Development of flood regional models in Gorganrood basin

Atefeh Abdolhay, Mohd Amin Mohd Soom, Bahram Saghafian and Abdul Halim B.Ghazali

Abstract**—**Irregular distribution of precipitation in time and space in north part of Iran results in frequent flooding. Two extreme floods have occurred in north eastern part of Iran in year 2001 and 2002 (August) which had not been reported till that time. These catastrophes resulted in loss of human and properties. In spite of research and executive works on floods, still flooding occurs in northern part of Iran. Therefore flood disaster management and flood prevention must be revised in this region. Due to insufficient gauging stations in this region, regional flood frequency analysis was applied. For each homogenous region flood model for different return period was developed. Percent areas of NDVI classes besides other parameters were used in developing models as independent variables. The result showed influence of this parameter in some return period on flood

Keywords**—**Hydrological skewness, Multiple regression, Outlier, Regional Flood Frequency Analysis

I. Introduction

AMONG the 17 main catastrophes in the world, flood is the most important natural hazard due to its loss of life and properties. In spite of extensive research on various aspect of flood, yet mankind suffer seriously from this disaster which necessitates more investigation.

Flooding occurs when a river or stream overflow unexpectedly and inundate the surrounding area. This over flow may be caused by continuous rainfall over several days, intense rainfall over a short period of time, erosion of river banks, or an ice or debris jam. Flooding causes the destruction of valuable agricultural land, structures such as bridges, roads and dams. Therefore flood prevention is one of the necessary aspects of water resource development. Direct estimation of flood is not always possible due to insufficient length of record and existence of ungauged sites. One solution to such problems is regional flood frequency analysis (RFFA). Since in practical hydrology there are cases with limited record or even no record, regional analysis may be applied. Regionalization is the one of the most widely used technique in regions without sufficient data. Regionalization is applied in two cases, first where there is no data and second for the sites with insufficient data by using stations with long record in the region. In other words, regionalization substitutes low temporal variability with high spatial variability.

There are different methods for regional flood frequency analysis such as multiple regression technique. Rabon [7] was the first investigator to use multiple regression analysis as a method of regionalizing flood-frequency information for Florida. The main objective of his study was to determine the adequacy of the existing network to provide information at gauged sites and also to provide information that could be transferred to ungauged sites. Moore [6] applied regression method for regional flood frequency in Britain and concluded that this model can be used for estimation of flood in ungauged sites. Arabkhedri [2] developed regression model for northern Alborz of Iran. Khanjani [5] studied floods in Jazmorian basin. Parameters such as mean elevation of basin, area, mean slope of river, mean slope of basin were used. Multivariate regression was applied by other researchers such as [2], [6] and [14]. Ghorbani [3] showed the accuracy of regression method over Index flood method especially in high return period. Stamey and Hess [16] used 426 stations for regional flood frequency analysis in Georgia. These stations had minimum of 10 year record. The region was classified into 4 homogenous groups according to area .They developed models between physical, climatic characteristics and peak flows for each homogenous region. Hammett [4] applied regression method for developing regional models in Florida. Since, in the study area we have insufficient data record we applied regional flood frequency analysis to determine flood quantiles.

II. Study Area and Data Utilized

Occurrence of floods, due to high-intensity rainfall for short duration, is the dominant natural disaster in the Iran, causing loss of human lives and properties. Gorganrood basin is one of the areas exposed to frequent floods so the need for estimation of floods in this area is necessary to manage future floods.

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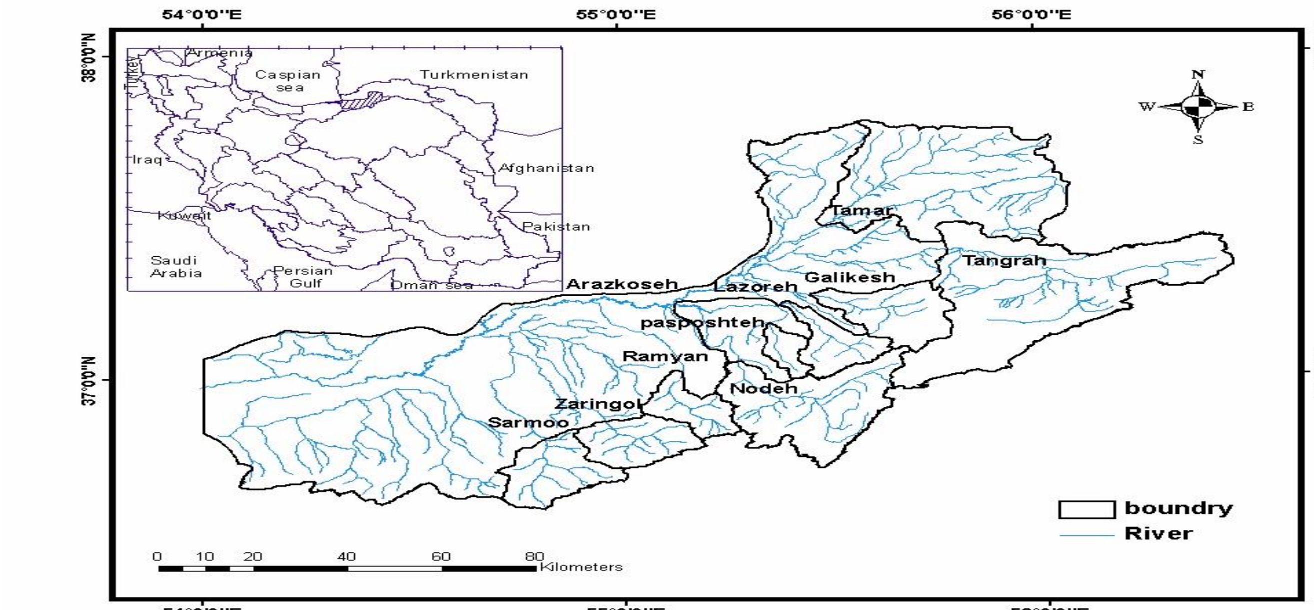

Fig. 1 Gorganrood Basin

Due to insufficient number of hydrometric stations in this area, direct prediction of flood is not applicable.

Gorganrood basin, as shown in Fig. 1, is located in south east of Caspian Sea between 54° 2‘ E to 56° 16‘ W longitude and 36° 34‘ S to 37° 47‘ N latitude. The total area of the basin is 13,170 km2 of which 7,838 km^2 is mountainous and 5332 km^2 consists of plain areas and alpine in the north and western parts of the basin. Gorganrood basin is part of Khazar basin according to general divisions of Iranians basin. This basin borders Atrak basin from north and east parts. The south part of Gorganrood basin is Shah Rood and Damghan basins while Neca basin is in the west. This basin is placed in Alborz mountain chain which separates gorgon basin from Markazi

study was from year 1969 to 2004. AMF of some years were not available. Thus the most appropriate stations with sufficient record during this period were identified

III. Methodology

Main steps in this study were identification of homogenous regions, flood frequency analysis and development of regional model. In this paper flood frequency analysis was carried out. Various issues including outliers and skewness were investigated and finally regional models were developed for each homogenous region in study area. Homogenous regions were identified in another paper named as “Identification of homogenous regions in Gorganrood basin “. In the first paper

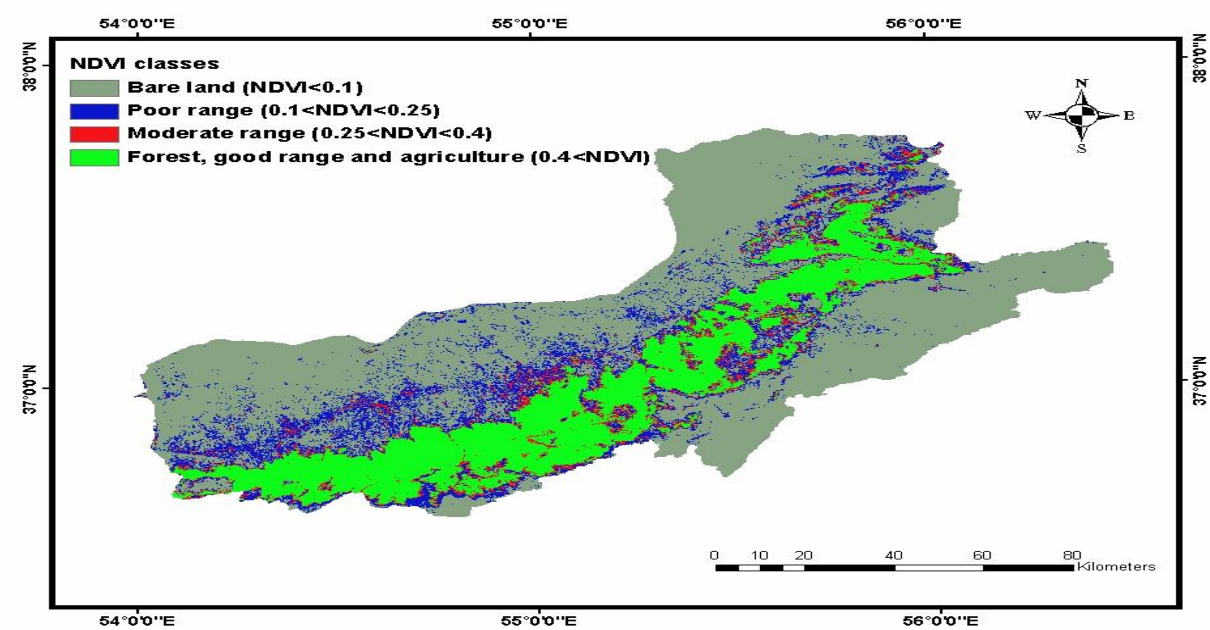

Fig 2 NDVI map of Gorganrood Basin

Row	Station	Test value (mean)	Cases smaller than Cut value	Cases greater than Cut value	Total cases	Number of runs	Z
1	**Arazkose**	109.73	17	17	34	18	0
2	**Pasposhte**	88.67	21	13	34	18	0.163
3	**Tamar**	95.78	22	12	34	14	-0.776
4	**Tangrah**	110.15	29	5	34	8	-0.738
5	**Ramyan**	54.59	22	12	34	9	-2.688
6	**Zaringol**	31.152	21	13	34	20	0.902
7	**Sarmo**	16.16	24	10	34	13	-0.683
8	**Galikesh**	84.78	26	8	34	9	-1.83
9	**Lazore**	47.54	24	10	34	16	0.161
10	**Node**	38.29	23	11	34	15	-0.153

Remote sensing provides a means of estimating of data affecting hydrologic processes in large basins, such as topography, soil moisture, land use classification etc. Satellite sensors record characteristics of vegetation by spectral radiance measurements. Several methods based on the band-rationing of vegetation sensitivity in the near-infrared (NIR) and visible (VIS) spectral bands, have been developed to convert the radiance measurements into vegetation indices [1].

There are numerous vegetation indexes among which NDVI (Normalized Difference Vegetation Index) is one the most practical ones. NDVI was first described by Rouse *et al* [13], though the concept was discussed by Kreigler *et al* [9] before Jensen [7].

NDVI is defined as the ratio of difference between reflectance of NIR (near infrared) and visible bands to sum of the reflectance of these two bands, as it is shown in (1). The negative values represents the water bodies and clouds, the values near zero shows bare soil and rocks, and the positive values represents the vegetation.

$$NDVI = \frac{NIR - visible}{NIR + visible} \tag{1}$$

Studies done by [5] showed a relationship between evaporation and NDVI. Regarding the effect of evaporation on runoff, it can be suggested that NDVI represents flow characteristics.

In arid climate, the mean value of contributing factors in runoff depends on soil characteristics such as texture, slope and land use. The runoff coefficient is representative of such characteristics which is used in SCS equation for estimation

Two outcomes are possible, data which is greater than test value *a,* and data lower than test value *b*. A run is described as sequence of these outcomes which is noted by R.

The null hypothesis states that a, b sequence are random which indicates that z has a normal distribution. Hence, the critical values of the standard normal distribution for desired significance level are obtained. This critical value is compared with z value calculated from (2).

flood. Since hydrologic losses are in some way detected by NDVI, it can be used as a contributing factor in regression analysis. NDVI information is useful in semi-arid regions as the state of the vegetation varies statistically during the year.

NDVI map was prepared from MODIS images in year 2001. This map was classified into four classes according to [18].

IV. Regional Flood Frequency Analysis

Hydrological data usage in water resource management and planning would be valid if the data have suitable characteristics. Therefore, the initial step in frequency analysis is quality control of data. In other words, events of the flood series should be checked for human interference. If the series is random it can be concluded that the series is caused by natural causes. Run test was applied for selecting stations with random data. Another analysis was outlier detection. The applied test was according to Bulletin 17-B guidelines prepared by Water Research Center [18].

A. Randomness

Statistical analysis is based on the assumption that peak flows are random variables without dependence between them. Nonparametric run test has been described by McGhee [10] for testing the randomness of data series. This test is based on comparing the data series value with a criterion termed as test value. Test value can be defined as median, mode and mean.

Table I Run test analysis result

$$z = \frac{R - \left(\frac{2ab}{a+b} + 1\right)}{\sqrt{\frac{2ab(2ab - a - b)}{(a+b)^2(a+b-1)}}} \tag{2}$$

Where:

a: number of values greater than test value

b: number of values smaller than test value

R: number of runs

The null hypothesis will be rejected if:

The null hypothesis will be rejected if $|z| \geq z_{a/2.}$ The results of run test are given in Table I.

Table II Result of outlier detection in hydrometric station

A. *Detection of outlier*

Outliers are data which deviate appreciably from remaining data. Deleting or retention of outlier influences the type and parameters of the distribution. Treatment of outlier requires both mathematical and hydrological adjustments. There are different methods for identification of outliers such as Dixon-Thompson test, Chauvenet method and so on. The applied method is according to Bulletin 17B (Interagency Advisory Committee on Water Data) [18].

High outlier threshold will be computed by the following equation,

$$X_H = \overline{X} + K_N S \tag{3}$$

X_H = Mean logarithm of peak flows
K_N = Values selected from the associated table
S = Standard deviation of X

If logarithm of the flood data is greater than X_H, the data will be considered as high outlier. Low outlier threshold will be computed by (4).

$$X_H = \overline{X} - K_N S \tag{4}$$

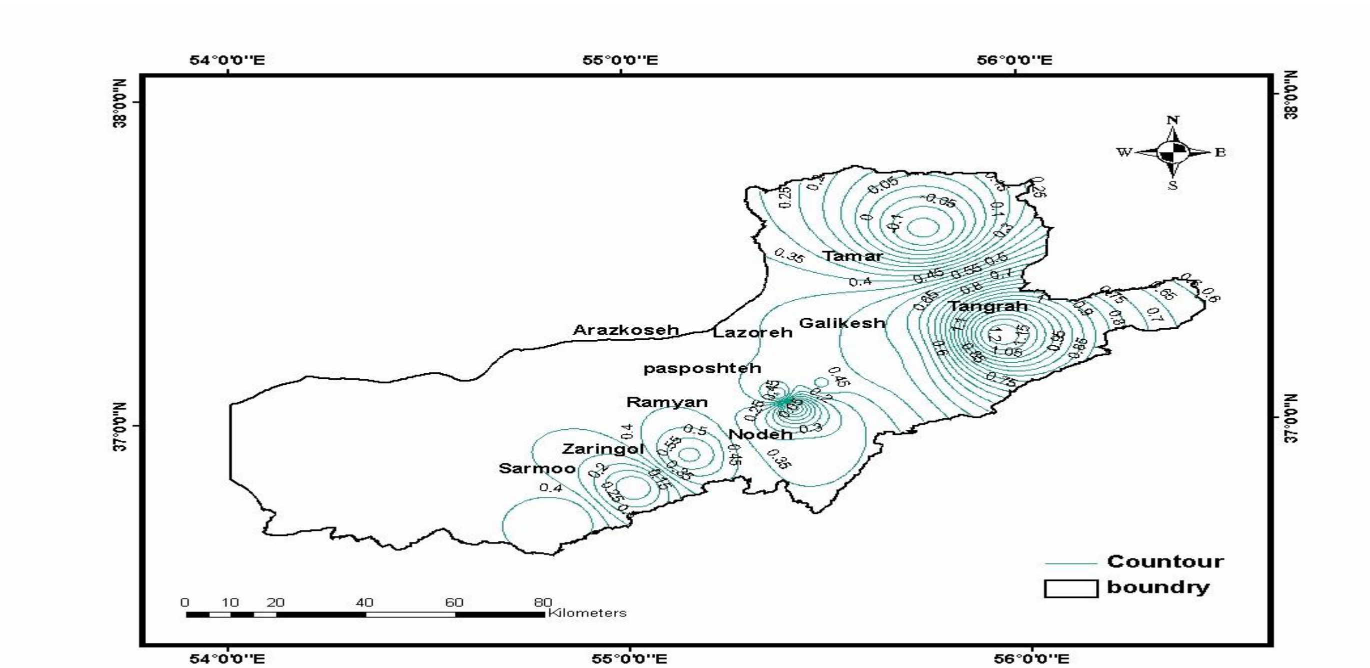

Fig. 3 Skew map of Gorganrood Basin

If logarithm of the flood data is less than X_H, the data will be considered as low outlier. Bulletin 17B recommends that high outliers should be adjusted by information of historical data. In case that there is no high outlier, this value should not be deleted unless the peak flow is seriously in error. After testing the high outlier, identification of low outlier is carried out.

Low outlier, contrary to high outlier, can be censored in

Row	Station	Standard Deviation	Station Skew	High outlier		Low outlier	
				Test value (x_H)	Outlier	Test value (x_L)	Outlier
1	**Arazkose**	0.222	-0.074	370	-	25	-
2	**Pasposhte**	0.369	0.554	560	-	7	-
3	**Tamar**	0.593	-0.125	1536	-	1	-
4	**Tangrah**	0.596	1.277	1058	1650	1	-
5	**Ramyan**	0.333	0.565	296	-	5	-
6	**Zaringol**	0.336	0.107	176	-	3	-
7	**Sarmo**	0.343	0.446	93	-	1	-
8	**Galikesh**	0.551	0.496	995	-	1	-
9	**Lazore**	0.420	0.458	371	-	2	-
10	**Node**	0.387	0.345	262	-	2	-

absence of historical data. High outlier should be adjusted according to historical data. It defines historical data as information out of systematic record which is used to extend the record of largest events to a historic period. This record is usually based on reports, people experiment and investigation on near site. Since no historical information existed in study area, high outlier adjustment based on historical flood couldn't be applied.

Distribution type	**Normal distribution**	**2-Log Normal**	**3-Log Normal**	**Gamma**	**Gumbel**	**Pearson III**	**Log Pearson III**
Tamar	35.1177	4.52941	10.7059	6	17.1765	39.5294	0.41176
Galikesh	40.4118	4.82353	15.7059	19.8235	31.2941	36.2941	0.11765
Lazore	39.8235	6.29412	20.4118	11.5882	30.4118	13.9412	1.88235
Pasposhte	39.5294	4.52941	18.0588	15.4118	31	5.70588	1.58824
Node	36.8824	6.29412	8.05882	7.76471	26.2941	20.7059	3.94118
Ramyan	28.0588	2.76471	19.2353	20.4118	23.3529	2.17647	1.88235
Zaringol	13.9412	4.52942	1	4.23529	10.1177	16.8824	4.52941
Sarmo	21	4.52941	8.05882	5.41177	11	5.41176	0.41176
Tangrah	50.4118	11	76.8824	53.3529	99.8235	91.2941	1
Arazkose	2.76471	6.29412	5.11766	4.2353	4.23529	12.4706	5.11765
Rank Score	58	28	41	35	55	50	15

Table III Flow characteristics of selected stations

The value of 1650 m^3/sec in Tangrah station, occurred in year 2001, was specified as a high outlier as is presented in Table II.

According to the report of the Ministry of Energy, this value was estimated from high water marks. It was first intended to assign this peak discharge of year 2001 as a historical record. Historical period of outlier required to be known for adjusting the outlier.

A. Skew Coefficient

The station skew is sensitive to extreme events. Therefore it is difficult to estimate accurate skew from small sample. Bulletin 17B recommends improving the accuracy of computed skew coefficient by weighting the station skew with generalized skew estimated by pooling information from nearby stations.

Three methods were recommended by Bulletin 17B for developing generalized skew coefficients:

Table IV Chi-square distribution comparison

1) Skew isolines on a map
2) Skew predication equation
3) Mean of station skew

The map of station skew was created, as is given in Fig. 3, and the mean of skew over the region was computed.

Through regression analysis a skew prediction equation , (5), was developed. The model was developed according to skewness of each station and the selected variables. These variables were selected for each station for developing regional models which are given in Table V.

$$Skew = -2.081 + 1.771 \times Gravilious \quad (5)$$

The MSE (means square error) of both methods were computed. Besides, the arithmetic mean of skew coefficient was measured.

Another skew coefficient which is used in this study is weighted skew coefficient. This parameter is combination of generalized skew coefficient and station skew coefficient. Under the assumption, that generalized skew is unbiased, weighted skew would give a better estimation of station skew. The weighted skew proposed by Bulletin 17 B is given in (6).

Station	**Mean**	**Standard deviation**	**Station skew**	**Regional skew**	**Weighted skew**	**MSE of station skew**	**MSE of regional skew**
Arazkose	1.98	0.22	-0.074	0.4	0.272	0.154	0.057
Pasposhte	1.78	0.37	0.554	0.4	0.435	0.196	0.057
Tamar	1.63	0.59	-0.125	0.4	0.260	0.158	0.057
Tangrah	1.46	0.59	1.277	0.4	0.524	0.347	0.057
Ramyan	1.59	0.33	0.565	0.4	0.437	0.197	0.057
Zaringol	1.36	0.33	0.107	0.4	0.322	0.156	0.057
Sarmo	1.07	0.34	0.446	0.4	0.411	0.185	0.057
Galikesh	1.55	0.55	0.505	0.4	0.422	0.191	0.057
Lazore	1.47	0.42	0.458	0.4	0.414	0.186	0.057
Node	1.40	0.38	0.345	0.4	0.386	0.176	0.057

Row	Station	Area (Km^2)	Average elevation of basin (m)	Gravilious coefficient	% Area of class2 NDVI	% Area of class4 NDVI
1	**Arazkose**	1656.6	1154	1.45	11	30
2	**Pasposhte**	112.3	918	1.45	8	81
3	**Tamar**	1563.4	749	1.23	13	75
4	**Tangrah**	1570.9	1385	1.71	6	86
5	**Ramyan**	243.3	1303	1.45	13	9
6	**Zaringol**	340.6	1536	1.21	4	17
7	**Sarmo**	395.3	2011	1.38	18	63
8	**Galikesh**	413.6	1246	1.42	18	47
9	**Lazore**	260.8	1166	1.58	16	31
10	**Node**	870.3	1571	1.65	20	33

$$G_w = \frac{MSE_G(G) + MSE_G(\overline{G})}{MSE_{\overline{G}} + MSE_G} \quad (6)$$

G : Station skew

G_w : generalized skew

MSE_G : mean-square error of station skew

$MSE_{\overline{G}}$: mean-square error of generalized skew

Mean square error of station skew was estimated from (7).

$$MSE_G \approx 10^{[A-B[LOG_{10}^{N/10}]]} \quad (7)$$

Where,

$A = -0.33 + 0.08|G|$ if $|G| \leq 0.9$

$A = -0.52 + 0.03|G|$ if $|G| > 0.9$

$B = 0.94 - 0.26|G|$ if $|G| \leq 1.5$

$B = 0.55$ if $|G| \leq 1.5$

In above equation, G is station skew and N is record length in years. The MSE of the isoline map was 0.057 and the MSE of equation was 0.072. Therefore the smaller MSE was accepted. Then this value was compared to variance of logarithmic skews (0.158). Since the MSE was smaller than the variance, the map method was accepted. Consequently the accepted regional skew was 0.4 and the MSE was 0.057 which are shown in Table III.

Since the PMF (Probable Maximum Flood) value of Glosetan 1 Dam according to [15] was about 5000 m^3/s, the flood quantiles obtained for Tangrah station using station skew and weighted skew could not be verified. Therefore, quantiles estimated based on generalized skew were found more reliable.

B. Selection of Probability Distribution

Seven probability distributions were fitted to the peak discharge. The performance of each distribution was assessed by chi-square value. Distribution with smallest value of chi-square was ranked as value one and the distribution with largest value of chi-square were ranked as value 7. The sum of assigned ranks shows the overall performance of each distribution. The results are given in Table V; it shows that the regional distribution is log-Pearson type III since the sum of the performance indices is smallest.

C. Regional Model

Through factor analysis the independent variable affecting flood were identified. The selected parameters are illustrated in Table V. Regression models were developed between the selected parameters and estimated flood quantiles.

Table VI Selected variables of sub basin

Initially, the regression models were developed for each return period in whole region. The results are given in Table IX. For each homogenous including Group 1 and Group 2 in part A of these papers, the regression models was developed which are given in Table VII and VIII.

R-squared and Standard error were used for comparing different models. It can be seen that the developed models for homogenous regions have higher R-squared.

Therefore, the R^2 in homogenous regions would be higher than models resulted for the whole region.

The R-squared in homogenous regions are more than 0.9. This means that the selected independent variables in models express more than 90 percent of discharge variation which shows their high influence on flood quantiles. It can be concluded that grouping the region into homogenous regions causes the effect of independent variables on discharge be more, and therefore the accuracy of models would be higher. High values of R-squared show the efficiency and suitability of selected independent variables.

V. Conclusion

The basic purpose of this study was to develop regression models to estimate flood quantiles in Gorganrood basin. The results showed that identification of homogenous regions produces more reliable models.

Table VII Regression models for Group 1

One of the independent variable used in analysis was classes of NDVI in order to consider the land cover impact in the analysis.

Two classes were recognized by factor analysis which highlights its importance.

Seven probability distributions were fitted to AMF of the selected stations and values of chi-square were obtained. The overall performances of fitted distributions were assessed with rank score. As shown in Table IV , LP3 with the smallest score was assigned as the regional distribution for the study area.

For each homogenous region and for the entire region regression models were developed. The obtained model for homogenous regions indicated the improvement of R-squared and standard error of models of homogenous regions which proves the necessity of homogenization in regional analysis.

The main contributing factors in whole region were mean elevation. In homogenous regions, area with NDVI greater than 4 was a contributing factor in some return periods, which indicates the importance of this factor in the formation of flood quantiles. In Group 1 for 5 year return period no model could be developed. It seems that it would because of insufficient and low quality data.

Table VIII Regression models for Group 2

Table IX Regression models for whole region

Whole region			
Model	**Return period (yr)**	R^2	**SE**
Log Q=-1.484Log($Elev^2$)+6.11	2	0.512	0.186
Q=-0.083(Elev)-0.027(Area)+173.47	5	0.811	20.49
Log Q=-0.001(Elev)+2.9	10	0.698	0.158
Log Q=-0.001(Elev)+3.108	20	0.623	0.19
Log Q=-0.001(Elev)+3.33	50	0.517	0.24
Log Q=-0.001(Elev)+3.487	100	0.443	0.29

Group 2			
Model	**Return period**	R^2	**SE**
Log Q=-2.8Log(Elev)+0.395Log(Area)+9.29	2	0.98	0.059
Q=-0.047(Elev)+0.051(Area)+0.303(Rain)-27.477	5	0.998	3.66
Log Q= -0.001(Elev)-0.004(N4)+3.312	10	0.997	0.019
Log Q=-0.001(Elev)+0.659(G)-0.001(Rain)+2.74	20	0.99	0.0096
Log Q= -0.001(Elev)+0.887(G)[1]+1.94	50	0.979	0.054
Log Q= -0.001(Elev)+1.021(G)+1.838	100	0.951	0.086

Group 1			
Model	**Return period**	R^2	**SE**
Log Q=2.243Log(Rain)-0.815Log(NDVI4) -3.488	2	1	0.00205
Log Q=-0.011(Area)-0.083(Rain)+56.88	10	0.99	0.0077
Q=-6.769(Area)-48.933(Rain)+34496	20	0.99	4.26
Log Q=4.6Log(Area)+20.047Log(Rain)-65	50	0.998	0.018
Log Q=5.33Log(Area)+23.22Log(Rain)-75	100	0.998	0.022

REFERENCES

[1] J. O. Adegoke and A. M. Carleton, "Relations between soil moisture and satellite vegetation indices in the U.S. Corn Belt," *American Meteorological Society*, vol. 3, no. 4, pp. 395–405, 2002.

[2] M. Arabkhedri, "Investigation on peak discharges of Northern Alborz basin," M.S. thesis, Dept. Natural Resources., Tehran Univ., Karaj, Tehran, 1989.

[3] F. Ghorbani., M. Fathimoghaddam., M. Bina "Using multiple regression for flood modeling, case study: Maroon, Allah and Jarahi catchments," presented at the 7th Int. Conf. River Engineering, Ahwaz, Iran, 2006.

[4] K. M. Hammett and M. J. Delcharco, "Estimating the Magnitude and Frequency of Floods for streams in West-Central Florida," U.S. Geological Survey, SIR 2005-5080, 15 p.

[5] B. L. Henricksen and J.W. Durkin, "Growing period and drought

[1] Gravilious coefficient

[2] Average elevation

early warning in Africa using satellite data ," *International Journal of Remote Sensing,* vol. 7, pp.1583–1603, 1986.
[6] A. Honarbakhsh, "Regional analysis of high flow (case study: Daryacheh Namak, Iran," M.S. thesis, Dept. Natural Resources., Tehran Univ., Karaj, Tehran, 1995.
[7] R. J. Jensen, *Remote Sensing of the Environment, an Earth Resource Perspective.* Upper Saddle River, New Jersey: Prentice Hall, 1985, ch. 3.
[8] M. Khanjani, M. Golmohammadi and Barani, "Regional flood modeling of rivers in Jazmorian basin," presented at the 5th River engineering conference, Chamran University, Iran, 1998.
[9] F. J. Kriegler, W. A. Malila, R.F. Nalepka and W. Richardson, "Preprocessing transformations and their effects on multispectral recognition," in *Proc.* 6th *Int. Symposium on Remote Sensing of Environment*, University of Michigan, Ann Arbor, MI, 1969, pp. 97-131.
[10] J. W. McGhee, *Introductory Statistics.* New York: West Publishing Co, 1985.
[11] R. J. Moore, "Combined regional flood frequency analysis and regression on catchment characteristics by maximum likelihood estimation," in *1987 Proc of Int. Symposium on Flood Frequency and Risk Analyses*, pp. 119-131.
[12] J. W. Rabon, "Evaluation of stream flow-data program in Florida," U.S. Geological Survey Open-file Rep, FL-70008: 70, 1971.
[13] J. W. Rouse, R. H. Haas, J. A. Schell, and D.W. Deering, "Monitoring vegetation systems in the great plains with ERTS," in *Proc. 3rd ERTS Symposium*, NASA, vol. 1, 1973, pp.309-317.
[14] Z. Shiravand, "Estimation of probable maximum flood (PMF) of Glosetan dam basin based on maximum synoptic rainfall," M.S. thesis, Dept. Natural Geography., Tarbyat Modarres Univ., Tehran, 1989.
[15] Z. Samadi, "Investigation factors affecting flood production and developing a quantitative model, using GIS (case study, Can catchment)," in *Proc. of AMS forum: Living with a limited water supply*, San Diego, CA, 2005.
[16] T. C. Stamey and G.W. Hess, "Techniques for estimating magnitude and frequency of floods in rural basins in Georgia," USGS Water-Resources Investigations Rep, 93-4016, 1993.
[17] M. Tokunaga and T. V. Thug, "Finding the relationship between vegetation index and coherence signature to utilize the product of radar interferometry in land cover application," presented at the 23rd Asian Conference of Remote Sensing, 25-29 November, 2002, Kathmandu, Nepal, Paper 178.
[18] Water Research Center. Guidelines for Determining Flood Flow Frequency Bull. 17B, 1981, Washington, DC. , US Water Resources Council.