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ASSESSMENT OF THE FLOOD POTENTIAL RANKING OF SUB-BASINS AND DETERMINATION OF FLOOD SOURCE AREAS

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The determination of flood source area and ranking sub-basins according to flood potential can play an important role in a management of large watersheds. The Hassan-Abad watershed, located in southeast Iran, was chosen for a study of the occurrence of floods. Each sub-basin share in the total watershed flood was established by using GIS and the HEC-HMS based SCS CN method. For this purpose, by successively eliminating sub-basins from the simulation process using a unit flood response method, the contribution of each sub-basin to the outlet flood peak was quantified. Results show that not only sub-basin areas influence their share in the total watershed flood potential, but also factors such as their location and flood routing in the main river are of a great importance. The contribution per unit area to the outlet flood peak was used as the basis to rank the sub-basin in terms of their flood potential.

INTRODUCTION

Flood is one of the natural hazards which have had an increasing trend in recent years, and several parts of the countries are affected by flood losses each year. In the past 50 years, 3700 flood events have been reported in Iran and about 53 percent have occurred in recent years (Sharifi et al., 2005). Assessment of environmental factors shows man's interference in the natural water cycle through destruction of vegetation in watersheds, irregular use of lands, and development of impervious surfaces, has increased flood potential in various regions. As a result, flooding expanse has increased and more land have been impacted by floods (Smith and Ward, 1998).

Selection of regional priority for the control of flood projects can be a political decision that should be confirmed by the study of physical, social and economic conditions of the region and the assessment of plan result effects (Djordjevic and Bruck, 1989). Sub-basins need an urgent priority for they possess critical conditions occurring near the main river or man-made features (dams, reservoirs, deviational dams and other structures) which are important to protect. Moreover, in some cases, priorities are determined according to people's interests, strategic situations, poverty, and so on (Najafinejad, 1996).

Considering the fact that in most of Iran's watersheds, the occurrence of floods and losses due to flooding are increasing, the determination of flood source area and ranking impact of sub-basins can optimize management of watersheds. For this reason, the Hassan-Abad watershed in southeastern Iran has a special position with regard to occurrence of floods. The watershed has experienced rather severe floods during the past several years, some of which have caused great damage to agricultural and residential lands, and even human losses. For example, the flood that occurred in March of 1986 killed six persons and caused great damage to residents, gardens, farms and livestock. This flood produced a lake with a length of 70 kilometers and width of 30 kilometers in Juyom. The lack of sufficient hydrometric stations, statistics and recorded information of floods in sub-basins in Iran's watersheds means that the intensity of floods cannot be predicted based only on recent data. Therefore, the role of mathematical hydrologic models in the determination of watershed flooding is clear. In most studies carried out for the assessment of sub-basin flooding in Iran, the whole watershed has been considered in a consolidated form and no attention has paid to the effects of river flood routing and sub-basin locations. Only Saqhafian and Khosroshahi (2005), Paqheh (2008), Saqhafian et al. (2008), and Farazjoo (2009) have regarded the above cases using hydrologic models and determined sub-basin contributions to watershed flooding in the Damavand, Garmabdasht, and Golestan dam watersheds, respectively. The goal of this research is to use Geographical Information Systems (GIS) and the HEC-HMS hydrologic model to determine the degree of sub-basin contributions to total outlet flooding of the Hassan-Abad watershed in Fars province in Iran. The identification and prioritization of sub-basins according to flood potential is also determined.

MATERIALS AND METHODS

The geographical location of the Hassan-Abad watershed is 27° 58' 00" to 28° 07' 00" north latitude and 53° 44' 00" to 53° 53' 00" east longitude. It has an area of 124 km^2 in Fars province south of Larestan city. It includes mountainous regions and part of the northern Zagros mountain ranges (Figure 1). The nearest village to the watershed is Hassan-Abad located east of the watershed. Some of the features of this watershed are shown in Table 1.

Determination of physiographic features of sub-basins

In this research, the Hassan-Abad watershed is divided into 10 sub-basins based on topography

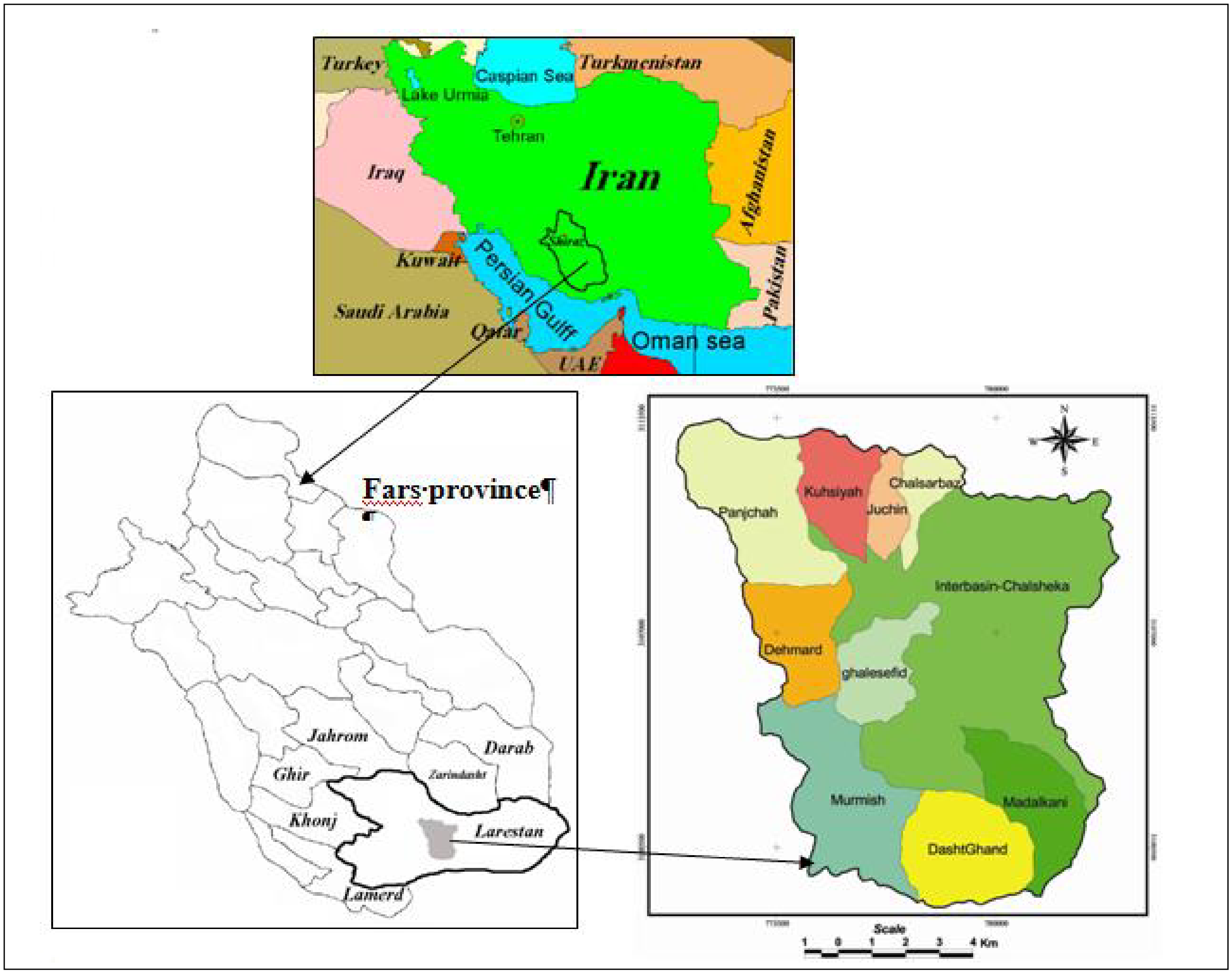

Figure 1. Location of Hassan-Abad watershed in the country and Fars province.

Table 1. Characteristics of Hassan-Abad watershed.

Sub-basin	Area (km^2)	Average Weight Height (m)	Average Gradient (%)	Main river Length (km)	Curve Number (CN)
Madalkani	8.91	1047.83	5.50	7.00	79.7
Joochin	3.00	1218.64	18.77	3.71	85.3
Chalsarbaz	3.35	1304.38	24.79	3.90	88.3
Chalshekar	47.64	1026.69	9.34	13.61	80.6
Murmish	14.88	1159.75	12.59	6.67	83.7
Panjchah	14.38	1235.00	15.20	8.22	84.8
Kuhsiyah	6.60	1328.67	17.84	4.58	85.4
Ghalesefid	6.67	1048.60	16.07	6.23	84.4
Dashtghand	11.02	1130.60	11.25	5.05	79.0
Dehmard	8.11	1073.66	10.36	5.44	85.0

(Figure 1). A Digital Elevation Model (DEM) of the watershed was prepared in Arc GIS 9.3 using the Triangular Irregular Network (TIN) method. Other physiographic features were extracted from DEM presented in Table 1.

Total average gradient of the watershed was 20.32 % and its average elevation is about 1109 m.

Determination of curve numbers of sub-basins

Curve number is the next parameter used in the SCS method for the determination of primary losses and lag time influenced by type of land use, hydrologic group, and antecedent soil moisture (Wanielista, 1990). A map of the region land use under study was extracted using IRS satellite images and inserted into GIS. Then a map of soil hydrologic groups was extracted by the use of watershed pedology. In the next step, we overlaid the land use and soil hydrologic group maps in Arc GIS 9.3 and prepared a CN map of watershed based on curve number determination tables (USACE, 2000). Then we determined average weighted curve number of each sub-basin as shown in Table 1.

Assessment data-observational of rainfall-runoff and determination of spatial and time distribution of rainstorms

For the calibration of HEC-HMS model, we need to insert observational precipitation data and its corresponding flood into the model. For this purpose, we prepared hydrographs of floods at the Hassan-Abad hydrometric station from Fars Regional Sewage Organization. Then, with the occurrence of each flood, we determined rainstorm spatial distribution using Inverse Distance Squared Method (IDSM) in Arc GIS 9.3 with a pixel size of 25 meters according to daily-recorded precipitation in four rain gauge stations around Hassan-Abad watershed. The time distribution of rainstorms was determined with the use of rain recording paper in a recording gauge. In spite of suitable numbers of floods, we inserted only four flood events into the model due to the sparse regional recording rain gauge network of Hassan-Abad hydrometric stations. Table 2 illustrates features of selected events.

Simulation of watershed hydrologic interaction with the use of HEC-HMS model

Table 2. Characteristics of flood events for the calibration of HEC-HMS.

Date	Soil moisture	Peak flow (m^3/s)
7-9 Mar, 1987	Dry	19.00
9-11 Dec, 1989	Dry	10.42
8-10 Dec, 2000	Dry	7.42
5-7 Jan, 2003	Dry	7.17

The HMS model is one of several different computerized mathematical methods for the simulation of rainfall-runoff events including several sub-models for runoff, surface flow, base flow, and channel flow. This model includes three basic parts called a watershed model, climatic model, and control indices. This model also has the ability to auto-calibrate and optimize parameters (USACE, 2000).

In this study, we determined the primary loss of rainfall and infiltration using SCS CN method. Then we used the SCS unit hydrograph method for the determination of watershed direct runoff hydrograph. Flood routing was implemented from each sub-basin outlet to Hassan-Abad watershed outlet using the Muskingum-Cunge method. Figure 2 illustrates a sample model of Hassan-Abad watershed

Calibration and validation of HEC-HMS model

In this research, we used a Simple-Split Sample Test for calibration and validation of the HEC-HMS model (Ewen and Parkin, 1996). In this method, observational floods were divided into two groups. Model parameters were calibrated with a set of data using target functions. Then the model was validated by running the model using optimized parameters for the second set of data. Finally, observational and simulation hydrographs were compared.

Determination of flood source area and prioritization of sub-basin flood potential

After the optimization of parameters, the model was implemented by the use of a 24-hour design rainfall with a return period of 50 years and a flood hydrograph was obtained at the outlet of each sub-basin. Then sub-basins of the Hassan-Abad watershed were prioritized based on flood potential by the use of a Successive Single Sub-watershed Elimination method (Saghafian and Khosroshahi, 2005) in the HMS model. By this method, we could determine the outlet flow of the total watershed each time we ran the model after flood routing in the main river without the impact of a particular sub-basin. This way, we could get the degree of impact on each sub-basin in the generation of outlet

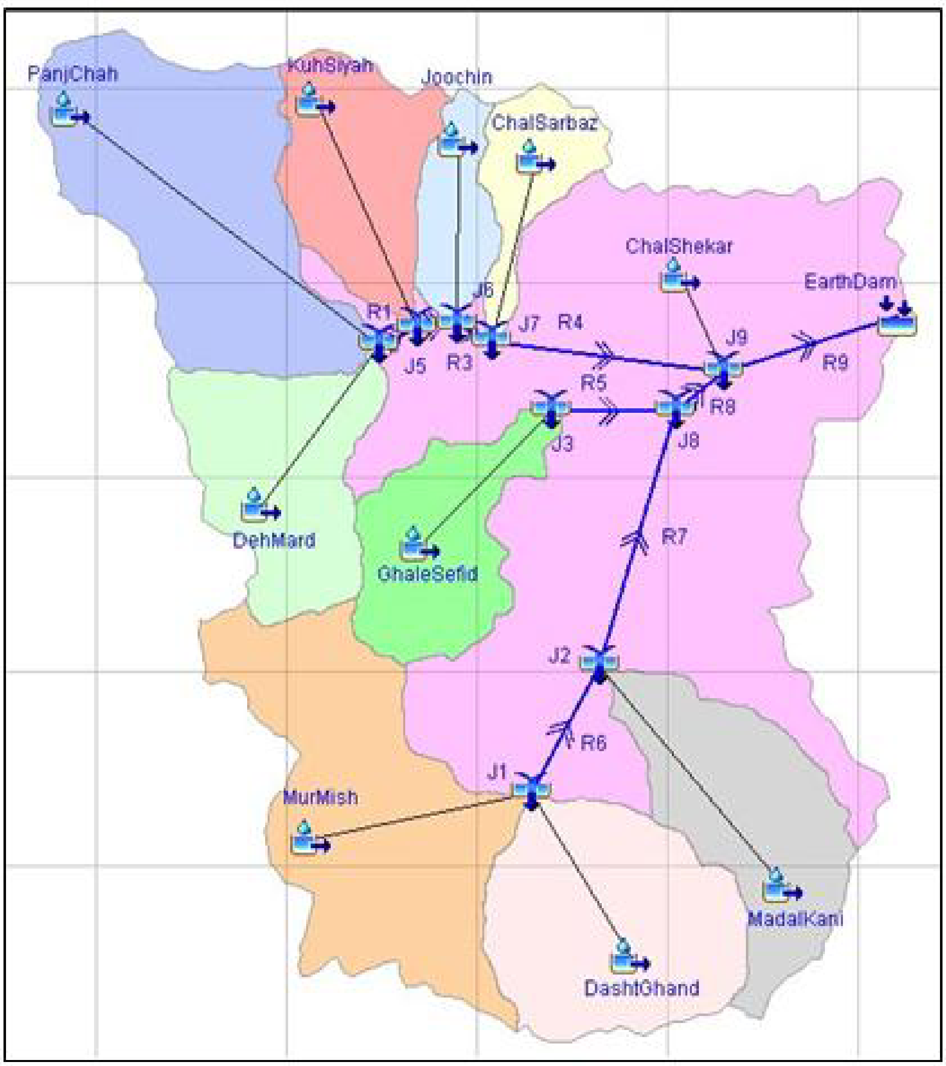

Figure 2. Creating watershed and Sub-basin in HEC-HMS.

flood. The sub-basin with the maximum share in the generation of outlet flood was considered as the maximum flood-generating sub-basin. Then other sub-basins were prioritized respectively according to their contribution to flood outlet. Flooding indices used here are defined as follows:

$$F = \left(\frac{\Delta Q}{Q}\right) \times 100 \tag{1}$$

$$f = \frac{F}{A} \tag{2}$$

where F is the sub-basin percentage share in total outlet flow of the watershed. ΔQ is the amount of reduction in outlet flow of the total watershed due to elimination of a particular sub-basin in m/s. Q is the outlet flow of the total watershed in m^3/s. f is sub-basin share in the outlet flow of total watershed in surface unit (flood index), and A is sub-basin area in km^2.

RESULTS

Optimization of model parameters and determination of sub-watershed outlet flow

Optimization results of parameters were inserted into the model, and model simulation results for a 50-year flood of each sub-basin are illustrated in Table 3. Figure 3 shows hydrograph calibration results at the Hassan-Abad hydrometric station.

Flooding prioritization of sub-basins

Prioritization results of sub-basins are presented in Table 4 and Figure 4.

CONCLUSIONS

Based on the results of Table 5 (columns 1 and 2) and Figure 4, the Chalshakar sub-basin has the

Table 3. The result of Optimized Factor in HEC-HMS.

Sub-basin	Optimized Factor			Rainfall (24-hour) (mm)	Peak flow (50-yr) (cms)
	CN	Initial Loss (mm)	Lag time (hr)		
Madalkani	79.7	12.94	1.68	26.6	10.2
Joochin	85.3	8.75	0.45	27.5	11.8
Chalsarbaz	88.3	6.73	0.37	27.6	16.1
Chalshekar	80.6	12.23	2.13	27.1	42.3
Murmish	83.7	9.89	0.94	26.0	26.8
Panjchah	84.8	9.11	0.97	27.1	26.6
Kuhsiyah	85.4	8.68	0.55	27.4	21.6
Ghalesefid	84.4	9.39	0.77	26.7	14.7
Dashtghand	79.0	13.5	0.92	26.2	22.9
Dehmard	85.0	8.96	0.84	26.6	16.8

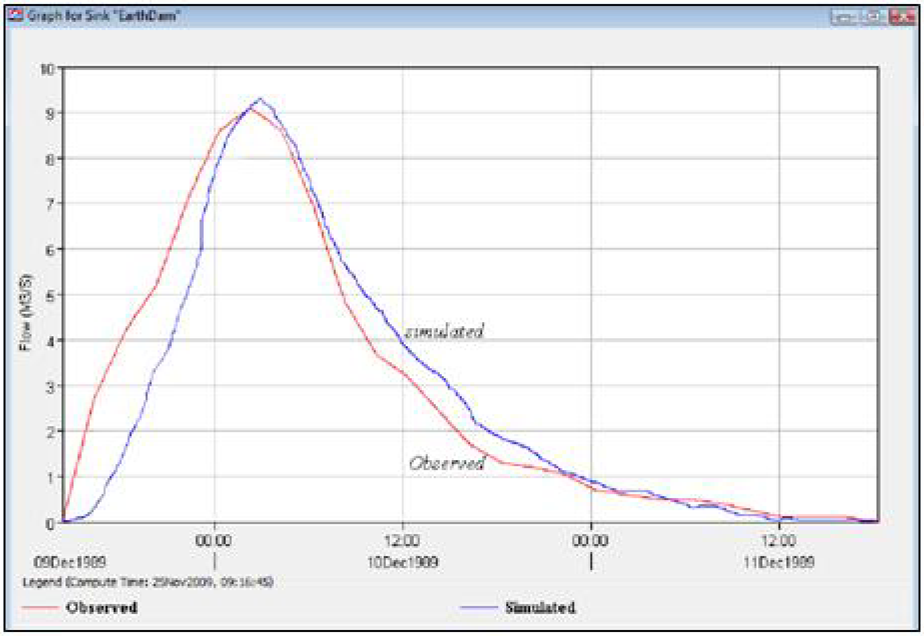

Figure 3. Observed and simulated hydrograph for 9-11 Dec, 1989 event.

Table 4. Ranking of sub-basins of Hassan-Abad.

Sub-basin	Q (m3/s) (1)	Priority ranking (2)	F (3)	Priority ranking (4)	f (5)	Priority ranking (6)
Madalkani	10.2	10	6.3	4	0.70	4
Joochin	11.8	9	2.6	9	0.88	1
Chalsarbaz	16.1	7	1.3	10	0.38	10
Chalshekar	42.3	1	38.3	1	0.80	2
Murmish	26.8	2	6.8	3	0.46	7
Panjchah	26.6	3	10.2	2	0.71	3
Kuhsiyah	21.6	5	4.2	6	0.64	5
Ghalesefid	14.7	8	3.0	8	0.45	8
Dashtghand	22.9	4	5.4	5	0.49	6
Dehmard	16.8	6	3.2	7	0.40	9

maximum amount of generating peak flow of 42.3 m^3/s at the watershed outlet and the Medalkeni sub-basin has the minimum peak flow 10.2 m^3/s. In the studies based on sub-basin peak flow without flood hydrograph routing from the location of sub-basin to the total watershed outlet no prioritization occurs. Thus, we cannot determine the contribution of sub-basins in total watershed outlet flooding. The sub-basin with more flow possesses the first priority.

In column 3 of table 5, prioritization is illustrated after sub-basin flood hydrograph routing in the main waterway based on the degree of contribution of each sub-basin to the outlet flood. When the amount of sub-basin flow impact is considered in the total watershed outlet peak flow after routings, sub-basin impact proportions not only depend on their area and peak flow, but on the interaction of effective factors such as their locations. Therefore, the sub-basin with more area or

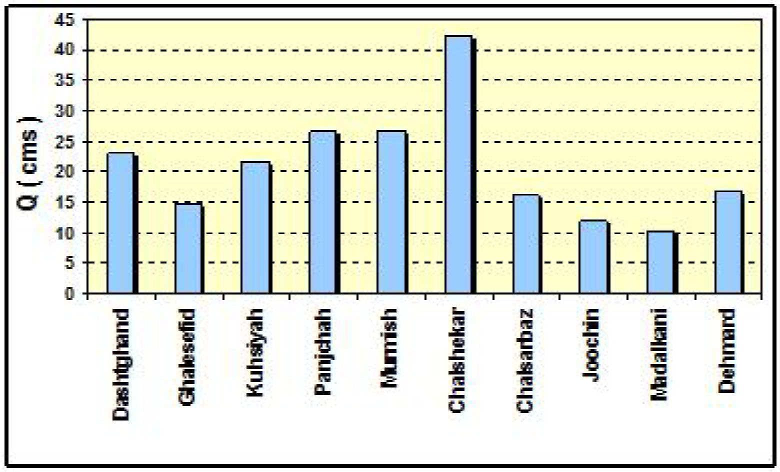

Figure 4. Ranking of sub-basins base on peak flow (Tr:50 yr).

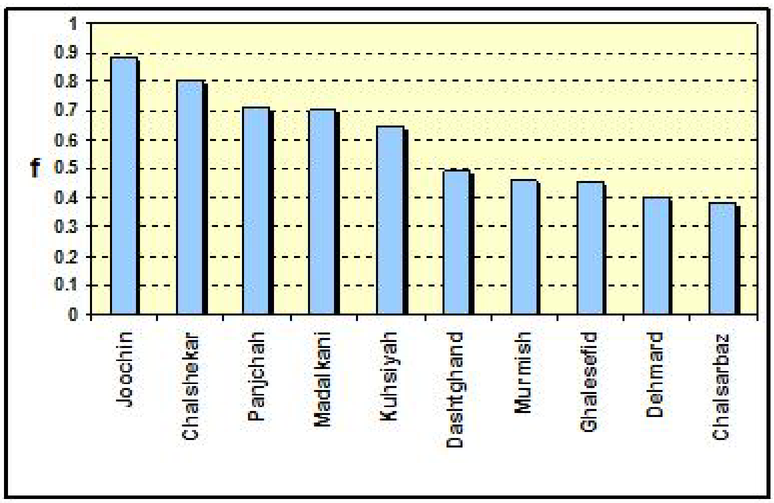

Figure 5. Ranking of sub-basins base on f index.

flow does not necessarily influence on the total outlet flood. For example, the Chalsarbaz sub-basin with the seventh priority according to its peak flow stands in the tenth order based on its contribution to the total outlet flood. This indicates flood routing interactions in the river, and sub-basin locations and features in the determination of their contribution to the total watershed peak flow.

In case that sub-basin areas influence flooding prioritization, prioritization can be done according to surface unit of sub-basins (column 5 of Table 5). In the executive section of controlling floods, outlet flood reduction is more important based on the surface unit of sub-basins. Therefore, final prioritization of Hassan-Abad sub-basins was carried out according to their contribution to the total watershed outlet flow in surface unit. Results are shown in Figure 5. We found that the Joochin sub-basin had the first and the Chalsarbaz sub-basin had the last rank. We should mention the Chalshakar sub-basin had a high priority in all cases and this showed a great flooding in this region.

Finally, results show we can assess interactions of physiographic and climatic factors with flood potential of watersheds by using GIS and hydrologic models and then prioritize flood potentials of sub-basins in a better way with regard to simultaneousness of sub-basin peak flow and the role of flood routing in waterways.

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