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Investigation of Regional Flood Intensity in Homogeneous Basins of Kerman Province, Iran

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Abstract

Understanding the flood phenomenon and its effective factors is, the prerequisite of its control and management. This phenomenon is influenced by hydrological, climatic and physiographic factors and it has always been one of the most important issues in hydrology. In this research 94 watersheds with corresponding hydrometric stations with the common period (1976-2011) were selected. Instantaneous peak discharge was calculated with a 50-year return period. 15 hydrological, climatic and physiographic parameters, affecting the flood intensity, including: average altitude, catchment area, Gravelius coefficient, slope, main river length, annual average precipitation, average number of rainy days, base flow index, hydrograph recession coefficient, curve number, permeability and percentage exceedances of, Q_2, Q_5, Q_{20} Q_{50} were calculated for each catchment. Factor analysis was performed after data standardization and the most important independent factors affecting flood intensity were chosen and multivariate regression equations were extracted by stepwise method. Results showed that R^2 value of all models were between 82% and 93% and indicates that the models were in good agreement with the data. The first model yields an adjusted R2 of more than 88%. The second, 80% and the third model, more than 91%. The value of predicted R2 of models ranges between 74% and 80%. The Durbin Watson statistic were between 1.81 and 2. The first model yields a standard deviation of 2.1 and the second 1.4 and the third model, less than 2.7.

Key words: Effective factors, Factor analysis, Flood intensity, Infiltration, Ungauged catchment

1. Introduction:

Flood as a natural fact has always been part of the dangers and events of human societies in the world and especially in Iran. Due to the special climatic zone, topography and special rainfall regime, this phenomenon has imposed a lot of human and financial losses on the country over the past years. According to Jalali (1986), the incidence of floods and related damages in the last 50 years (ending in 1986) in Iran has grown by more than 250 percent. Also, according to Khosroshahi and Ghavami (1998), more than 3700 damaging floods have been registered in the period of 1951-2001, which makes Iran the seventh most flood-prone in the world. Understanding the factors affecting flooding is a prerequisite for its control and management. Sustainable flood risk management also requires appropriate data.

One of the problems in most watersheds of Iran is the lack of complete and accurate data and information due to the lack of hydrometric and climatological station. This leads to uncertainty related to the management of this phenomenon. Attention to this problem led to the naming of the 2003-2012 decade as a forecast in the ungauged catchments by the International Hydrological Association (Zare-Chahouki et al., 2013). Generalization of data to ungauged catchments requires comprehensive research on the relationship between geometric and hydro climatological characteristics of basin with stream flow data (Smakhtin, 2001). The most important factors in the occurrence of floods can be divided into three groups: climatic, edaphic and managerial

(Mahdavi and Hashemi, 1997). The occurrence of floods in each region depends on several factors, the most important of which are: basin factors, including: physical factors, such as: area, slope, density, geological and soil factors, vegetation, climatic factors and lack of watershed management. Factors related to river characteristics and materials, sedimentation, riverside land use, destruction of river banks and development of urban areas (Najafi and Nasri, 2010).

In the last two decades, several studies have been conducted based on the analysis of relationships between different climatic and hydrological parameters to identify this phenomenon. The multiple regression was analyzed and presented between floods and some watershed characteristics, including area, diameter, shape factor, length and slope of the main river, forest area and average annual rainfall (Arabkhedri, 1995). Some researcher has used the sensitivity analysis process of experimental models to determine the most important factors affecting the flood, which provides useful information about the characteristics of the factors used and the degree of dependence of the model output on these factors. In this regard, Mahdavi et al. (2004) analyzed the sensitivity of ten experimental models with respect to area and determined its effect on the peak flood discharge with return periods of 2, 5, 10, 20, 50, and 100 years. Also, Malekinezhad and Kowsari (2009) considered the curve number method as a sensitivity analysis and examined the relative importance of five factors including: curve number, time concentration, area, rainfall in certain return periods. The results showed that the curve number compared to other factors has the greatest effect on the output of the model. The most important factors and parameters influencing the creation and intensification of flood discharges in 14 hydrometric stations of the Isfahan-Sirjan watershed located in the central part of Iran were investigated by Najafi and Nasri (2010) using factor analysis method. The results showed that time of concentration with a 37.9%, basin slope with 29% and drainage density with 24.6%, have the greatest effect on creating or intensifying flood discharges in the region. The most important factors influencing the maximum peak flow were investigated by Dastorani and Hayatzadeh (2010) through the sensitivity analysis of experimental relationships. They analyzed the sensitivity of 10 conventional experimental relationships and results showed that all relationships were sensitive to low areas and have a high impact on peak flood discharge at the model output. Factors affecting flooding in Zarabad watershed were investigated by Hashemi et al. (2012) and a negative correlation between vegetation cover and flooding have been reported. The effect of geology, vegetation cover, slope, curve number, basin shape and drainage density on runoff production using the Analytical Network Process (ANP) method were investigated by Khairizade et al. (2013). They concluded that the slope factor with 30% and runoff with 28% contributed the most to the flood occurrence. Also, in another study, the flood zoning of Baghan watershed was studied using analytical hierarchical analysis method. In this study, topographic, geological, vegetation and hydro-climate parameters were used and the results showed that the hydro-climate parameters have the greatest impact on flooding in the study area (Nasirnejad et al., 2014). In a similar study, the factors affecting the floods occurrence in the Hawiq basin were investigated by Abedini and Khoshkhoy-Delshad (2016) using the network analysis process method. The results showed that the slope, permeability, flow velocity, erosion and time of concentration with (0.341) and lithological factor with value (0.287) were the most important. Porhemmat (2017) evaluated the regional models of estimating the annual runoff coefficient at different levels of probability using the measured data of 108 hydrometric stations in the Karkheh, Dez and Karun basins. The parameters used include area, slope, Gravilius coefficient, rainfall, main river length and slope, average height, drainage density and basin perimeter. Results showed that runoff coefficient at different levels of probability had a high correlation coefficient with 10 selected factors. The results of Masfaei and Malekinejad (2017) researches in 23 watersheds of Qazvin province showed that 5 factors, including: perimeter, equivalent diameter, time of concentration, river length and basin area were the most important factors affecting maximum flood in Qazvin province. Porhemmat and Kazemi (2017) presented the regional equations of runoff coefficient using 15 geological, morphometric and hydro-climatic components in Karkheh basin. The results showed that the accuracy of the relationships presented in the first and second homogeneous regions was equal to 17.97 and 27.81%, respectively. Parvaresh et al. (2018) prioritized the factors affecting flood potential and runoff coefficient in Sarkhon watershed of Bandar Abbas. The results showed that the most important factor was permeability and in the next step, the vegetation and slope. Research results of Milly et al. (2008), Stonstrom et al. (2009), Montanari et al. (2013) recommend the use of relationships between different components of the basin and floods for different topics such as estimating and predicting hydrological changes. In a study conducted by Benson (1963) in New England as a humid climatic zone, the most important component affecting floods was the area and slope of the main river. Also, the results of Bar-Kochba and Simon (1972) research conducted in humid areas of northern Ohio, USA, showed that the most important factors influencing floods in large basins, were area and main river slope, and for small basins, area, precipitation and soil index. Riggs and Hess (1993) examined ten methods of regional flood analysis in the United States and determined the effective parameters in flood discharge. They concluded that the basin area was the most important and effective parameter and in the next stage, river slope and average annual rainfall, were more important in flood production. The results of the Langhammer and Vilímek (2008) studies conducted in the Ottawa river basin in central Europe indicate that the most important factor influencing floods was the change in landscape and agricultural and urban land uses. The effects of initial precipitation and rainfall intensity on flooding have been investigated by Blöschl et al. (2015), Berghuijs et al. (2016), Gao et al. (2018) assuming that the relationships between the key characteristics of the basin and flood at the regional level and their correlation relationships for forecasting were not clear, the key characteristics of the basin include: slope, altitude, bedrock depth, soil erodibility, forest cover, urban, soil dryness index, area and drainage density were studied to understand the impact on flood intensity at 404 basins in the United States. Results showed that the slope has the highest effect also, forest cover, soil, geology and climate have low impact. According to the results of the above studies, the flood intensity varies in time and space due to the effects of various physical, hydrological and climatic factors. Therefore, research on the identification of factors affecting it will be useful for estimation in ungauged catchment. In order to conduct the research, it was necessary to consider an area in terms of size and number of basins in order to find an example of analysis of factors affecting flooding in accordance with the hydrological unit. For this purpose, it was tried to do this research at least at the province level in order to be compatible with the risk management and water resources management programs of the province in future research.

2. Materials and methods

2.1. Study Area

Kerman province is one of the vast provinces of Iran. With an area of 181737 km^2, it is located between 25^{o}, 55′ to 32^{o}, 53 north latitude and 53^{o}, 26 to 59^{o}, 29 east longitude. It has covered about 11% of the country's area. The climate was as arid and semi-arid. The average annual rainfall was 145 mm (Kazemi et al., 2018) and the amount of rainfall in the province was estimated 27 billion cubic meters (Porhamat, 2016). The location of studied area presented as Fig. 1. The code and geographical coordinates of the basins and the characteristics of the selected parameters for the factor analysis were presented in Table 1 and 2.

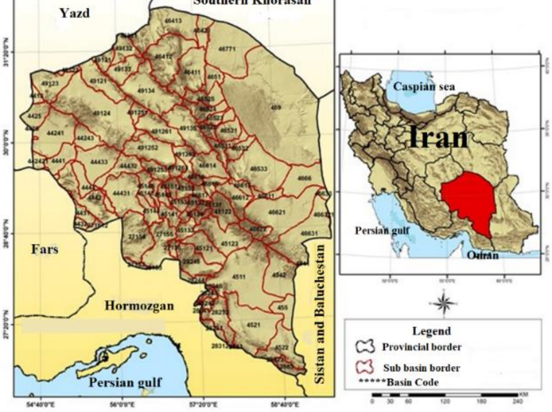

Fig. 1. Study area

2.2. Methodology

Stream flow data of 94 hydrometric stations, related to 7^{the} order basins with a common period of 1976-2011 were selected. Using a topographic map with a scale of 1: 50,000 and determining the location of stations, the study area was determined and 15 hydro-climatological and physiographic parameters affecting flood intensity include: average height, area, Gravilius coefficient, river length, basin slope and hydro-climatological parameters including: average annual rainfall, average number of rainy days, BFI, FDCI, curve number, permeability and Q_2, Q_5 Q_{20}, Q_{50} were calculated for each basin.

Table 1. Code and geographical coordinates of the basins

latitude	Longitude	Basin code	latitude	Longitude	Basin	latitude	Longitu	Basin
29 º9′	58 º31′	4653	26 º22′	58 º40′	28523	27 º53′	58 º49′	455
29 º24′	58 º7′	4661	30 º15′	54 º53′	44241	30 º98′	58 º26′	469
29 º13′	58 º29′	4661	29 º8′	55 º44′	44243	26 º20′	57 º09′	2843
29 º13′	58 º29′	4661	29 º11′	55 º8′	44431	26 º21′	59 º00′	2863
29 º41′	57 º8′	4661	29 º42′	55 º6′	44432	26 º96′	53 º93′	4413
29 º41′	57 º8′	4661	28 º29′	55 º7′	45121	30 º60′	54 º23′	4425
29 º37′	57 º47′	4661	28 º6′	57 º8′	45122	30 º59′	54 º22′	4426
29 º35′	57 º47′	4661	28 º30′	57 º7′	45123	28 º99′	55 º05′	4431
29 º19′	59 º39′	4662	28 º9′	57 º42′	45131	28 º80′	55 º45′	4432
28 º6′	58 º55′	4662	28 º8′	57 º23′	45132	29 º74′	55 º19′	4441
29 º11′	59 º33′	4663	28 º8′	57 º21′	45133	29 º72′	55 º25′	4442
29 º19′	59 º39′	4663	28 º8′	57 º41′	45134	29 º48′	55 º45′	4444
30 º8′	58 º17′	4677	28 º9′	57 º07′	45141	27 º53′	58 º49′	4511
31 º50′	55 º41′	4912	28 º9′	56 º9′	45142	27 º53′	58 º12′	4521
31 º08′	55 º39′	4912	29 º04′	56 º6′	45143	27 º56′	59 º14′	4541
31 º07′	55 º40′	4912	27 º56′	59 º14′	45144	27 º71′	58 º44′	4542
31 º07′	55 º40′	4912	27 º7′	58 º41′	45145	30 º98′	57 º8′	4651
31 º53′	55 º40′	4913	29 º13′	56 º9′	45151	29 º58′	58 º00′	4666
31 º13′	55 º9′	4913	29 º13′	56 º9′	45152	28 º24′	55 º9′	27153
31 º12′	55 º9′	4913	28 º94′	57 º8′	45153	28 º25′	56 º21′	27154
31 º9′	56 º16′	4913	32 º39′	55 º9′	46331	28 º31′	56 º37′	27155
31 º19′	56 º9′	4913	31 º15′	57 º54′	46411	28 º32′	56 º8′	27156
28 º41′	55 º7′	2716	31 º35′	57 º37′	46412	27 º81′	56 º8′	28153
30 º08′	54 º6′	4424	31 º38′	57 º42′	46413	27 º34′	57 º25′	28231
28 º6′	59 º5′	4663	31 º36′	57 º44′	46421	27 º34′	57 º52′	28232
30 º3′	56 º24′	4912	30 º19′	58 º10′	46521	27 º28′	57 º20′	28241
30 º10′	56 º40′	4912	30 º29′	58 º01′	46522	27 º60′	57 º35′	28242
29 º7′	56 º56′	4912	30 º44′	57 º8′	46523	27 º59′	57 º35′	28243
29 º9′	56 º9′	4912	30 º44′	57 º8′	46524	27 º63′	57 º35′	28244
29 º8′	56 º9′	4912	30 º8′	57 º7′	46525	27 º97′	57 º24′	28245
			30 º19′	58 º11′	46531	27 º80′	57 º39′	28246
			30 º01′	58 º23′	46532	27 º14′	57 º13′	28312

Table 2. Minimum, average and maximum values of selected parameters

F_{RP50}	Q_2	Q_5	Q_{20}	Q_{50}	NR	IR	K	BFI	CN	P	S	RL	Gc	A	H	Parameters / Descriptive statistics
84	89	84	85	57	51	89	0.86	0.62	73	192	16.4	917	1.55	2715	1845	Average
98	98	98	98	79	90	98	0.98	0.84	91	373	31.0	5096	2.34	26113	3105	Maximum
38	58	38	57	30	58	52	0.44	0.33	22	70	0.2	86	1.20	108	527	Minimum

H: average height of the basin (m); A: basin area (km^2); Gc: Cravilius coefficient; RL: River length (km); S: average basin slope (%); P: average annual rainfall (mm); CN: curve number; BFI: base flow index; K: recession coefficient; IR: permeability (mm / day): NR: average number of rainy days; FDCI: flow duration indices (Q_2, Q_5, Q_{20}, Q_{50}); F_{RP50}: Flood intensity index (maximum discharge with a return period of 50 years).

Then, the maximum instantaneous discharge with a return period of 50 years per unit area of the basin were selected as the main indicator of flooding. Data standardized and factor analysis was performed to identify the independent factors affecting flood.

Then, the homogenization of the basins was performed using the most important effective factors, and the Ward method. Regression equations were extracted in homogeneous area and validation was performed. In order to evaluate the accuracy of relationships, 5 basins were considered as controls and the extracted relationships were applied to them and accuracy of the regression models were checked based on correlation coefficient, standard error and validation were performed in significance level of 0.01.

2.2.1. Flood intensity index

The maximum instantaneous discharge was considered as the flood index. The value of which in this study was selected as a normalized parameter with a return period of 50 years per unit area of the basin. To calculate the maximum instantaneous discharge at the ungauged basins, the correlation analysis between the maximum instantaneous discharge and the maximum daily discharge was used. Also, to estimate the maximum instantaneous discharge, correlation relations and regional analysis of the maximum daily discharge with long-term average discharge with rainfall and the area of basins with simultaneous statistics were used (porhemmat, 2017).

2.2.2. Normalization of The data

Due to the existence of some factors, such as: low accuracy of the measuring devices and the involvement of other unknown factors, some of the available data was not reliable. To eliminate the effect of inappropriate data and prepare them to enter the analysis process. Kolmogorov-Smirnov test was used to test the normality of the data.

2.2.3. Standardization of parameters

The units of parameters were different from each other. Therefore, to make it possible to compare the parameters, standardization was performed using the following equation (1).

$$n = \frac{(x_{i-}\overline{\mathrm{x}})}{S_{td}} \qquad (1)$$

Xi: the variables (i); $\overline{\mathrm{x}}$ and S_{td} are the mean and standard deviation of the variable, respectively.

2.2.4. Factor analysis

In this research, factor analysis (Principal component analysis) method using IBM SPSS Statistics 20.0 was used for 15 variables in selected basins. Varimax rotation was performed to clarify the relationship among factors. Then, factor scores were extracted using the default regression method. To indicate the proportion of variance in variables that might be caused by underlying factors, anti-image correlation matrix and the Kaiser-Meyer-Olkin measure of sampling adequacy were performed. Accuracy of the regression models were checked based on correlation coefficient, standard error, relative error, and validation were performed in significance level of 0.01. Relationships between flood intensity index (F_{RP50}) dependence factor and other independent factors were investigated using regression method (Equation 2).

$$F_{RP50} = aMr + bHc + C \qquad (2)$$

where Mr: morphometric factor, Hc: hydro-climatic factor and a, b, c: constant correlation coefficients.

3. Results and Discussion

The minimum, maximum and average values of selected parameters affecting flooding extracted according to the research method and were presented in Table (3). Bartletts test was performed and Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was calculated to check the appropriateness of the data for factor analysis. The factor analysis process in SPSS was performed following hydrological homogenization of the basins. Results showed that significance level was less than 0.01 and the KMO was 0.730. According to Bouchard and Lohlin (2001), this rate indicates that the existing correlations between the data were appropriate and allow the process of factor analysis to continue. The result of the factor analysis process, showed that all the parameters had an extraction value more than 0.565, which indicates that all parameters have effect on the variance and therefore all were included in the factor analysis process.

Table 3. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.730
Bartlett's Test of Sphericity	Approx. Chi-Square	1770.338
	df	78
	Sig.	.000

The Scree Plot of the eigenvalues in each of the extracted factors was shown in Figure (2). As it turns out, the amount of variance explained decreases significantly with the extraction of the fourth factor onwards. The first factor with an eigenvalue of 47.488 has the highest impact and the second factor with a rate of 18.419% was in the next level of impact. The third and fourth factors have almost the same and close influence.

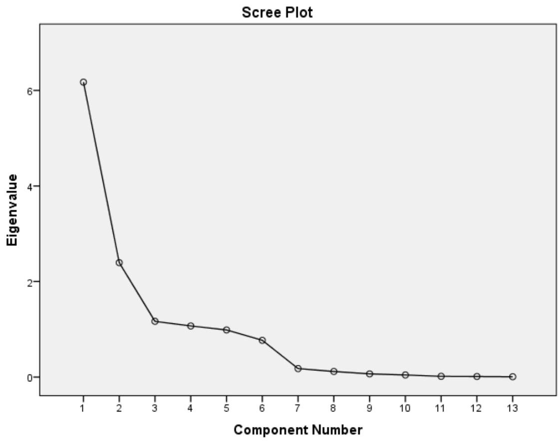

Fig. 2. A screen plot of the principle component number against eigenvalue

Factors affecting flood intensity were classified into four categories that explain 83.113% of the variance of the data, Table (4). The parameters of curve number, base flow index, recession coefficient, permeability, and FDCI (Q_2, Q_5) were included in the first component, which explains 47.488% of the data variance.

Table 4. Total Variance Explained

Component	% of Variance	Cumulative %
1	47.488	47.488
2	18.419	65.908
3	8.974	74.882
4	8.232	83.113

The factor load for the first component was in the range of 0.877 to 0.977, and the highest load related to Q_2 at 0.977 and the lowest to BFI with a factor load of 0.877. The noteworthy point was the high factor load on all the parameters of the first component. Given that the permeability of the basin was a determining factor in the runoff threshold as well as flooding. In this component, all parameters affecting the permeability were in one category.

The basin curve number, BFI, recession coefficient and FDCI, indirectly reflect the basin permeability. The placement of all parameters that somehow reflect the permeability of the basin and affect flooding were consistent with the results of various researchers, including Hashemi et al. (2012); Mosafaeei and Malekinejad (2017).

The parameters of average annual rainfall and number of rainy days were in the second component. The highest load in this category belongs to the number of rainy days with a factor load of 0.883 and in the next order, the average annual rainfall with a factor load of -0. 861. This component explains 18.419% of the variance of the data. The important point was that both parameters related to precipitation were in the same category and the factor load was close to each other. The parameters of basin area and river length and Gravilius coefficient with factor loads of 0.859, 0.813 and -0.544 with 8.974% in describing the variance of the data were located in the third component. Factor load close to each other and placing both parameters of river length and area in one category, it shows the validity of these parameters in flood analysis of the studied area.

The slope of the basin with a load of 0.741 and height with a factor load of 0.653 were located in the fourth component, which explains 8.223% of the variance of data related to flooding. According to Gerbing and Hamilton (1996), the factor load above 0.3 has an acceptable significance level and between 0.3 and 0.4 has a moderate significance level and above 0.5 has a strong significance level. Therefore, considering that the factor load of all variables was more than 0.5, so the correlation between variables and factors was high and has a strong level of significance. Also, considering that all parameters have more than 0.5 extraction value, therefore, all parameters should be considered to analyze the factors affecting flooding and the role of none of the parameters in flooding can be ignored and left out of the process of factor analysis. This output was consistence of the results of Hashemi et al (2012) research on the highest weight of rainfall impact in floods and the results of the report of Masfaei and

Malekinejad (2017) on the high impact of Gravilius coefficient along with rainfall and was recommended for estimating and predicting flooding in basins.

Cluster analysis was used to homogenize the regions. According to the extracted dendrogram and based on Euclidean distance between 5 to 10 basins were divided into three homogeneous groups. To validate the groups, the diagnostic test was used and after changing the groups four times based on model evaluation, the accuracy of the model was 100%. Table (5) shows the basins located in each of the homogeneous areas.

3.1. Regression relationships:

The results of the regression relations with the involvement of all sub-basins in homogeneous regions showed that the flood intensity index against the selected physiographic and hydrological parameters have a significant correlation at the 0.01 level. Multivariate regression models for flood intensity index were extracted using the stepwise method in homogeneous regions and were presented in Table 6 and model summery in Table 7.

Table 5. Homogeneous groups of basin

Cluster number	Basin code
1	28243;2863;4425;4441;27153;27154;271 55;27156;28153;28231;28232;28241;282 42;28243;28244;28245;28246;28312;285 23;44241;44243;44431;45131;45143;451 [illegible]
2	469;4413;426;4431;4432;4442;4444;4511 ;4651;4666;44432;46331;46411;46413;46 421;46521;46522;46523;46524;46525;46 531;46532;46533;46611;46613;46621;46 631;46633;46771;49121;49122;4913;491
3	455;4521;4541;4542;45121;45122;45123; 45132;45133;45134;45141;45142;45152; 45153;

Table 6. Regression equations in homogeneous regions

No	Regression Equation
1	F_{RP50}= 8.87 Gc - 0.1488 S% + 0.0334 P + 4.371 CN - 64.44 BFI - 61.9 K - 1.040 Q_{20} - 0.2118 Q_{50} - 0.768 NR-19.3
2	F_{RP50}= 0.284 IR - 0.0836 S% + 0.917 Q_2 - 0.1895 Q_{20} + 0.1587 Q_{50}-11.0
3	F_{RP50}= 3.073 CN - 75.6 K + 0.507 Q_2-93.6

**. Correlation is significant at the 0.01 level (2-tailed).

No= Cluster number

Table 7. Model Summary

No	S	R^2	R-sq(adj)	R-sq(pred)	SE	P-Value	DW
1	2.1772	91.25%	88.33%	80.63%		0.00	1.819
2	1.4232	82.88%	80.43%	74.79%		0.01	2.628
3	2.7696	93.25%	91.22%	80.47%		0.00	2.973

SE=Standard Error; S= Standard deviation; R^2= Coefficient of determination; R-sq(adj)= Adjusted R^2 R-sq(pred)= Predicted R^2 ؛DW= Durbin-Watson Statistic, No= Cluster number

In this study we use R^2 to determine how well the model fits data. The higher R^2 value, the better the model fits. R^2 value of all models were between 82% and 93% and indicates that the models were in good agreement with the data. As we know adjusted R^2 is the percentage of the variation in the response that is explained by the model, adjusted for the number of predictors in the model relative to the number of observations. Adjusted R^2 is calculated as 1 minus the ratio of the mean square error (MSE) to the mean square total. In each homogeneous region, models with different numbers of predictors were compared using adjusted R^2 and the best model was selected. The first model yields an adjusted R^2 of more than 88%. The second 80% and the third model, more than 91%. The value of predicted R^2 of models ranges between 74% and 80%. As is clear from table 6 predicted R^2 of the models were substantially less than R^2 and may indicate that the model was over-fit.

The Durbin Watson statistic was used to test for autocorrelation in the residuals from statistical models. DW value of all models were between 1.81 and 2.9 and it shows that we have positive autocorrelation in the model of homogeneous region (1). And in zone 2 and 3 models, negative autocorrelation.

We used standard deviation to assess how well the model describes the response. The first model yields a standard deviation of 2.1 the second 1.4 and The third model, less than 2.7. Considering that the value of the standard deviation was low in all models, it shows that the model describes the response better.

4. Conclusion

In this research the instantaneous peak discharge value was calculated with a 50-year return period and considered as flood index. Over all conclusion of the results of factor analysis of hydrological, climatic and physiographic parameters, affecting the flood severity, showed that all parameters have effect on the variance and were included in the factor analysis process. Descriptive statistics and also evaluation metrics for regression equation reflects the confidence on the regression equations to estimate flood severity in ungauged catchments of Kerman province, Iran. Due to the fact that the prerequisite of an analysis in accordance with the reality is the correct selection of the effective parameters on flooding and considering that at this level of research, it was not possible to extract and use some effective parameters, therefore it is suggested that in the future researches, and at more precise scales, to increase the accuracy of the analysis; Other parameters should be added to the factor analysis to increase the justification of data variance. Factors related to other components of precipitation, including intensity, duration, frequency, area of flood zones and subsurface geological characteristics, direction of geological layers, faults and joint density, and Karst geology should also be considered as an effective factor on flooding.

5. Acknowledgment

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6. Disclosure statement

No potential conflict of interest was reported by the authors

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