International Journal of Emerging Engineering Research and Technology
Volume 6, Issue 3, 2018, PP 80-87
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Regionalization and Monitoring of Meteorological Period in Karkheh Catchment Basin Using Standard Rainfall Indices and Rainfall Deciles

Saeid Eslamian[1], Mohsen Ghasemi[1], Somayeh Soltani[1], Kaveh Ostad-Ali-Askari[2]*, Vijay P. Singh[3], Nicolas R. Dalezios[4]

[1]Department of Water Engineering, Isfahan University of Technology, Isfahan, Iran.
*[2]*Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran.*
[3]Department of Biological and Agricultural Engineering & Zachry Department of Civil Engineering, Texas A and M University, 321 Scoates Hall, 2117 TAMU, College Station, Texas 77843-2117, U.S.A.
[4]Laboratory of Hydrology, Department of Civil Engineering, University of Thessaly, Volos, Greece & Department of Natural Resources Development and Agricultural Engineering, Agricultural University of Athens, Athens, Greece.

****Corresponding Author:** Dr. Kaveh Ostad-Ali-Askari, Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran. Emails: Koa.askari@khuisf.ac.ir , Kaveh.oaa2000@gmail.com*

ABSTRACT

Drought is one of the most devastating natural disasters that often occurs in different parts of Iran. In this research, in order to monitor the drought in Karkheh watershed, two standard rainfall and rainfall decimals were used and rainfall data of 12 meteorological stations was used. Homogeneity of rainfall data was investigated by sequencing test. After preparing the data, the standard rainfall index was calculated at 12, 9, and 24-month scale as well as annual precipitation deciles. The severity of drought and percent and percentage of village were determined using Kriging method. The results showed that drought of the meteorological period firstly, SPI, drought frequency is based on the index in shorter time scale of the standard rainfall index, and in the event of continued adverse weather conditions, the meteorological drought also occurs in long-run time scales. The severity and frequency of meteorological droughts decrease from west to east of the basin. Also, the percentage of drought (the ratio of drought periods to the entire statistical period) increased, the severity of drought would also increase.

Keywords: *Drought, Standard rainfall index, Distribution, Deciles, Rainfall, Karkheh, Hydrometeorology.*

INTRODUCTION AND REVIEW OF RESOURCES

Water is a pivot of sustainable development and human life, and like many divine blessings, there is a dual nature of good and evil. Water, on the one hand, causes flood damage, resulting in massive damage and financial losses, and on the other hand, the shortage (drought) causes a major change in ecosystems. Dry-year is one of the most progressive and most dangerous natural disasters and is characterized by a persistent and abnormal lack of moisture. Drought can be viewed from four meteorological, hydrological, agricultural and socio-economic considerations. Due to the presence of Iran in the world's dry world belt, its rainfall has three characteristics: low levels, severe fluctuations and uneven distribution. The successive fluctuations in precipitation cause the drylands of varying severity and weaknesses in the country to inflict significant damage on the ecological and economic systems of affected areas. Mackie et al. (1993) (quoted by Xiao) have defined criteria for the occurrence of a drought on a different time scale, they said that a drought occurs when the standard rainfall is persistent and the occurrence of a drought It is high time that the positive SPI index is 1 or less and if the drought event will end. Therefore, each occurrence has a periodic drought that is determined by its start and end, as well as the severity of each fish that has occurred during the dry season (Xiao, 2006).

The standard rainfall index has been widely used by various researchers to quantify dryness. Bourdie et al. (2001), Lucas and Wassilylides (2004), Boyan (2004), Giddings et al. (2005) and Hoong et al. 2005) used the standard rainfall index to monitor droughts around the world, a powerful tool for studying drought. In Iran, Islamian et al. (2006), Darvishi Baghy (1381), Ramezani (2001), Safdari (2003) used the index for drought monitoring of SPI and used this indicator to monitor drought in different parts of Iran.

Research Methodology

Geographical Location of the Area

The watershed of the Karkheh River in the west of Iran is located in the middle and southern regions of the Zagros Mountains. The basin is divided into four sub-basins by the division of the Iranian Water Resources Research Organization into No. 21. Karkheh Basin is located in the geographical range between 46 degrees 5 minutes 49 degrees and 10 minutes' east longitude and 30 degrees 8 minutes 34 degrees 56 minutes' north latitude. The area of this basin in Iran is 50,768 square kilometers, of which 33674 Km is the mountainous land and about 17594 square kilometers it is composed of plains. Four sub-basins of Karkheh watershed are Kashkan, Qarshso, Gamasiab, and Meyreh. Annual precipitation in the basin is 450 mm for the northern parts of the basin up to 150 mm for the southern parts of the basin. Figure 1 shows the location of this basin in Iran.

Used Data

The data required in this study includes monthly rainfall data from different stations at the basin level provided by Iran Water Resources Research Organization. Among the stations in the Karkheh Basin, 12 stations were selected with relatively good distribution in the catchment area (Tabat, 1369). The specifications of these stations are given in Table (1). The 36-year statistical period from 1380 in this research - 1345 to 81 years - has been used for 46 years for selected stations.

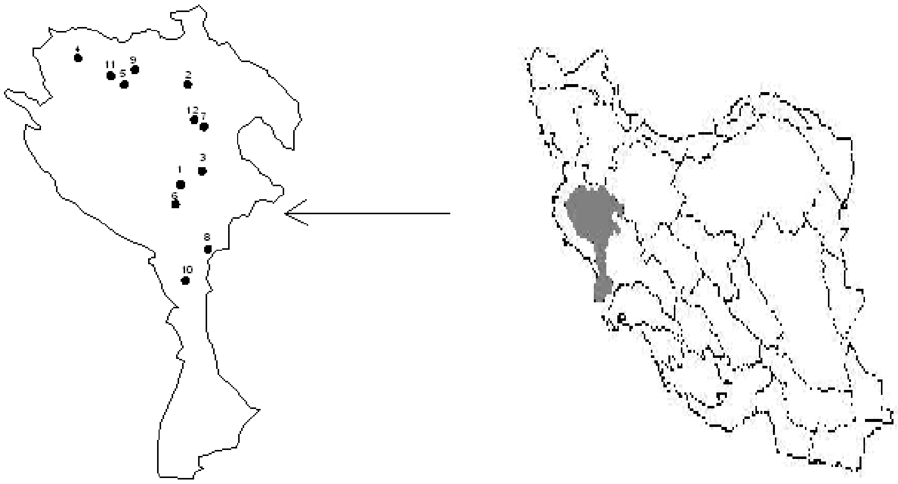


Fig1. *Location of the Karkhe Catchment Basin and Selected Stations.*

Table1. *The Specifications of Stations*

Number	station	Longitude	latitude
1	Aran	55’ 47°	24’ 34°
2	Afarine	55’ 47°	19’ 33°
3	Cham anjir	15’ 48°	26’ 33°
4	Do abmerk	47’ 46°	37’ 34°
5	Ghare baghestan	15’ 47°	14’ 44°
6	Jelogir	48’ 47°	58’ 32°
7	Kaka reza	16’ 48°	43’ 33°
8	Pay pol	9’ 48°	25’ 32°
9	Polchehr	25’ 47°	20’ 44°
10	Poldokhtar	43’ 47°	9’ 32°
11	Plokohne	7’ 47°	21’ 34°
12	Sarab seyd ali	12’ 48°	47’ 33°

Standard Rainfall Index (SPI)

The standard rainfJK6789226478903ll index was presented in 1995 by Maki et al. (Quoted by Hayes). This index is derived from K the difference in rainfall from the mean for a specific time scale and then divided by standard deviation and is the only effective factor in calculating this element of rainfall. This index can be calculated on the time scale of 24, 12.6, 3 and 48 months (Hayes, 2006).The purpose of this indicator is to assign a numerical value to the rainfall so that different areas with different climates can be compared. SPI compares the total cumulative rainfall for a specific station or area at a specific time interval (for example, the last 3 months or the last 6 months) with the average rainfall for the same interval throughout the statistical period. Table 2 shows the classification of drought conditions for different SPI values. The values of the SPI index are derived from the approximations provided by Abramovitz and Estegon Comes (Hughes, 2002). This approximation is as follows:

$$0 < \mathrm{H(x)} \le 0.5$$

$$t = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)}$$

$$t = \sqrt{\ln\left(\frac{1}{(1-H(x))^2}\right)}$$

$$0 < \mathrm{H(x)} \le 0.5$$

$$0.5 < \mathrm{H(x)} < 1$$

(1),(2),(3),(4),(5)

In the above equations (H (x)), the accumulated rainfall probability is observed at a given scale, which is obtained by gamma distribution. Also, the constants of the above equations are:

$c_0 = 2.515517$, $c_1 = 0.802853$, $c_2 = 0.010328$

$d_1 = 3.432788$, $d_2 = 0.189269$, $d_3 = 0.001308$

Conceptually, SPI represents the standard deviations above or below the average. Mackey et al. described the intensity of drought based on the SPI index as follows (Hughes, 2002).

$$S = \sum_{i=1}^{D} SPI_i \qquad (6)$$

In this formula S, drought severity, SPI is the standardized precipitation rating for periods less than one (drought periods) and D is the number of drought periods.

Decimal Index

This index was presented by Maher and Gibbs in 1967. This indicator is essentially derived from the distribution of the probability distribution of long-term recorded long-term rainfall over a fraction of every ten percent of the distribution, and each section is called a decile. The first decade indicates the amount of rainfall that is less than 10% of the precipitation and the second decade indicates a rainfall that is less than 20% of the rainfall (Hayes, 2006).

$$SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right)$$

$$SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \qquad (6),(7)$$

The only effective factor in calculating this rainfall index is the time scale used in this index is the monthly and annual scale. This method is presented to avoid the defects in the normal percentage method. The dechla index has been selected as an Australian drought monitoring system for drought monitoring, because it has relatively simple computations and requires fewer data than Palmer's method. Instead, the bug of this method is that long-term climate statistics are needed to calculate deciles. In table 3, the severity of drought is shown by this index (Hayes, 2006).

Table2. *Classification of Drought*

Drought situation	SPI
Extremely moist	Up to 2
Very moist	1.5 to 1.99
Middle moist	1.49 to 1
Normal	0.99 to -0.99
Light dry	-1 to -1.49
Hard dry	-1.5 to 1.99
Extremely dry	Less to -2

Table3. *The Severity of Drought*

category	percent	situation
1-2	The lowest 20%	The lowest normal
3-4	After 20% lowest	After lowest normal
5-6	20% normal	normal
7-8	Next high 20%	Next high normal
9-10	Highest 20%	Highest normal

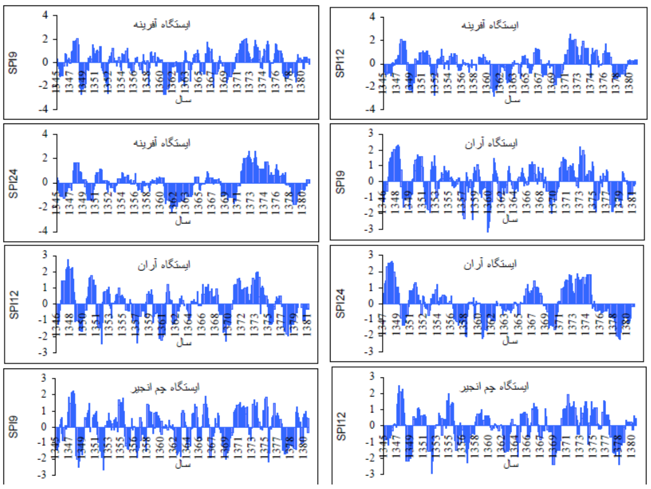
METHOD AND MATERIAL

In this study, in order to monitor the meteorological drought in Karkheh watershed, two SPI indices and rainfall deciles were used among drought indices. Before data analysis is performed, it is necessary to ensure the quality of the data as well as the completeness of the data series. Without conducting an accurate assessment of the data, statistical analysis does not produce reliable results. In order to verify the homogeneity of rainfall data, the sequence test method was used and it was determined that the rainfall data in the selected stations are homogeneous. SPI was used to calculate the SPI index in the 9, 12, and 24-month intervals (Saadati, 2006). The SPI program is a program that inputs its monthly rainfall data and outputs a monthly standardized precipitation (SPI). After calculating the SPI, the drought severity was determined using the relation (5) for the selected stations. In order to divide the droughts by SPI, two characteristics of drought severity and relative frequency of drought were zoned: the percentage of drought frequency, drought duration ratio In order to calculate the frequency of drought in different stations, first, according to the calculated SPI values of drought periods, it was determined from the sum of these courses the total period of drought in each station was calculated and finally, by dividing the period of drought over the entire statistical period, the percentage Drought frequency for each station in three scales: 12, 9 and 24 Month was achieved.

Because the droughts in this study are studied in long-term scales, the annual rainfall index was calculated and evaluated. In order to calculate the annual deciles at the stations, first, the annual precipitation statistics were arranged in ascending order for each station in the entire statistical period. The distribution of rainfall in each plant was then divided into ten sections. This work was done using SPSS software. In order to categorize the index of rainfall, 10% was selected. Because this decay shows the critical conditions of rainfall (Hayes, 2006). Drought zoning in this study was performed using SURFER 8 software and Kriging method. The Kriging method provides the possibility of obtaining a quantity of a quantity at a point with known coordinates using the same quantity at other points with known coordinates. Kriging is known as the best unbiased linear estimator, and one of the most important features is the possibility of achieving an error associated with any estimate.

RESULTS AND DISCUSSION

After calculating the SPI index, at 9, 12, and 24-month scales, the charts of this indicator were plotted for different stations (Fig. 2). Using these charts, you can specify the years in which the drought occurred. According to the SPI and decay indexes, in most areas of Karkheh watershed occurred during 1963-63, 1969-70, 137-78, and 1978-1793 meteorological droughts. Sadati (2006) also determined the SPI index of 1378-1377 and 1378-1388, which has occurred in most areas of Isfahan province.



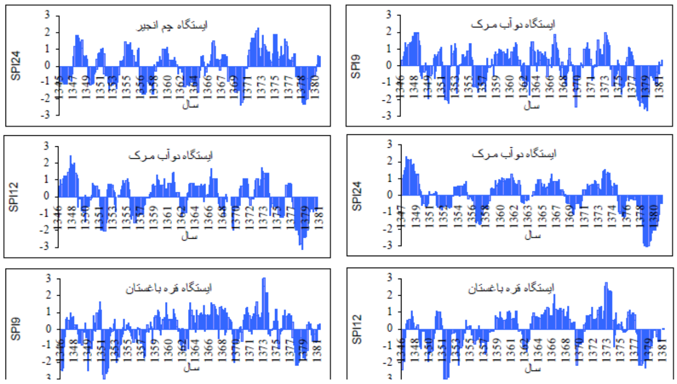
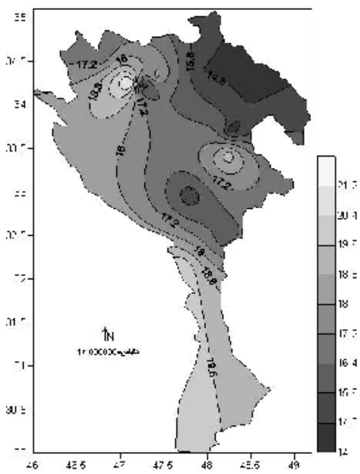
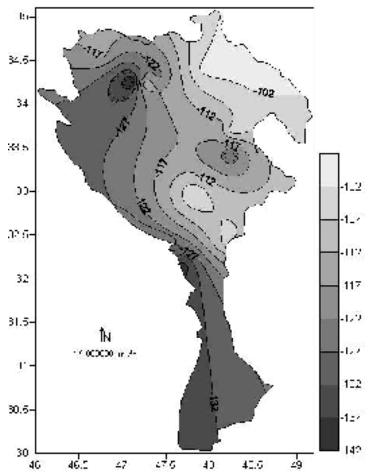


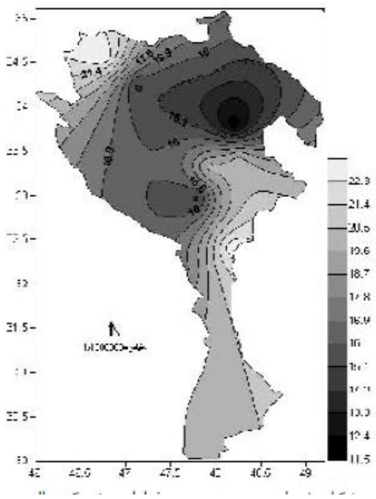
Fig2. *Indicator Chart*

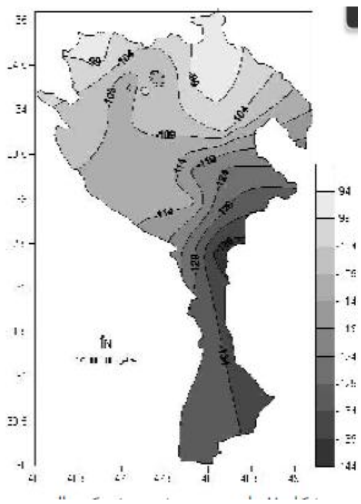
Based on the SPI variation charts and its comparison for 12, 9, and 24-month periods, the results are as follows:

- The SPI index has more fluctuations in the short-term scales than long-term scales, and it can be interpreted that short-term SPI is more sensitive to moisture conditions.
- 2- In the 9-month time scale, the number of droughts with high proposed thresholds is low, but the duration of these droughts is low. Whatever the time scale is increased, the number of droughts is low and the duration of droughts is longer. 3. Dryings occur initially at shorter time scales and, if drought persists, also occurs in long-term time scales.
- Asian (2006) also achieved similar results in the application of the SPI index in the Khorasan Razavi province. Drawings from drought zonation based on the SPI index are shown in Figures 3 to 8.









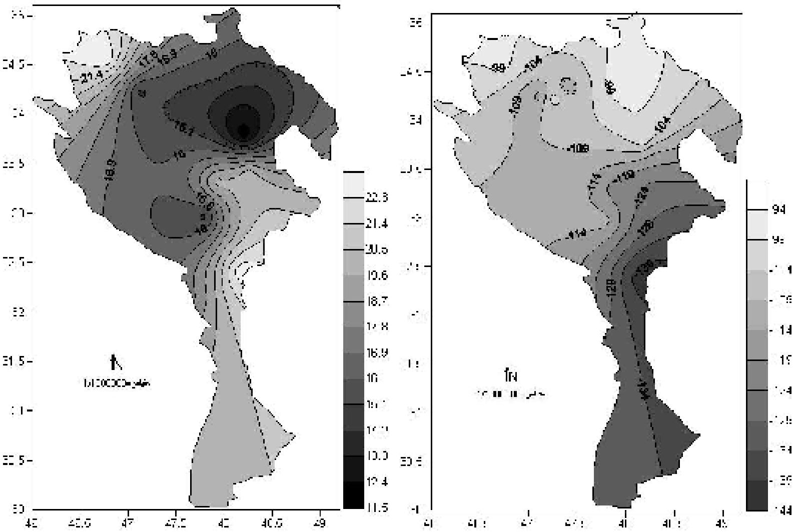


Fig3 -8. *Drawings from Drought Zonation Based on the SPI Index*

The results showed that the highest drought severity occurred on the 9 and 12-month scale in the south of the basin, and the lowest severity of drought occurred in the northeastern part of the basin. Also, changes in drought severity in the central part of the basin are more than the rest and the severity of drought decreases from west to east of the basin. Also, the highest frequency of drought occurred in the south and northwest basins and the lowest frequency of drought occurred in the northeastern basin.

Also, from west to east of the basin, the frequency of droughts is reduced. Comparison of drought severity zoning maps and relative frequency of dry years based on the SPI index in the 9 and 12-month scale shows that these two characteristics in the basin have the same changes and in the basin area where the frequency of drought increased, the intensity Drought has also increased. The highest drought severity occurred on a 24-month scale in the southeast of the basin and the lowest severity of drought occurred in the north basin. The drought severity decreased by twenty-four-month SPI from east to west of the basin. Also, the frequency of droughts in the south and northwest of the basin is lower and in the north-eastern part of the basin.

Table4. *Rainfall at Different Stations*

90%	80%	70%	60%	50%	40%	30%	20%	10%	
635.3	549	499	461	436.2	389.8	377.8	320.8	293.9	**Aran**
693.9	623.8	550.4	516.4	502	502	462.4	345.8	298. 9	**Afarine**
635.8	590.1	556.5	528.4	484	452.2	419.6	358.6	314. 4	**Cham anjir**
641.1	587.2	567.5	553.5	471.5	454.7	386.7	351.8	289.5	**Do abmerk**
491.6	471.4	450.4	440.4	395	375	358	300.7	219	**Ghare baghestan**
701.6	596.1	542.27	471.2	429.7	381.9	314.9	291.7	242. 7	**Jelogir**
695.8	653	592.1	534.2	501	465.2	419.2	387. 8	320	**Kaka reza**
437.1	376.1	336.2	321.1	270.6	258.3	236	212.2	190	**Pay pol**
554.3	506.1	467.9	387.9	372.2	375.5	320.1	436.6	239.4	**Polchehr**
639.6	544	503.4	435.8	402.2	372.8	350.2	271.4	212.7	**Poldokhtar**
514.2	472.7	435.7	401.2	394	374.3	354.2	258.7	223.4	**Plokohne**
774.8	665.5	576.5.	536.6	519.2	461.9	430.6	356.6	279.3	**Sarab seyd ali**

Table 4 shows rainfall at different stations. After calculating the annual decompositions, annual precipitation statistics were allocated to each station for each station in each of the ten categories. The results showed that according to the decile index in most areas of Karkheh watershed occurred during 63-62, 70-69, 1377-78 and 1378-1793 weather meteorological events.

Figure 9 shows the 10% decomposition in the Karkheh basin. According to this form, eastern parts of the basin have better conditions, and in the south of the basin, it is 10 percent less than the rest.

The map also shows that the northern parts of the basin have better conditions than the southern side of the basin.

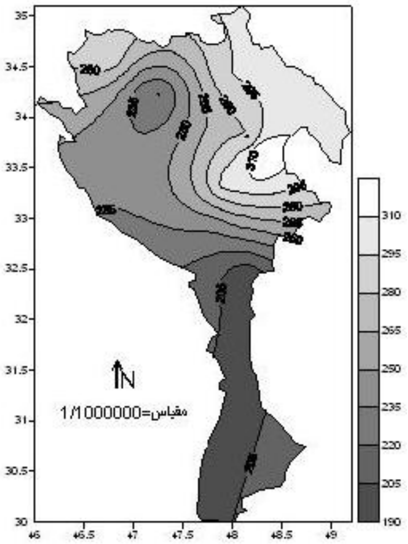


Figure9. *Decomposition of 10%*

Conclusion

In this study, droughts in the Watershed Karkheh basin were investigated in the statistical period between 1345-1696 and 1380-181. Two SPI and decile indicators were used to determine drought weather periods. The results showed that meteorological drought with different intensities based on SPI indices and rainfall deciles in the catchment area occurred and the entire drought zone experienced meteorological phenomena. According to the results obtained during the years when the SPI index of drought was severe, the rainfall was higher in the first, second and third decades. This suggests that the two SPIs indicate a nearly identical result in determining the drought status. In general, the severity and frequency of meteorological droughts have decreased from west to east of the basin, and the severity and frequency of meteorological droughts in the basin area have a direct relationship with the increase in the frequency of drought, its severity has also increased.

According to the results of this study, the SPI index has limitations in addition to its advantages. Short-term measures of the SPI index of three and six months are not suitable for drought monitoring, since they also show partial fluctuations in rainfall as droughts. They give in the long-run (24 and 48-month) scales, the SPI indicator is not suitable for drought monitoring, since SPI values on these scales are zeroed.

According to the results, the rainfall index is also limited. One of these constraints is the time scale of this indicator, which is not measurable as the SPI index in the 9, 6, 3, and ... months. Another limitation on the decay index is that the exact indicator of the drought is not determined on an annual basis, meaning that the annual decades determine the years of the drought, but it is unclear at what times these droughts have occurred. The results of calculations of deciles showed that according to the decay index in most areas of Karkheh watershed occurred during 1963-63, 1969-70, 137-78 and 1978-1793 meteorological droughts. The decomposition area map also showed that the northern parts of the basin had better conditions than the southern parts of the river.

References

[1] Bhuiyan, C. 2004. Various drought indices for monitoring drought condition in Aravalli terrain of India. Proccedings of the 2nd ISPRS Conference, Istanbul.

[2] Bordi, S., Frigio, S., Parenti, P., Speranza, A. and Sutera, A. 2001. The analysis of the standardized precipitation index in Meditteranean area. Annali Di Geofisica, 44(5-6): 965-977.

[3] Giddings, L., Soto, M., Rutherford, B. M. and Maarouf, A. 2005. Standardized precipitation index zones for Mexico. Atmosfera, PP: 33-56.

[4] Hayes, M. J. 2006. Drought Indices. Available online at: http: www. drought.unl.edu. what is indices.htm.

[5] Hughes, B. L. and Saunders, M. A. 2002. A drought climatology for Europe. Int. J. Climatol, 22:1571-1592.

[6] Hung, W. U, Hayes, M. J., Wilhite, D. A. and Svoboda, M. D. 2005. The effect of the length of record on the standardized precipitation index calculation. Int. J. Climatol, 25: 505-520.

[7] Lukas, A and Vasliliades, L. 2004. Probilistic analysis of drought spatio-temporal characteristics in Thessaly region, Greece. National Hazard and Earth System Sciences, 4: 719-731.

[8] Shiau, J. T. 2006. Fitting drought duration and severity with two-dimensional copulas. Water Resources Management, 20: 795-815.

Citation: *Saeid, E., Mohsen, G., Somayeh, S., Kaveh Ostad, A., Singh, V. and Nicolas R., D. (2018). "Regionalization and Monitoring of Meteorological Period in Karkheh Catchment Basin Using Standard Rainfall Indices and Rainfall Deciles". International Journal of Emerging Engineering Research and Technology, 6(3), pp.80-87.*