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Selection of variables for the purpose of regionalization of Iran's precipitation climate using multivariate methods

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Abstract

The study of precipitation climate in any region is important from the view of agricultural production, drainage of urban and agricultural lands, erosion, flood, drought, water resources and civilization. In the present study the regionalization of Iran's precipitation climate was considered. Since the use of various type and number of variables may lead to different boundaries in the resulting precipitation climates, it is helpful to select those precipitation related variables, which represent most of the information from all candidate variables. The selected variables were then used to regionalize Iran's precipitation climate using factor analysis and clustering techniques. Data from 77 weather stations in Iran were used from 1956 to 1998. Twelve variables were selected from the 57 candidate variables, using Procrustes Analysis. The H and Z-statistics, which are based on the L-moment technique, were used to test the homogeneity of each region and select the distribution which best-fitted annual precipitation records- in that region. The countrywide area was divided into six regions with homogeneous and one with heterogeneous precipitation climates. Growth curves, for dimensionless annual precipitation, are illustrated for each region.

Keywords: Cluster analysis; Factor analysis; Iran; L-moment; Precipitation climate; Procrustes analysis

1. Introduction

Precipitation is one of the most important factors in agricultural water management, especially in the dry land farming of Iran. Regionalization of precipitation climates is useful for the optimum design and management of water related activities. Precipitation climates have been studied in different regions such as Guyana (Shaw, 1987); Austria (Ehrendorfer, 1987; Holawe and Dutter, 1999); the Balkans (Maheras and Kolyva-Machera, 1990); the Ijzer watershed 'in western Belgium and northern France' (Mallants and Feyen, 1990); Ethiopia (Eklundh and Pilesjo, 1990); USA (Guttman, 1993; Guttman et al., 1993); Uganda (Basalirwa, 1995); Tropical regions (Jackson and Weinand, 1995); Botswana (Regenmortel, 1995); Spain (Esteban-Parra et al., 1998); the Volcanic Island of Tahiti 'French Polynesia' (Wolting et al., 2000) and Myanmar (Roy and Kaur, 2000). Each of these studies used different type and/or number of variables to

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delineate precipitation climates. For example, Guttman (1993) used seven geographic and climatic variables while Mallants and Feyen (1990) used only daily precipitation data. There seems no general guide for determining the type and number of variables used in precipitation climate studies.

The main objectives of the present study were: (i) Selection of several important variables, which represent most of the information from 57 candidate variables, using Procrustes Analysis (PA), (Krzanowski, 1987), (ii) Regionalization of Iran's area into homogeneous precipitation climates using factor analysis (FA) and cluster analysis (CA) on the selected variables and (iii) Description of each region using weighted-average dimensionless quantile functions or growth curves.

2. Materials and methods

2.1. Study area

The area chosen for this study is the Islamic Republic of Iran. Iran is located in the southwest of Asia. Iran's area is about 1,648,000 km^2 and it lies approximately between 25°N and 40°N in latitude and between 44°E and 64°E in longitude. Iran's important mountains are the Alborz and Zagros ranges. The Alborz Chain Mountains lie from the northwest to northeast and the Zagros Mountains lie from the northwest to southwest part of Iran. These two ranges play an important role in the non-uniform spatial and temporal distribution of precipitation in the whole country.

2.2. Station selection

Data series from 77 weather stations over Iran's area were gathered from 1951 to 1998. Three issues were considered when selecting the climatic stations: (i) Representativeness; (ii) Availability of data and (iii) Length of record. All of the selected stations had at least 30 years data.

2.3. Source, type and screening of data

All data were taken from records at the Meteorological Organization of Iran. Data for fifty-seven variables (Table 1) were obtained for each of the 77

Table 1
Climatological and geographical variables used in the study

Variable(s) description	Variable(s) symbol(s)
Site latitude (°)	X_1
Site longitude (°)	X_2
Site altitude (m)	X_3
Annual total precipitation depth (mm)	X_4
Mean annual of monthly average relative humidity (%)	X_5
Average number of days with precipitation (>1 mm) in a year.	X_6
Annual average of max 24 h precipitation in a month (mm)	X_7
Average of percentage precipitation in winter (January–March)	X_8
Average of percentage precipitation in spring (April–June)	X_9
Average of percentage precipitation in summer (July–September)	X_{10}
Average of percentage precipitation in autumn (October–December)	X_{11}
Mean of dry month precipitation (mm)	X_{12}
Mean of winter dry month precipitation (mm)	X_{13}
Mean of summer dry month precipitation (mm)	X_{14}
Mean of summer wet month precipitation (mm)	X_{15}
Mean of winter wet month precipitation (mm)	X_{16}
Mean of winter precipitation (mm)	X_{17}
Mean of monthly precipitation for every 12 months (January –December) (mm)	X_{18}–X_{29}
Average number of days with precipitation for every 12 months (January–December)	X_{30}–X_{41}
Average of max 24 h precipitation for every 12 months (January–December) (mm)	X_{42}–X_{53}
The ratio of the mean of max 24 h precipitation to total annual precipitation.	X_{54}
The ratio of the mean precipitation for the two consecutive months with the lowest mean in the year to that for the two consecutive months with the highest mean	X_{55}
The beginning month of two consecutive months with the lowest mean in the year	X_{56}
The beginning month of two consecutive months with the highest mean in the year	X_{57}

stations. Missing data were estimated using the inverse square distance method (Viessman et al., 1989). The same period (1956–1998) was used for all sites.

Systematic errors in mean monthly and annual precipitation data (1001 time series) were inspected by fitting a linear trend function to each set and the slopes of fitted lines were tested for significance (Salas et al., 1980). Nearly all series were homogeneous ($P < 0.05$). However, the data records of those ($n = 5$) sites, which showed non-homogeneity, were adjusted using double mass analysis (Linsley et al., 1982).

2.4. Procrustes analysis

The general features of the complete data can be captured by a set of principal components (PC). Although k ($< p$) of corresponding principal component scores (PCS) summarize the data, they typically involve, all of the original p variables. If p is too large, some problems may arise. A PC is defined as a linear combination of the original variables. Since the number of loadings of a PC is equal to the number of variables and a PC is usually interpreted on the basis of corresponding loadings, so its interpretation may not be easy in such a condition. Therefore, it is reasonable to reduce the number of variables to some number q, which must satisfy $q \geq k$ but not much larger than k. Because the PA is an efficient method in selecting the most important variables, which preserve overall configuration of whole data (Krzanowski, 1987), we used it to find the best set of q variables. This method approximates (by least-squares) the matrix of PCS by translation, scaling, and rotation of the q-variable data matrix.

The PA method is described by Krzanowski (1987) in detail, therefore, will be briefly introduced here. It is based on component principal analysis (PCA) and singular value decomposition (SVD). Consider the schematic diagram shown in Fig. 1. The standardized data matrix, $X(n \times p)$, consists of the measured values of p variables for each of the n sites. Data are first standardized to take account of different scale units. For the purpose of predicting the essential dimensionality of the data, PCA is performed initially on $X(n \times p)$. The matrix of PCS for the first k selected PCs is denoted by $Y(n \times k)$. It is possible to select any subset

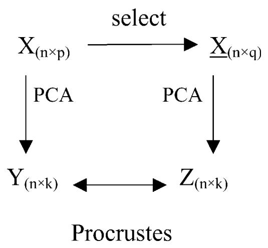


Fig. 1. Variable selecting processes by procrustes analysis.

of q variables from p, which satisfies the two conditions: (i) $q < p$ and (ii) $q \geq k$. Suppose that $\underline{X}$ denotes the $n \times q$ reduced data matrix and Z is the corresponding $n \times k$ matrix of PCS. If the true dimensionality of the data is indeed k, then Y can be viewed as the 'true' configuration, while Z is the corresponding 'approximate' configuration based on only the q important retained variables. The sum of squared differences between the two configurations is as follows:

$$M^2 = \mathrm{Trace}\{YY' + ZZ' - 2\Sigma\}. \tag{1}$$

In this formula, the prime $'$ refers to matrix transpose and Σ is a diagonal matrix, obtained by SVD of the $Z'Y$ matrix as

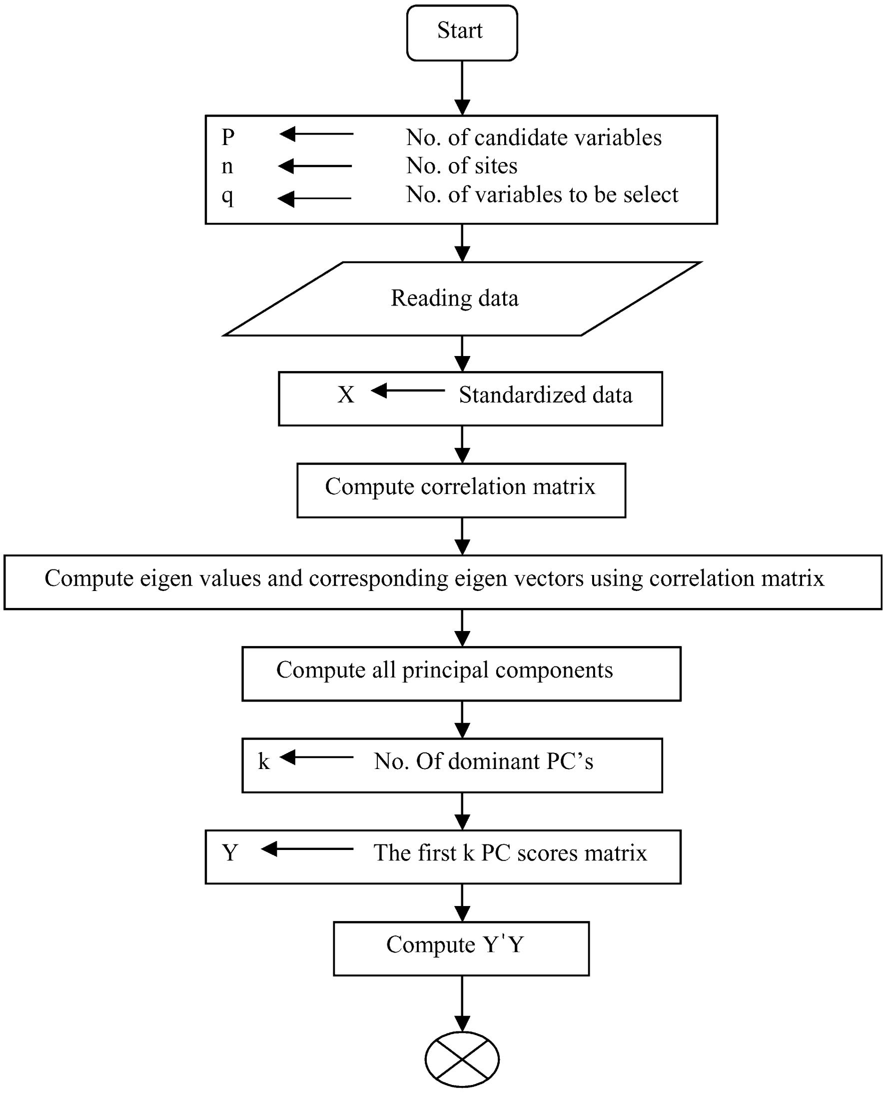
$$Z'Y = U\Sigma V' \tag{2}$$

where $UU' = I_k$, $V'V = VV' = I_k$.

We used the backward elimination process (Krzanowski, 1987), to delete redundant variables in PA by running a computer program, in the Fortran 90, namely CRITERION (Dinpashoh, 2003). The flowchart of this program is shown in Fig. 2. In this program, numerical methods (Overall and Klett, 1973) were used to calculate the eigen values and corresponding eigen vectors of the correlation matrices. Readily available subroutines (Nikkhah-Bahramy, 1997) for the SVD of matrices were also used in our program. The number of PCs for which their eigen values were greater than unity, were considered as k. Six PCs satisfy this condition and account for over 92% of the total variance. Then, to select 12 variables from the 57 candidates by PA, the CRITERION program was run. Another number could be selected instead of 12 (considering the two above-mentioned constraints) but this seemed a reasonable choice as a large number of variables (e.g. 55) led to the previously mentioned interpretation problems while a small number (e.g. 7) led to poor similarity between ‘true’ and ‘approximate’ data configurations. The final selected variables are discussed in Section 3.2.

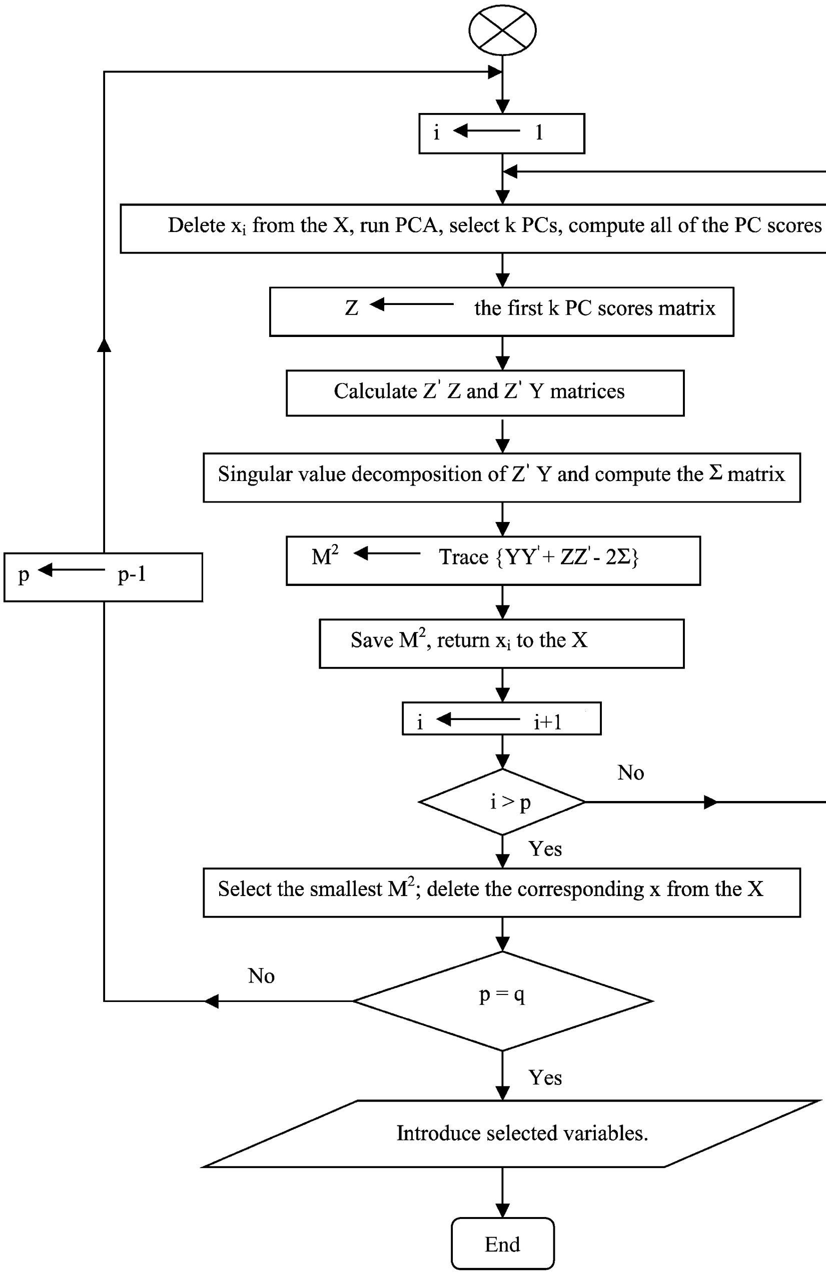
2.5. Factor analysis

The method of FA is described in different textbooks such as Harman (1976), Basilevsky (1994), Manly (1994) and Rencher (1995). This method frequently appears in climatic (Anyadike, 1987; Johnson and Hanson, 1995; Bartzokas et al., 2003) or hydrologic studies (White, 1975; Beaudoin and Rousselle, 1982). The 77 × 12 matrix of standardized selected variables, which was defined by PA in Section 2.4, was subjected to FA. The first three factors, accounting for 98% of total variance, were selected and subjected to VARIMAX NORMALIZED ROTATION (Overall and Klett, 1973). This method



(a)

Fig. 2. Flowchart of CRITERION variables selection model.



(b)

Fig. 2 (*continued*)

of rotation is widely accepted as the most appropriate type of orthogonal rotation (Puvaneswaran, 1990; White et al., 1991) for climate data (Richman and Lamb, 1985; Ogallo, 1989; Kadioglu, 2000). Loadings greater than 0.7, were considered as important loadings. Factor scores for each of the 77 sites were calculated from the standardized variables and the associated factor loadings.

2.6. Cluster analysis

The 77×3 matrix of factor scores was subjected to hierarchical clustering based on the method of Ward's minimum variance (Gong and Richman, 1995; Jackson and Weinand, 1995) using Euclidean distance (Fovell, 1997). This method is one of the most frequently used hierarchical clustering techniques for climatic classification (Kalkstein et al., 1987). It seems that there is no general guide for selecting the number of clusters (Fovell, 1997). We cut the dendrogram from the distance of six to define initial precipitation climates of Iran.

2.7. Homogeneity test

The homogeneity of sites within clusters was determined using L-moment techniques (Hosking and Wallis, 1993). L-moments are expectations of certain linear combinations of order statistics (Hosking, 1990). L-moments are described in detail by Hosking (1990) and Hosking and Wallis (1993), and were used by Castellarin et al. (2001) and Guttman (1993). They suffer less from the effects of sampling variability and are more robust to outliers in the data. The homogeneity measure assumes that in a homogeneous region, all sites will have the same population L-moments, but sample L-moments will differ because of sampling variability. It compares the dispersion of the observed L-CVs (i.e. a function of L-moments which is analogous to the coefficient of variation), at the sites to the dispersion that would be expected in a homogeneous region; the expected dispersion is obtained through simulation. In this study, the H-statistic, which is based on the L-moment technique (Hosking and Wallis, 1993; Castellarin et al., 2001), was used to test for the homogeneity of mean annual precipitation within a group. This method was described in detail by Hosking and Wallis (1993) and used by Guttman (1993) for a similar study in the USA. If $H < 1$, the region is regarded as 'acceptably homogeneous' if $1 =< H < 2$, 'possibly heterogeneous' and if $H >= 2$ 'definitely heterogeneous' (Hosking and Wallis, 1993).

If the sites within a group show up as homogeneous according to the test then the group becomes a distinct region. For heterogeneous groups a discordancy measure called 'D' (Hosking and Wallis, 1993) was computed for all sites and then sites with $D > 3$ were removed from the group and inserted into another neighboring group. Then H-statistic was performed again to test for the homogeneity of the remaining sites in the group. If that cluster still remained heterogeneous, then the S-statistic (Wiltshire, 1986) was used to detect other additional discordant sites. These sites were also removed from the cluster and inserted into another neighboring one. This iterative process was performed until acceptable results were obtained. The summary of results is shown in Table 3.

2.8. Distribution fitting

The regional average L-moments were computed and used to fit the candidate distributions. The five candidate distributions used in this study were: (i) Generalized Extreme Value (GEV); (ii) Pearson Type III (PT3); (iii) Generalized Pareto (GP); (iv) Generalized Logistic (GL) and (v) Generalized Normal (GN). The aim was to choose from these candidate distributions, the one that gives the best fit to the data. The Z-statistic, constructed by Hosking and Wallis (1993), was used to evaluate the goodness-of-fit. This measure is based on the difference between the L-kurtosis, the fourth L-moment, of the fitted distribution and the regional average L-kurtosis of the sample data. L-kurtosis was used because the first three L-moments were used to estimate the three parameters of the distribution. If the absolute value of Z was less than or equal to 1.64, the fit of a distinct distribution was assumed reasonable (Hosking and Wallis, 1993). The distribution with the lowest absolute value of the Z-statistic was selected in this study. If none of the candidate distributions fitted the data, the Wakeby five parameter distribution (Guttman et al., 1993), which is widely recommended, (Hosking and Wallis, 1993), was fitted to the data. For the homogeneity test and goodness of fit, we used the available ready routines (Hosking, 1991).

3. Results and discussions

3.1. Precipitation

Figs. 3–5, respectively, represent Iran's isohyetal, coefficient of variation (CV) and coefficient of skewness (CS) (Stedinger et al., 1992) maps for mean annual precipitation in the study period. The average annual precipitation of Iran, which was estimated by isohyetal method (1956–1998), was about 241 mm. Over half of the country's area receives less than 200 mm/year and over 75% received less than 300 mm/year. The area, which receives more than 500 mm/year, was only 8%. The portions of spring (April–June), summer (July–September), autumn (October–December.) and winter (January–March) precipitation are about 20, 4, 23 and 53% of the total annual precipitation, respectively. Based on available data the annual precipitation CVs vary from 18% in the north (between Caspian Sea shoreline and Alborz mountains) to 75% in the southeast of the country (south of Sistan-Balochistan province). The CV increases from north to south. Also the CV increases as the amount of annual precipitation decreases (Fig. 4). Nearly all sites had positive CS for annual precipitation (Fig. 5). The normality of annual precipitation data series was tested using CS values (Salas et al., 1980) for all sites. The critical CS value of an annual precipitation data series for the time span of 43 years corresponding to the 0.02 significance level, was 0.843 (the thick curve shown in Fig. 5). Except for the southeastern and southwestern part of the Caspian Sea, Yazd, Bushehr and the southeast of the country, CS values were less than 0.843; so it can be concluded that most areas of the country had normal annual precipitation series.

3.2. Selected variables

We assumed that all 57-candidate variables had similar effect (equal weight) on defining

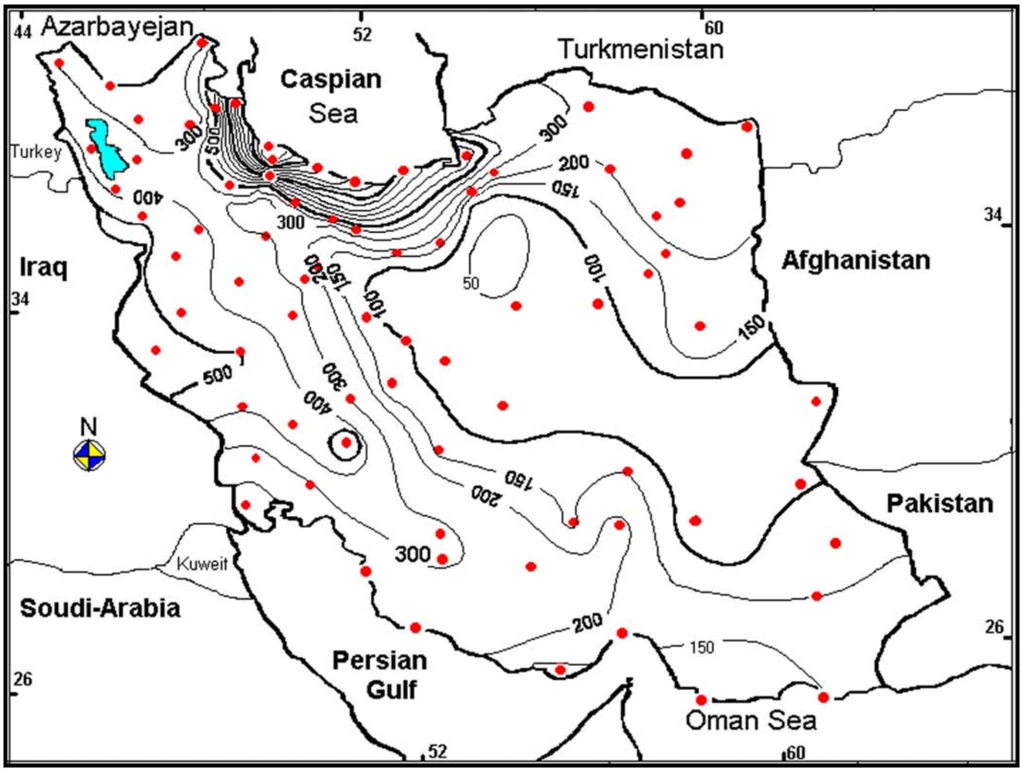


Fig. 3. The mean annual precipitation (mm) in Iran during 1956–1998.

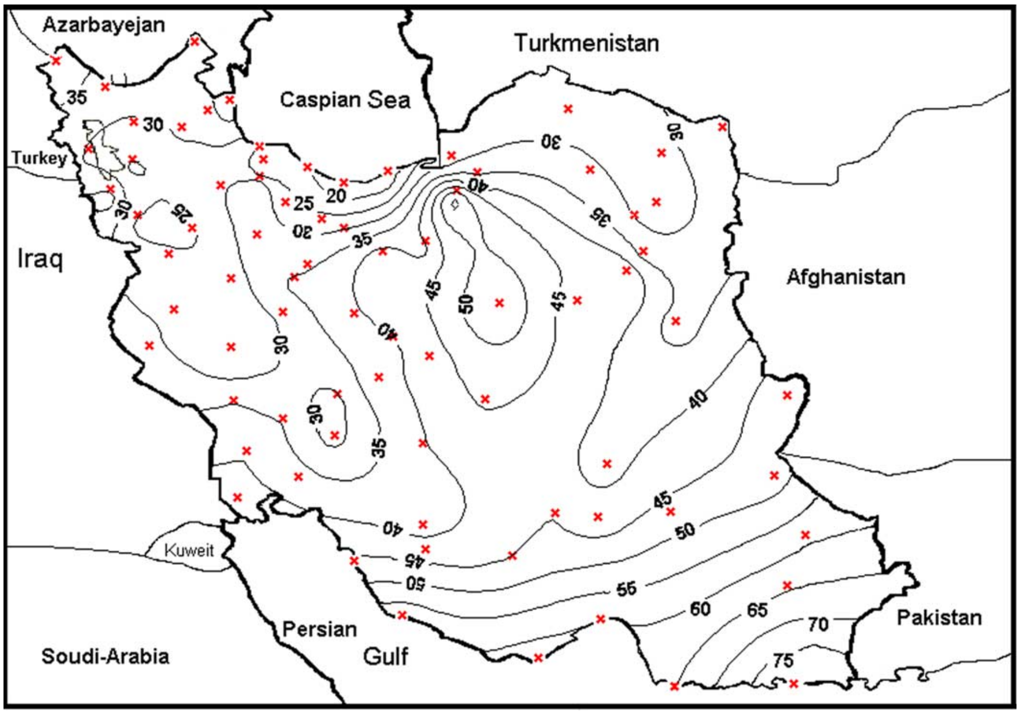


Fig. 4. Coefficient of variation for annual precipitation in Iran during 1956–1998 (%).

the precipitation climates of Iran. Twelve variables selected by means of PA were: (1) average of annual precipitation; (2) total precipitation in the driest month of the summer; (3) July precipitation; (4) November precipitation; (5) the number of days with precipitation in September; (6) the 24 h maximum precipitation in October; (7) the amount of precipitation in the driest month of the year; (8) the winter total seasonal precipitation; (9) October precipitation; (10) number of days with precipitation in August; (11) number of days with precipitation in October and 12) the average of 24 h maximum precipitation in November. These variables (after standardization) were then used as input data for FA.

3.3. Factor analysis

On the basis of FA on the 12 selected variables the first three orthogonal factors were retained, accounting for about 92, 4 and 2% of total variance, respectively (Table 2). After normalized varimax rotation the first and second factors accounted for about 43 and 40% of total variance, respectively.

3.3.1. Factor 1

After varimax rotation the first factor involves a large loading for the following five variables: (1) mean precipitation in the driest month of the year; (2) mean of precipitation in the driest month of summer; (3) July precipitation; (4) number of days with precipitation in August and (5) number of days with precipitation in September. This factor indicated the precipitation in the warm season so it was named ‘summer precipitation’. The first factor scores for 77 stations are presented as isopleths in Fig. 6. The curve pattern illustrated by the first factor scores (Fig. 6) was similar to those of the isohyetal map (Fig. 3). Positive scores are mainly seen in the southern coastal area of the Caspian Sea and southeast part of Iran. These areas are the wettest and driest regions of Iran with regard to annual precipitation, respectively (Fig. 3). In these parts of the country summer precipitation is not an uncommon phenomenon. The main source of

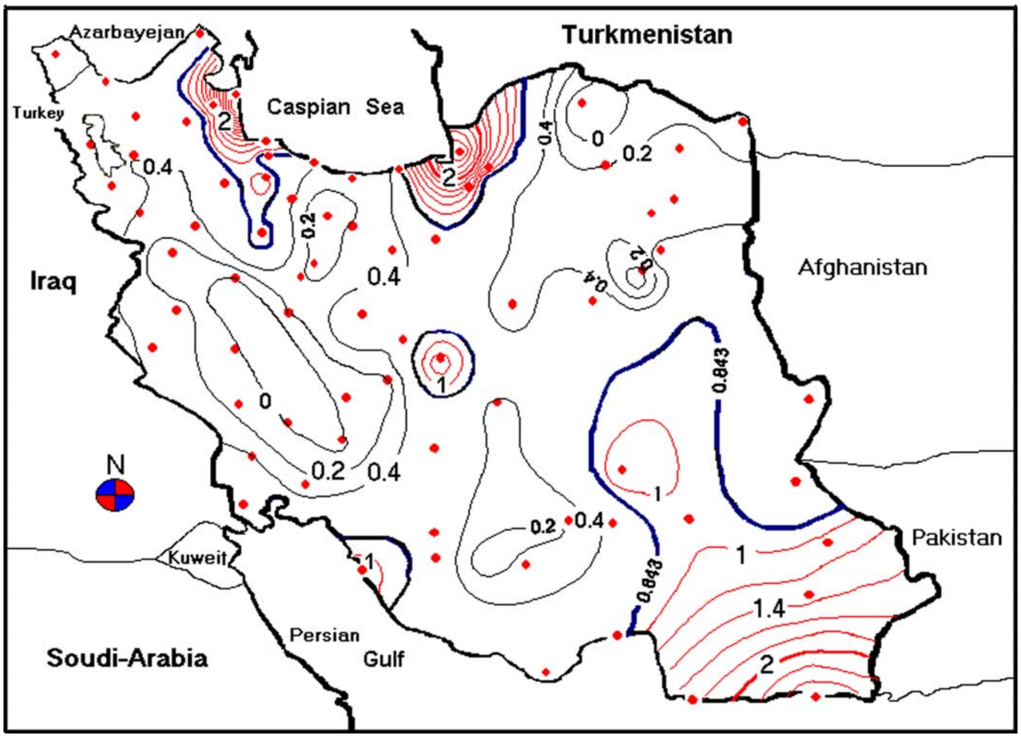


Fig. 5. Coefficient of skewness for annual precipitation in Iran (1956–1998).

Table 2
Factor loadings for the 12 variables selected by Procrustes analysis

Variable	Unrotated			Varimax normalized rotation		
	$F1$	$F2$	$F3$	$F1$ 'summer rainfall'	$F2$ 'yearly,winter and November precipitation'	$F3$ 'October precipitation'
X_4	0.970	−0.208	0.038	0.502	0.778	0.357
X_{12}	0.976	0.139	−0.109	*0.783*	0.533	0.296
X_{14}	0.980	0.143	−0.113	*0.790*	0.533	0.295
X_{17}	0.941	−0.296	−0.045	0.464	0.834	0.256
X_{24}	0.973	0.177	−0.109	*0.804*	0.502	0.307
X_{27}	0.987	−0.007	−0.081	0.688	0.648	0.296
X_{28}	0.962	−0.241	0.018	0.485	0.800	0.33
X_{37}	0.955	0.235	−0.003	0.784	0.436	0.403
X_{38}	0.963	0.232	0.036	0.771	0.439	0.442
X_{39}	0.890	0.119	0.436	0.486	0.439	0.753
X_{51}	0.979	−0.006	−0.064	0.676	0.641	0.309
X_{52}	0.941	−0.294	0.036	0.431	0.825	0.327
Cumulative variance	92%	96%	98%	43%	83%	98%

X_4: annual total precipitation depth (mm); X_{12}: mean of dry month precipitation (mm); X_{14}: mean of summer dry month precipitation (mm); X_{17}: mean of winter precipitation (mm); X_{24}: mean of July precipitation (mm); X_{27}: mean of October precipitation (mm); X_{28}: mean of November precipitation (mm); X_{37}: average number of days with precipitation for August; X_{38}: average number of days with precipitation for September; X_{39}: average number of days with precipitation for October; X_{51}: average of max 24 h precipitation for October (mm); X_{52}: average of max 24 h precipitation for November (mm).

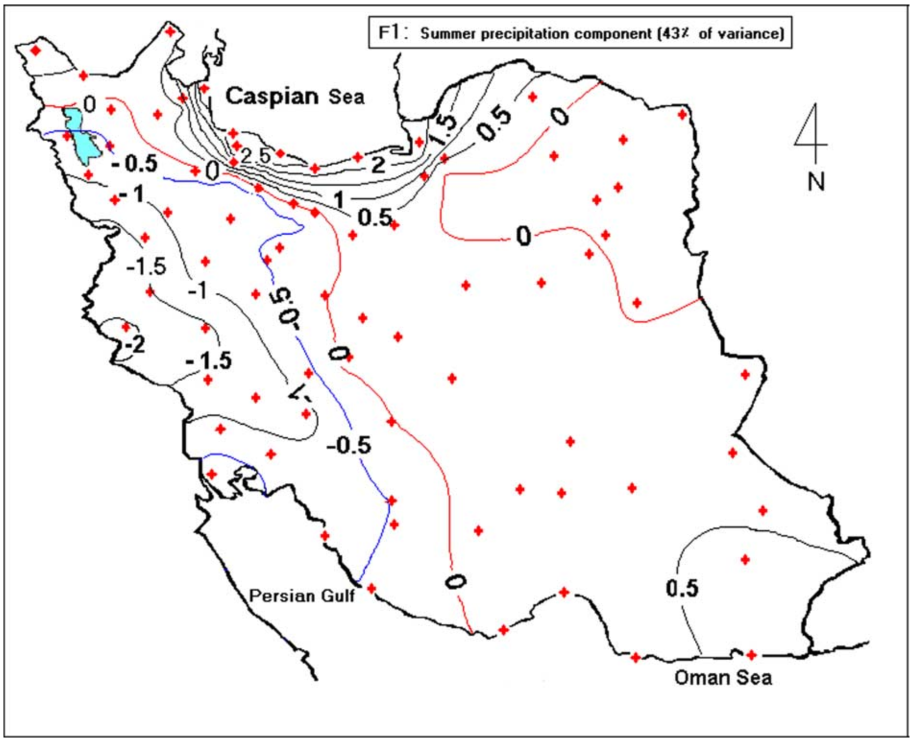


Fig. 6. Isolines of the first factor scores obtained from the 12 selected variables.

summer rainfall in the coastal area of Caspian Sea is attributed to the Caspian Sea (Alijani, 1997) while the main source of the moisture in the southeast part of the country is attributed to Bangal Gulf streams, which come to Iran only in summer from the southeastern part of Iran (Alijani, 1997). On the other hand the sites with negative values are mainly located in the west part of Iran. The summer precipitation in this region (except some northern provinces such as East and West Azarbayejan and Ardebil) is nearly zero due to the presence of Azor's sub-tropical high-pressures (Alijani, 1997).

3.3.2. Factor 2

The second factor has large loadings for the following four variables: (1) total annual precipitation; (2) winter seasonal precipitation; (3) amount of precipitation in the driest month of year and (4) November precipitation. Factor 2 is thus named 'annual, winter and November precipitation'. Positive scores are seen in the southern coastal region of the Caspian Sea (except at Gorgan) such as the west of Zagros Chain Mountains. The main source of moisture in these areas comes from the westerly Mediterranean wind, which brings moisture from Mediterranean Sea to the western part of Iran and cold Siberian northern winds, which comes in winter over the Caspian Sea (Alijani, 1997). Vast areas in the country, especially in dry regions, showed mainly negative factor scores (Fig. 7). These areas seem not to be in the path of the two kinds of winds, which come to Iran in winter time.

3.3.3. Factor 3

The third factor has large loading for only the number of days with October precipitation. So the third factor is named 'October precipitation'. As seen from Fig. 8, the north and northwest parts of Iran had positive factor scores. In these regions October precipitation was relatively high. While in most central areas, such as the southern half of the country, negative scores were present. In these

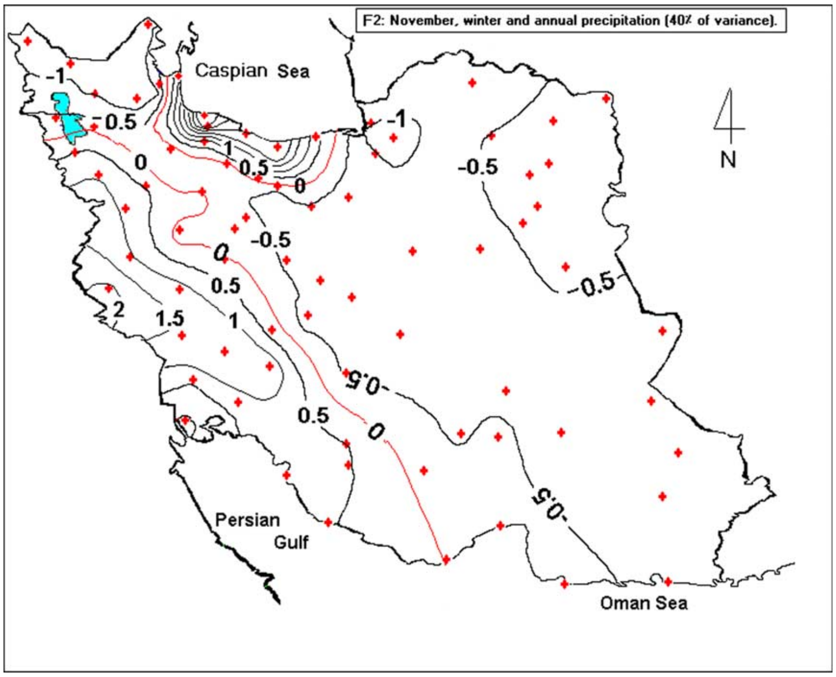


Fig. 7. Isolines of the second factor scores obtained from the 12 selected variables.

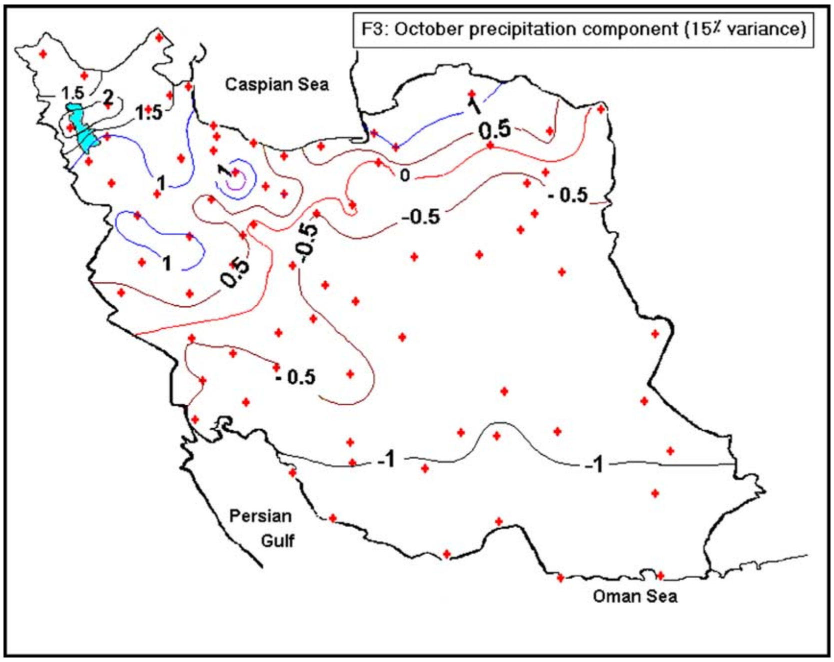


Fig. 8. Isolines of the third factor scores obtained from the 12 selected variables.

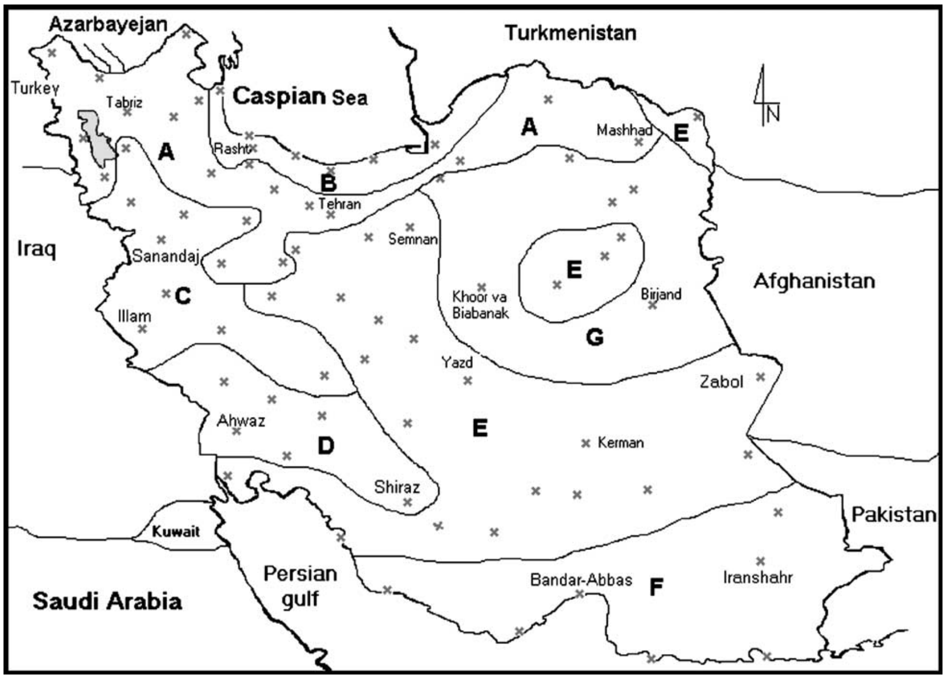


Fig. 9. Precipitation climates of Iran using multivariate analysis with 12 selected variables.

regions, the amount of October precipitation was relatively low.

3.3.4. Precipitation climates

The iterative process for re-clustering of regions, and assessing the discordancy and homogeneity measures for the new clusters led to the seven precipitation climates shown in Fig. 9. Minor modifications to the cluster algorithm groupings of stations removed most of the heterogeneity identified by the L-moment tests. All regions (except region G) were homogeneous ($H < 1$) with respect to annual precipitation data where using the H-statistic as homogeneity test. Region G with an H-statistic greater than 5 is considered as a heterogeneous region (Table 3). The number of stations varied between 6 and 24. All regions (except region E) show geographic consistency. It seems that boundaries between dry regions, especially between regions E and G, cannot be clearly defined using available data.

3.3.5. Growth curves

The regional growth curve is the ratio of the magnitude of the annual precipitation event of return period T years to the mean annual precipitation considered as a function of T; it is assumed to be the same for all sites in a region. The regional growth curves for precipitation climates of Iran were presented in Fig. 10. Values were computed for 10 quantiles (0.01–0.999) and seven regions for annual precipitation. The values for the quantile 0.5 (the ratio of mean to median) for all regions are less than unity. Similar result reported by Guttman et al. (1993) for dry regions of USA. Large slopes of growth curves are evident for dry regions of Iran such as F. This region is located in the coastal regions of the Persian Gulf and Oman Sea, which had a high CV ($>50\%$). However, humid regions, like B, had a somewhat flatter growth curves. Region B is located in the coastal regions of the Caspian Sea, having a lower CV (about 25%). The value of dimensionless annual precipitation for the non-exceedance probability of 0.02 is high (about 0.6) for Caspian Sea shoreline and was low (0.017) for

Table 3
Some useful information for seven precipitation climates of Iran obtained from the 12 variables selected by Procrustes analysis

Region	Location	No. of sites	*H*-statistic value	Distribution	*Z*-statistic value
A	Some areas of East and West Azarbayejan, Ardebil, Ghazvin, Tehran, Hamadan and Northern Khorasan provinces	18	−0.19	GN[a]	−1.35
B	Southern coastal region of Caspian sea	7	0.89	GL[b]	−1.47
C	Some areas of southern East Azarbayejan, Kordistan, Illam, Loristan, Kermanshah and northern half of Chahar-Mohale-Bakhtiary provinces	9	−0.11	GN	−0.4
D	Khozistan (except Abadan), Kohgiloye-va-Boier-Ahmad, central and northwest of Chahar-Mohale-Bakhtiary provinces	6	−0.15	GEV[c]	−0.1
E	Western half of Persian Gulf, southern Khozistan, southern Fars, southern Kerman, north of Sistan-Balochistan, west half of Yazd, central Esfahan, Markazi, Ghom, western Semnan and center and northeast of Khorasan provinces	24	0.49	GEV	0.47
F	Eastern half of coastal region of Persian Gulf, Oman coastal region, Fars, southern Sistan-va Balochistan provinces	7	−1.6	GL	0.38
G	South of Semnan, vast areas of Khorasan, southern and eastern Yazd and west of Esfahan provinces	6	5.19[d]	Wakeby	–

[a] Generalized normal.
[b] Generalized logistic.
[c] Generalized extreme value.
[d] Heterogenous.

Oman Sea and Persian Gulf shoreline. The growth curves of regions G and D are somewhat similar except in the tails of distributions. It seems that regions with high CV of annual precipitation series have steep growth curves for dimensionless annual precipitation in Iran.

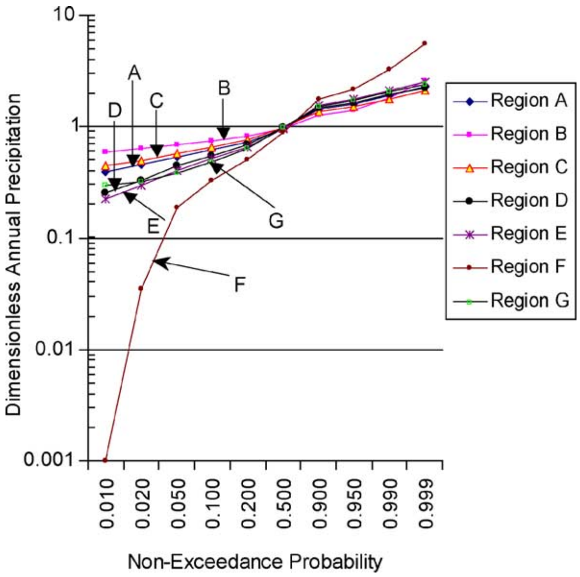


Fig. 10. Growth curves of seven precipitation climates of Iran.

4. Conclusion

By the methodology described herein seven distinct precipitation climates for Iran have been recognized, of which six are homogeneous with respect to the '*H*-statistic'. The precipitation climates of Iran are depicted on Iran's area map. As the homogeneity of groups increases, the confidence that can be placed on quantiles from probability distributions derived from regionally weighted L-moments increases (Guttman, 1993). Growth curves are illustrated for each region (Fig. 10). Three homogeneous regions B, C, and A have relatively flat growth curve slopes. Therefore, predictions of annual precipitation amounts for sites within these regions should have high reliability. These areas have relatively small CV's for annual precipitation amounts. However, dry regions such as F has steep growth curve slope and seems to be due to its large CV for annual precipitation amount. It is concluded that in a drought (wet) condition, dry regions of Iran like region F, which have a steep growth curve slope, could experience a low (high) annual precipitation amount compared to their mean. In wet conditions and in arid areas rainfall comes as high intensity storms, which causes flash floods (Farquharson et al., 1992). In dry conditions and in arid areas (e.g. region F) the dimensionless annual precipitation, growth factor, is much smaller than humid regions. Therefore, the impacts of drought seems would be high for dry regions of Iran.

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