities of a mountainous stream on Oahu, Hawaii. J Hydrol 2006; 327(3-4): 525-38.
15. Kerh T, Lee C S. Neural networks forecasting of flood discharge at an unmeasured station

using river upstream information. Adv Eng Softw 2006; 37(8): 533-43.
16. Dawson C W, Abrahart R J, Shamseldin A Y, Wilby R L. Flood estimation at ungauged sites using artificial neural networks. J Hydrol 2006; 319(1-4): 391-409.
17. Jalilvahabi J. Zoning flood risk using remote sensing and geographical information systems in Taleghan watershed, Master thesis, Tarbiyat Modarres University. 1997.
18. Mosavi A. Flood zoning Chehelgazi watershed in Kordestan province using GIS model HEC_HMS, Master thesis, Islamic Azad University, Tehran. 2002.
19. Motiei H, Behnia A, Barbod M. Flood zoning in watersheds by combining GIS and mathematical models, Sixth Seminar on River Engineering, Shahid Chamran University, Ahvaz, 2002; 1367-74.
20. Ghanavati E. Geomorphologic characteristics of Gamasiab basin alluvial fans. Geogr Res 2004; 18(4): 174-82. [In Persian]
21. Yamani M, Enayati M. The relationship between geomorphological characteristics of basins and flood capability (Analysis of flood data through geomorphological comparison of Fashand and Behjatabad basins). Geogr Res 2005; 37(54): 47-57. [In Persian]
22. Sokolova D, Kuzmin V, Batyrov A, Pivovarova I, Tran N A, Dang D, *et al*. Use of MLCM3 software for flash flood modeling and forecasting. J Ecol Eng 2018; 19(1): 177–85.
23. Le P V V, Kumar P, Valocchi A J, Dang H V. GPU-based high- performance computing for integrated surface-subsurface flow modeling. Environ Modell Softw 2015; 73: 1–13.
24. Gourley J J, Flamig Z L, Hong Y, Howard K W. Evaluation of past, present and future tools for radar-based flash-flood prediction in the USA. Hydrolog Sci J 2014; 59(7): 1377–89.
25. Gourley J J, Flamig Z L, Vergara H, Kirstetter P E, Clark R A, Argyle E, *et al*. The Flash project: Improving the tools for flash flood monitoring and prediction across the United States. Bull Amer Meteor Soc 2017; 98(2): 361–72.
26. Maryanaji Z, Marofi S. Investigation of runoff flow created by maximum 24 hours rainfall in Ghara-Chay basin using SCS method and GIS application. Agri Res 2005; 5(3); 71-83. [In Persian]
27. Ghaemi H, Morid S, Shams A G. Flood models in Karkheh sub-watershed. Neyvar 1996; 30: 10-27. [In Persian]
28. Heidarpour B, Saghafiyan B, Goliyan S. The effect of involving exceptional outlier data on design flood magnitude. Curr World Environ 2015; 10(2): 698-706.
29. Heidarpour B, Panjalizadeh Marseh B, Ekramirad A, Hosseinnezhad A, Ghasemian Langroudi A. Detection of outlier in flood observations: A case study of Tamer Watershed. Res J Recent Sci 2015; 4(3): 150-3.
30. Adeyemo J, Olofintoye O. Optimized fourier approximation models for estimating monthly streamflow in the Vanderkloof Dam, South Africa. In: Tantar AA. *et al*. (eds) EVOLVE - A bridge between probability, set oriented numerics, and evolutionary computation V. Advances in Intelligent Systems and Computing, 2014. 288. Springer, Cham.
31. Dastourani J, Yazdani A, Gholipour H, Hasheminasab S N. Investigation of snow and ice coefficient of Isfak watershed. Fifth National Conference on Environment, Energy and Biosafety. Mehr Arvand Institute of Higher Education and Center for Sustainable Development Solutions. 2016. [In Persian]
32. Alizadeh A. Principles of Applied Hydrology, Press Razavi, Sixteenth Edition, 2003. 816p.