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The Variation of Annual Precipitation and Precipitation Concentration Index of Iraq

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Abstract: *The shortage of water and the increasing temperature have an effect on the distribution and the amount of rainfall. The long-term of dry or wet season is showed in this paper through Run Theory using monthly precipitation data of 29 stations in Iraq that are divided into three zones for30 years from* 1980 to 2010 *in order to understand the behavior of precipitation. The annual precipitation of Mosul, Amara and Diwaniya stations fluctuated between dry and wet years. Also, the number of dry years is larger than the number of wet years for the three zones of Iraq. In the northern zone, the longest dry succession years are found in Sinjar with 24.3% and Teleafer 23.1%, while the longest wet succession years found in Makhmoor with 18.5% of the total annual precipitation over the study period. In the middle zone, the longest dry and wet succession years are found in Khahlis and Heet stations with 23.8% and 15.6% of total annual precipitation over the period respectively. At least, in the southern zone, the longest dry succession years is found in Rutba station with 30.7% stations of the total annual precipitation over the study period which is the longest dry succession of all and the longest wet succession period was in Samawa station with 48.7% of total annual precipitation over the period. On the other hand, the precipitation concentration index was calculated for each station throughout study period and it varies between less and more than 16 referring to that the precipitation doesn't have a uniform distribution and sometimes irregular or strong irregular distribution, thus, the study area is divided into two zones: moderate precipitation concentration zone which has a range of PCI<16 and maximum frequency of 83.87% of all years for Sulaymaniyah and minimum frequency of 51.61% of all years of Kirkuk, Khahlis and Rutba stations. While the High precipitation concentration Index zone has an irregular or strong irregular distribution with maximum frequencies of 93.54% of all years for AL-Hai station and minimum frequency of Tuz station of 54.83% of all years. Also, the Standard precipitation concentration index SPCI at each station is computed and Emadiyah station has a minimum change through the study period with PCI<16 zone whereas, Duhook and Rutba have a maximum change of SPCI. The SPCI has a big variation in PCI>16 zone exceptionally, Biji, AL-Hai and Samawa stations.*
Keywords – *Run theory, Precipitation, Dry season, Wet season, Iraq*

I. Introduction

The Drought and the shortage of Food due to climate change could be a problem for the world.Also, the increasing in the mean precipitant in the globe could be a result of the rising atmospheric moisture content associated with warming [(1)]. Therefore, making a plan and the management of precipitation that depend on prediction of precipitation amount can help humankind to face these problems. The precipitation constriction index [(2)] allows quantifying the relative distribution of precipitation patterns. It also provides a good presentation to the spatial variability of monthly precipitation [(3)]. Therefore, the precipitation constriction index leads many researchers to make studies about it.

Raziei et al. (2008), analyzed spatial distribution of the seasonal and annual precipitation in western Iran using data covering the period 1965–2000. They applied The Precipitation Concentration Index (PCI) to regionalize climate in study area and used nine precipitation-derived. They suggested five spatially homogenous sub-regions that could be identified, characterized by different precipitation regimes [(4)].

The monthly precipitation data of Spain was used by Luis et al.(2011) to find the Precipitation Concentration Index and they studied the mean values of annual, seasonal and wet and dry periods of PCI in the conterminous Spain for two normal periods (1946–1975) and (1976-2005). They found that during the wet (months) period, the Atlantic storm track effects on Precipitation in Spain to follow a general NW-SE spatial pattern, while during the dry (months) period, it follows a predominantly N-S spatial pattern. Also, they show that the annual values of PCI combine the two patterns and show a SW-NE PCI gradient. They found that the changes in PCI seem to be complex and appear to be related to global atmospheric features and synoptic and local factors affecting precipitation trends [(5)].

Ngongondo et al. (2011), studied the spatial and temporal characteristics of rainfall in Malawi. They analyzed monthly, seasonal and annual scales of Rainfall variables and indicators of study period. They used Mann–Kendall and linear regression methods to analyzed temporal trends, and used spatial correlation function to investigate the spatial rainfall variability. Furthermore, Heterogeneity of monthly rainfall was investigated using the precipitation concentration index (PCI). They showed that the country was further characterized by unstable monthly rainfall regimes, with a value for all PCIs of more than 10 and an increase in the inter-annual rainfall variability [(6)].

Valli et al. (2013), focused on the assessment of changes occurring in the temporal distribution of rainfall with 30-years database of monthly precipitation to identifying the Monthly, Seasonal and Annual distributions, variations and trends in ten districts of study area. Precipitation Concentration Index was analyzed at annual and seasonal scale to identify the pattern of rainfall in the study area for the period of 1981-2010 which showed an irregular distribution of rainfall with values in the range of 16 to 35.

Zhao et al. (2011), developed a precipitation concentration index to categorize the variability of annual precipitation. They found that the variability in summer contributed to the annual variability less than that of other seasons. Also, in different years, there is a great difference in the contribution of the different monthly variabilities to the annual mean variability. They showed the variability of precipitation increased in north of Xinjiang, especially the increasing was significantly in mountainous regions, whereas, the variability increased slightly in South of the Xinjiang only, consistent with the distribution of precipitation.

In this paper, the run test is used to determine which year is dry or wet, based on the mean of study period and explain longer succession dry or wet period to describe the behavior of precipitation and succession of dry or wet years. Moreover, the precipitation concentration index and standard precipitation concentration index are calculated for all stations of the study period.

II. Data and methodology

2.1 Study Area and Data Acquisition

The monthly precipitation data of 29 weather stations of Iraq are obtained from the Iraqi Meteorological Origination and Seismology (IMOS) of period 1980-2010.

All stations are divided into three zones according to the annual precipitation of metrological stations of Iraq [(11)]. Table 1 gives the description of the stations. The annual mean is estimated at 216 mm, but in the northeast, the ranges of rainfall graded from 1200 mm to less than 100 mm which covers 60 % of south of Iraq. The annual winter precipitation is over 400 mm of the northern zone stations with a Mediterranean climate. The middle zone is located between Desert and Mediterranean zones have annual precipitation in range of 200–400 mm in winter season. The southern zone or Desert zone was distinguished by precipitation amount at 200 mm in winter season or less annually [(12)].

Table 1: Description of Stations

No.	Stations	Longitude (°)	Latitude (°)	Elevation (meter)
Northern zone				
1	Emadiyah	43.30	37.05	1236
2	salahaddin	44.20	36.38	1075
3	Sulaymaniyah	45.45	35.53	843
4	Sinjar	41.83	36.32	583
5	Duhook	43.00	36.87	554
6	Teleafer	42.48	36.37	373
7	Kirkuk	44.35	35.47	331
8	Dukan	44.95	35.95	276
9	Mosul	43.15	36.31	223
10	Tuz	44.65	34.88	220
11	Khanqin	45.38	34.35	202
12	Makhmoor	43.60	35.75	22
Middle zone				
13	Biji	43.53	34.9	116
14	Hadithah	42.35	34.13	108
15	Samaraa	43.88	34.18	75
16	Heet	42.75	33.63	58
17	Ramadi	43.32	33.45	48
18	Khahlis	44.53	33.83	44
19	Baghdad	44.40	33.3	32
20	Hai	46.03	32.13	17
21	Amara	47.17	31.83	9
22	Basrah	47.78	30.52	2
Southern zone				
23	Rutba	40.28	33.03	222
24	Najaf	44.32	31.95	53
25	Kerbela	44.05	32.57	29
26	Hella	44.45	32.45	27
27	Diwaniya	44.95	31.95	20
28	Samawa	45.27	31.27	11
29	Nasiriya	46.23	31.02	5

2.2 Study Methods

2.2.1 Run theory

Run Theory indicates that the same events which have continuous appearance. When (Pi, i=1, 2… n), the annual precipitation could be a discrete sequence. The average annual precipitation (P) was considered as the threshold value, therefore; abundant precipitation of a period will be observed when Pi > P, that means there is a positive variation. Also, little precipitation of a period can be considered when Pi ≤ P, that means there is a negative variation.

When Pi > P or Pi ≤ P occurs more than twice in succession, the period is referred to as continuous wet or dry years, with the former being referred to as positive runs and the latter as negative runs, thereby analyzing the variations in precipitation [13,14].

2.2.2 Precipitation Concentration Index (PCI)

PCI refers to The Precipitation Concentration Index [15]. The equation 1 uses was annual scale for each station:

$$PCI = \frac{\sum_{i=1}^{12} P_i^2}{(\sum_{i=1}^{12} P_i)^2} * 100 \qquad ...1$$

Where Pi is the monthly precipitation in i month.

- PCI < 10 indicates uniform precipitation distribution (low precipitation concentration).
- PCI >11 and <15 indicates moderate precipitation concentration.
- PCI >16 and < 20 indicates irregular distribution.
- PCI > 20 indicates a strong irregularity (i.e., high precipitation concentration).

For seasonal precipitation, the previous equation was modified to be suitable for Climate of Iraq which has recording rainfall data of eight months:

$$PCI_{seasonal} = \frac{\sum_{i=1}^{8} P_i^2}{\left(\sum_{i=1}^{8} P_i\right)^2} * 75 \qquad ...2$$

Moreover, the standard precipitation concentration index (*SPCI*) are calculated to understand the features of annual precipitation concentration variations [14].

$$SPCIzi = (PCIzi - \overline{PCIz})/\overline{PCIz} \quad ...3$$

Where PCIzi is the PCI of i-th year at station Z; and $\overline{PCIz}$ is the average PCI at station Z.

III. Results and Discussion

3. 1 Variances of Annual Presentation:

The runs of years above and below of the mean are shown in Table 2. The maximum runs are noticed in Mosul, Amara and Diwaniya stations which refer to a big fluctuation in the amount of precipitation. Also, the maximum runs above the mean were found in Makmoor only located in the northern zone whereas Kerbela and Diwaniya have a maximum runs above the mean in the southern zone that means these stations have wet years more than dry years of study period in spite of the drought that effect on the study area because the number of dry years of all station is larger than wet years. As be obvious, the runs above the mean are always less than the number of runs below the mean in the middle zone. The number of runs below the mean is larger than above the mean of all stations in the three zones except the stations that are mentioned above. In addition, the maximum runs below the mean (dry years) are recorded in Rutba station in the southern zone due to the desert climate and drought effecting. Depending on the total annual precipitation series in Iraq by runs test, the analyzing of precipitation's characteristics in dry and wet years from 1980 to 2010 was performed. The most common dry or wet year's succession was two years of three zones is shown in Table 3. The longest dry period was 13 years is found in Rutba station in the southern zone from 1997-2010 and takes 30.7% of total annual precipitation over the period. Also, in spite of the drought effect in this area, the longest wet period was 10 years in Samawa station for the same zone which takes 48.7% of total annual precipitation over the period.

Table 2: Numbers of dry and wet years of all station according to runs test

No.	stations	mean	runs	Above the Mean	Below the Mean
Northern zone					
1	Emadiyah	701.474	14	14	17
2	salahaddin	602.670	12	15	16
3	Sulaymaniyah	699.648	13	15	16
4	Sinjar	366.488	10	11	20
5	Duhook	547.422	15	13	18
6	Teleafer	317.346	12	13	18
7	Kirkuk	348.932	12	12	19
8	Dukan	736.019	14	15	16
9	Mosul	358.877	16	14	17
10	Tuz	279.118	15	14	17
11	Khanqin	290.538	14	12	19
12	Makhmoor	293.945	12	16	15
Middle zone					
13	Biji	198.845	16	15	16
14	Hadithah	125.564	10	13	18
15	Samaraa	168.022	14	13	18
16	Heet	121.706	15	15	16
17	Ramadi	114.028	16	13	18
18	Khahlis	173.022	11	14	17
19	Baghdad	112.208	16	12	18
20	Hai	124.854	16	15	15
21	Amara	169.118	17	13	18
22	Basrah	138.403	14	14	17
Southern zone					
23	Rutba	112.0008	10	10	21
24	Najaf	96.72581	16	15	16
25	Kerbela	90.56185	12	16	15
26	Hella	99.60645	16	13	18
27	Diwaniya	103.5993	18	16	15
28	Samawa	95.14003	10	14	17
29	Nasiriya	123.2323	15	11	20

Whereas, the longest dry period of northern zone was 9 years in Sinjar from 1997-2005 with 24.3% of total annual precipitation over the period and Teleafer at the same period with 23.1%, however, although, the amount of rainfall in the northern zone is larger than other zones, the longest wet period was 5 years from 1984-1989 in Makhmoor with 18.5% of total annual precipitation over the period. The longest dry and wet period of the middle zone were 9 years from 2001-2009 in Khahlis station with 23.8% of total annual precipitation over the period and 8 years from 1998-2005 in Heet with 15.6% respectively.

Table 3: the succession of dry and wet years of three zones of Iraq

Zones	2	3	4	5	6	7=>
Positive						
Northern zone	20	18	8	1	0	0
Middle zone	13	6	10	1	0	1
Southern zone	6	3	5	0	1	2
Negative						
Northern zone	15	6	16	5	2	3
Middle zone	12	9	10	1	0	4
Southern zone	12	3	9	2	0	2

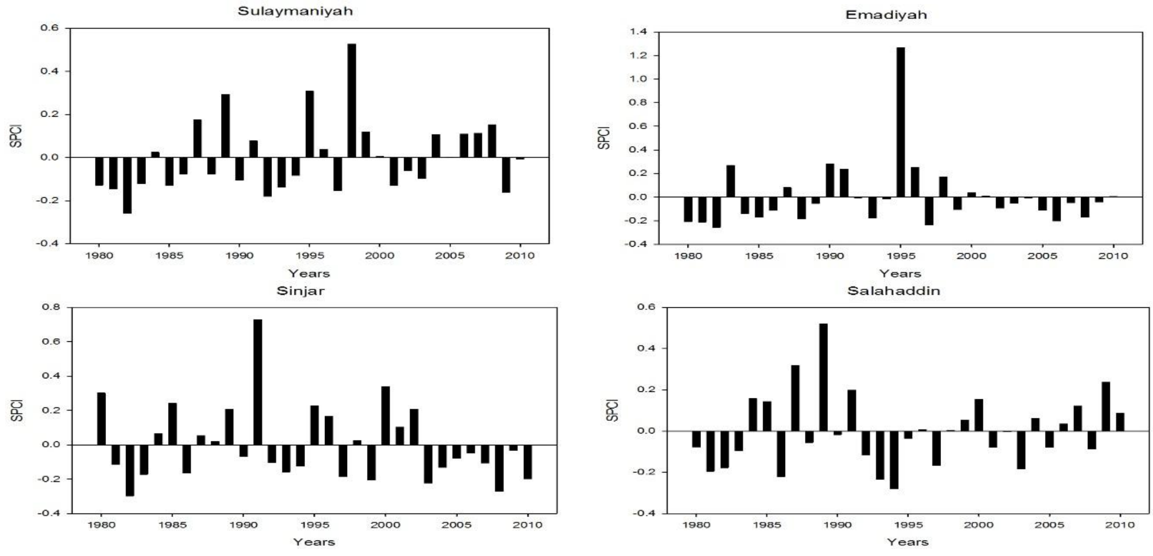
3. 2 Variances and Characterizes of PCI

The temporal analysis of Precipitation Concentration Index shows the range of PCI<10 has never been recorded (Table 4). In addition, the most years of study period varies between <16 and >16 for all stations which indicates that the concentration of precipitation is not low for the study area. According to results, the stations are classified to two zones based on PCI<16 and PCI>16. The PCI<16 zone has a larger frequencies than others with 63.52% of years of all stations. In this zone, Sulaymaniyah station takes a maximum frequency of PCI<16 with 83.87% of all years during study period. Whereas, Kirkuk, Khahlis and Rutba stations have a minimum frequency of PCI<16 with 51.61% of all years during the study period. On the other hand, the PCI>16 zone obviously has a larger frequencies of this range than others with 76.20% of most years of all stations and the maximum frequency of this range was noticed in Hai station with 93.54% of years. Whereas, Tuz station takes a minimum frequency of same rang of PCI with 54.83% of years, which means Tuz, Kirkuk, Khahlis and Rutba stations have fluctuation between 16<PCI>16 because the amount of precipitation is fluctuated. In contrary, Sulaymaniyah and Hai stations are more stable in term of PCI value than other stations because they have a maximum frequency of PCI range of years that is also due to the precipitation amount. Standard precipitation concentration index SPCI is found in all stations to understand the variances of PCI value during the study period. The standard precipitation concentration index SPCI was found to understand the variation of PCI of all station according to the classification of PCI variation.

Table 4: the frequencies of precipitation concentration index in stations

No.	stations	<10	<16	>16	% no. of years with PCI<16 (1980-2010)
PCI<16 zone					
1	Emadiyah	00	24	7	77.41
2	salahaddin	00	22	9	70.96
3	Sulaymaniyah	00	26	5	83.87
4	Sinjar	00	18	13	58.06
5	Duhook	00	21	10	67.74
6	Teleafer	00	19	12	61.29
7	Kirkuk	00	16	15	51.61
8	Dukan	00	23	8	74.19
9	Mosul	00	19	12	61.29
10	Khahlis	00	16	15	51.61
11	Khanqin	00	17	14	54.83
12	Makhmoor	00	20	11	64.51
13	Rutba	00	16	15	51.61
PCI>16 zone					% no. of years with PCI>16 (1980-2010)
14	Biji	00	12	19	61.29
15	Hadithah	00	9	22	70.96
16	Samaraa	00	12	19	61.29
17	Heet	00	9	22	70.29
18	Ramadi	00	11	20	64.51
19	Tuz	00	14	17	54.83
20	Baghdad	00	9	22	70.96
21	Hai	00	2	29	93.54
22	Amara	00	5	26	83.87
23	Basrah	00	4	27	87.09
24	Najaf	00	4	27	87.09
25	Kerbela	00	7	24	77.41
26	Hella	00	6	25	80.64
27	Diwaniya	00	5	26	83.87
28	Samawa	00	4	27	87.09
29	Nasiriya	00	5	26	83.87

Figures 1 and 2 show the fluctuations of SPCI of each station according to PCI<16 and PCI>16 zones. The SPCI of Emadiyah station could be little than other stations in the same zone in spite of the anomaly value at 1995, whereas, Duhook and Rutba have a biggest change of SPCI in PCI<16 zone.



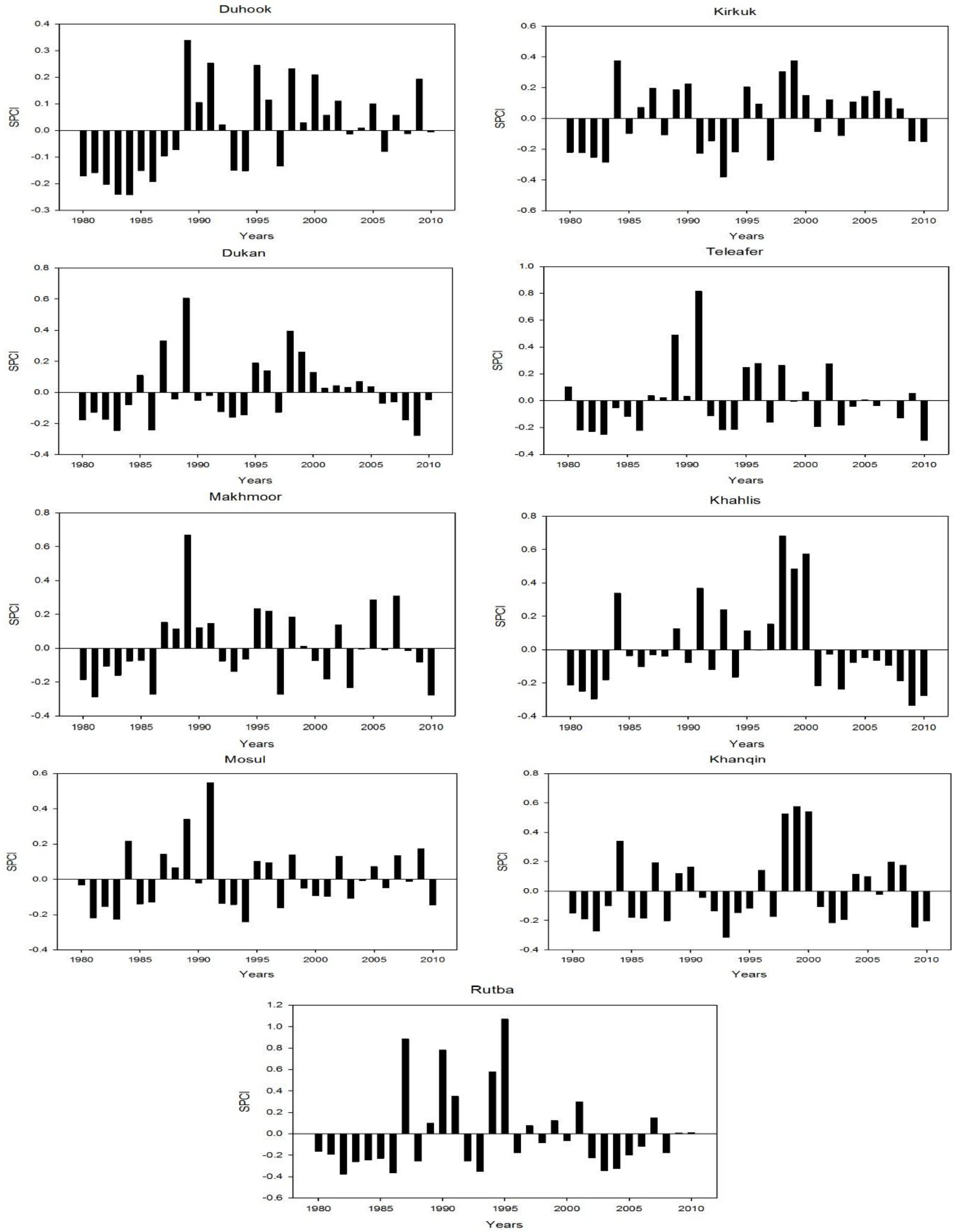
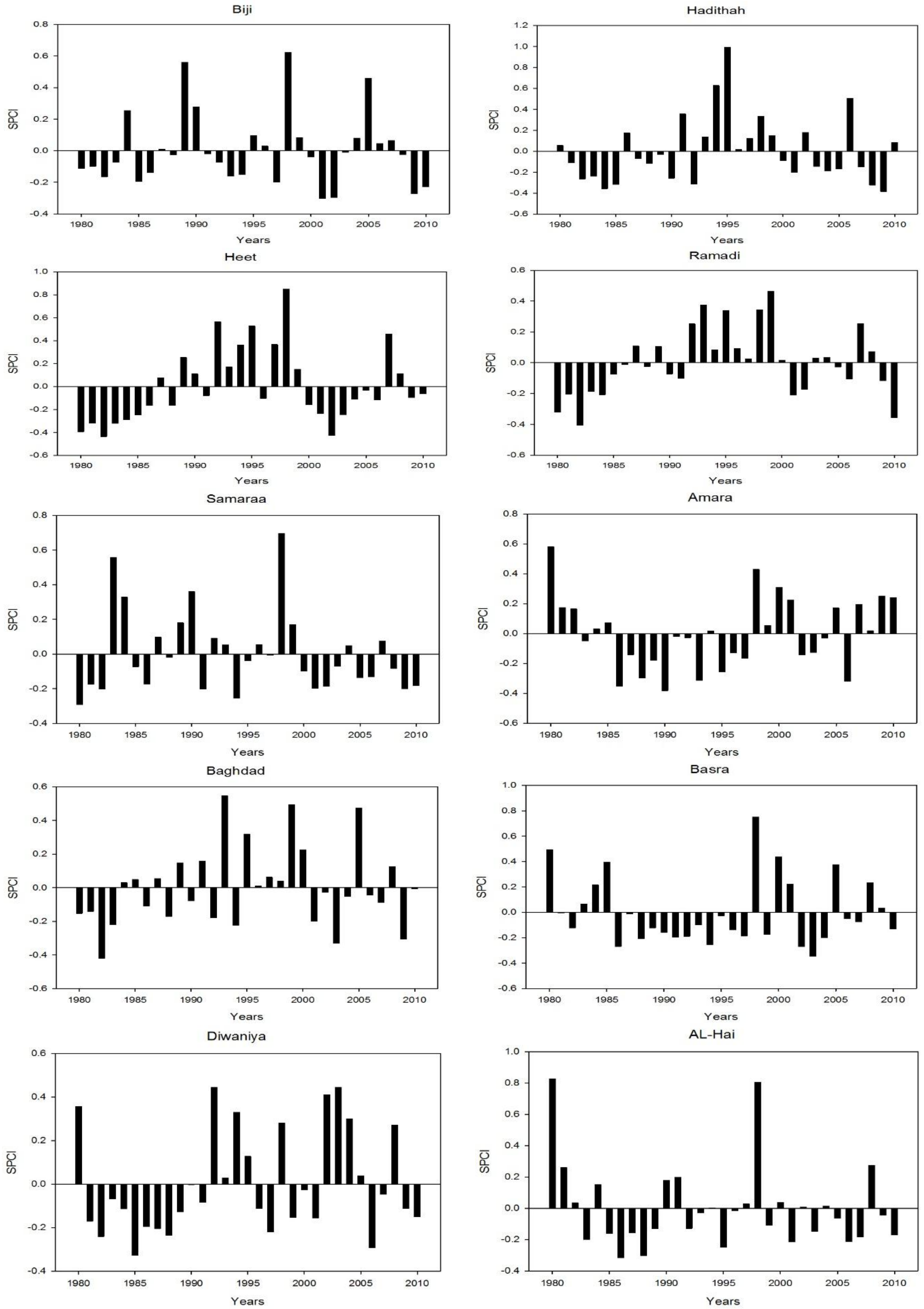


Figure 1: the variation of SPCI of PCI>16 zone stations during study period

On the other hand, the variations of SPCI in PCI>16 zone could be clear in all stations, except, Biji , AL-Hai and Samawa stations that have a little change in SPCI values compare with others despite the anomaly values in some years.


Biji
Hadithah
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Samaraa
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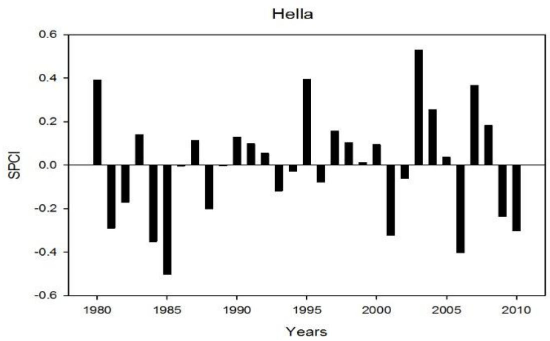

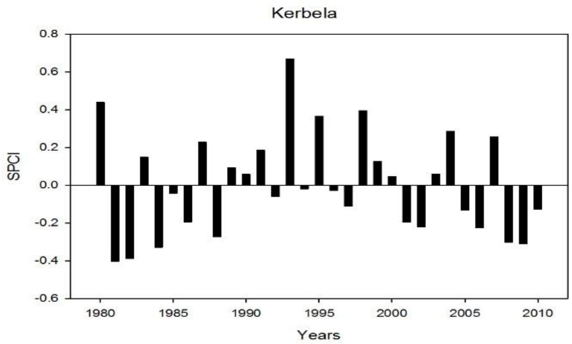

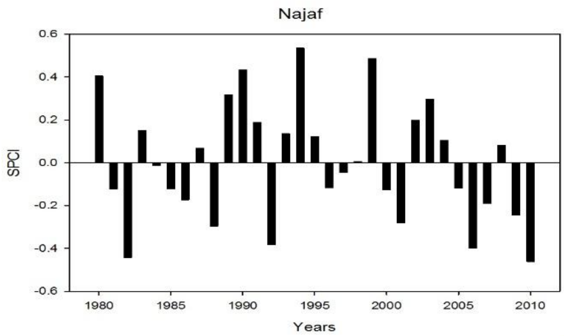

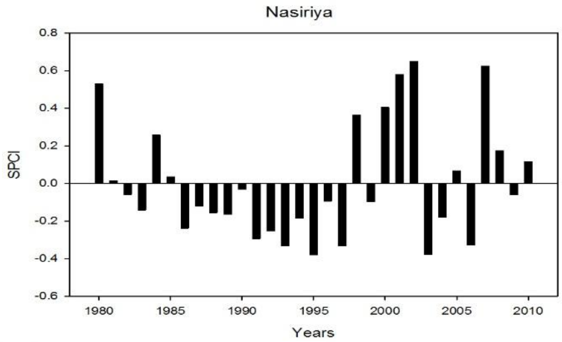

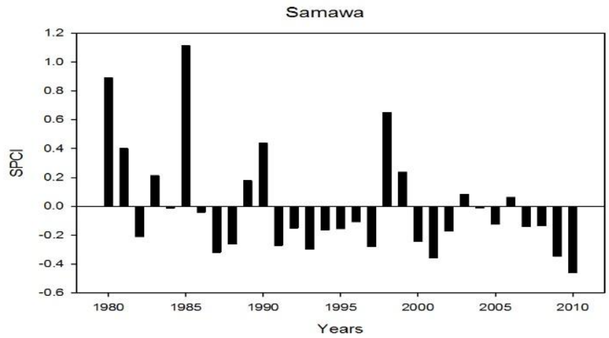

IV. Conclusion

The annual precipitation of Mosul, Amara and Diwaniya stations fluctuate between dry and wet years throughout study period according to the Run Theory. The number of dry years is larger than the number of wet years for the three zones of Iraq. The maximum number of wet years was found in Makhmoor station in the northern zone and Kerbela and Diwaniya stations in the southern zone. In the middle zone, the drought was obvious because the number of dry years were larger than wet years of all stations. The desert climate and the drought have a big effect on Rutba station where the maximum number of dry years was recorded there and also, the longer succession of dry years was found in the same station of 13 years with 30.7% of total annual precipitation over the period, whereas, the longest wet period was 10 years in Samawa station of same zone which takes 48.7% of total annual precipitation over the period. The most common dry and wet year's succession was two years of three zones. Also, the longest dry succession of northern zone was 9 years in Sinjar with 24.3% and Teleafer 23.1%, of total annual precipitation over study period and the longest wet succession was 5 years in Makhmoor with 18.5% of total annual precipitation over study period. Conversely, the longest dry and wet succession of the middle zone were 9, 8 years with 23.8% in Khahlis station of total annual precipitation over the period and 15.6% in Heet respectively. On the other hand, the behavior of precipitation concentration index of study area varies between <16 and >16 also, the range PCI<10 was not found in this study of all stations throughout study period, therefore the precipitation of study area is classified as having a non-uniform distribution and, according to PCI the precipitation sometimes it is classified as having an irregular or strong irregular distribution. The study area is divided to two zones based on the range of PCI these zones: Moderate precipitation concentration zone which have range PCI<16 with maximum frequencies 63.52% of years of all stations. Also, 83.87% of all years of Sulaymaniyah station takes PCI<16, whereas, 51.61% of all years of Kirkuk, Khahlis and Rutba stations take PCI<16. The second zone which has a high precipitation concentration Index has an irregular or strong irregular distribution where 76.20% of all years takes PCI>16. 93.54% of years in AL-Hai station take PCI>16 and this maximum frequencies of this rang in this zone, whereas Tuz station has only 54.83% of its years have PCI>16.

The Standard precipitation concentration index SPCI fluctuates at each station. The anomaly value of SPCI at 1995 in Emadiyah station and has a minimum change throughout study period in PCI<16 zone and Duhook and Rutba have a maximum change of SPCI. The SPCI is a little variation of Biji , AL-Hai and Samawa stations and all stations have a big variations in PCI>16 zone.

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