Analysis of Seasonality Precipitation Concentration in Northern of Iraq

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Abstract

This research is about analysis seasonality of precipitation concentration in the north of Iraq, by using multiple methods of precipitation concentration Index .The first is the standard vectors method that determines the date of concentration and the number of the rainy months, the second, precipitation concentration index (PCI) that classify the degree of (PCI) annually, supra-seasonal, seasonal depending on monthly precipitation data from nine metrological stations For 36 years (1979-2014), using Excel, Arc map 10.8 and Oriana software in calculates and representation of precipitation concentration. the result shows that all stations in the study area share the same date (Jan.-Feb.) and the stations differ in the length of the rainy season (7-9) month. and for PCI results, PCI annual shows denote a moderate concentration in the whole study area, PCI supra-seasonal value shows (in the wet season uniform rain distribution, the dry season value shows high concentration, PCI seasonal Shows (autumn) moderate concentration, winter: low concentration in all stations, in the spring: PCI value shows the moderate concentration in Erbil, Kirkuk, Sulaymaniyah, Salaheddin, and the other stations shows uniform rain distribution.

Keywords*: seasonal rain concentration, mathematical vector, PCI.*

تحليل التركز الفصلي للمطر شمالي العراق

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الخلاصة:

يتناول البحث تحليل التركز الفصلي للمطر في شمال العراق , باستخدام عدة مؤشرات للتركز المطري وفصلية الامطار منها اسلوب المتجهات الرياضية (STANDARD VECTORS) والذي يقيس موعد التركز وعدد الاشهر الممطرة, ومؤشر التركز المطري (PRECIPITATION CONCENTRATION INDEX) والذي يصنف درجة التركز على المستوى (السنوي ونصف السنوي والفصلي) بالاعتماد على المعدلات الشهرية لأمطار (9) محطات مناخية (أربيل، السليمانية، الموصل، دهوك، كركوك، سنجار، زاخو، صلاح الدين، بعاج) للفترة من (1979-2014), وتم الاستعانة ببرنامج EXCEL وبرنامج ORIANA 4في ايجاد وتمثيل هذا التركز وموعده ودرجته.

ولقد تبين من نتائج البحث ان محطات المنطقة تشترك في نفس خواص التركز , اذ اظهرت نتائج اسلوب المتجهات الرياضية ان أمطار المنطقة تتركز في اواخر شهر كانون الثاني وبدايات شهر شباط وان المحطات تختلف في طول الموسم المطري بين (9-7) اشهر , اما مؤشر التركز المطري فقد بين ان التركز المطري السنوي اظهر اعتدال متوسط في توزيع الامطار ، اما بالنسبة للتركز المطري النصف سنوي اظهر النصف الرطب وجود اعتدال واضح في توزيع الامطار واما النصف الجاف فقد ظهر تركز شديد، اما التركز المطري الفصلي فقد اظهر فصل الخريف اعتدال متوسط في التوزيع في اما فصل الشتاء فقد اظهر تعادل واضح في التوزيع اما فصل الربيع فقد اظهرت بعض المحطات (اربيل ، السليمانية، كركوك، صلاح الدين) اعتدال متوسط اما باقي المحطات اظهرت عادل واضح في التوزيع .

الكلمات المفتاحية: التركز الفصلي للمطر ، المتجهات الرياضية، مؤشر التركز المطري PCI.

Introduction:

The Studies that related to rainfall and measuring concentration and seasonality of rain are so important at present due to climate changes that are increasing and effects day after day, especially in marginal areas that already suffer from climatic fluctuations, specifically rain, which is the most important element of the climate and the most unsteady, it has a major impact on the environment and human activities.

1-1. Objective of Research

Measuring the seasonal concentration of precipitation using mathematical standard such as the method of mathematical vectors and the indexes of precipitation concentration.

1-2. Research issue

Variation in the seasonality of precipitation and its reflection on the seasonal concentration of precipitation.

1-3. Research importance

Determining the date of rain concentration and how to distribute the amount of precipitation during the months to an area is very important in determining the beginning of the agricultural season and the type of crop, as the actual value of rain is affected by the time of precipitation.

1-4. The location of the study area

The study area is Located in northern Iraq as it extends from latitude 37.22.55 to latitude 35.28.00 north, and from longitude 45.20.00 to longitude 41.50.00 east, which includes five Governorates.

Map 1 The location of the study area
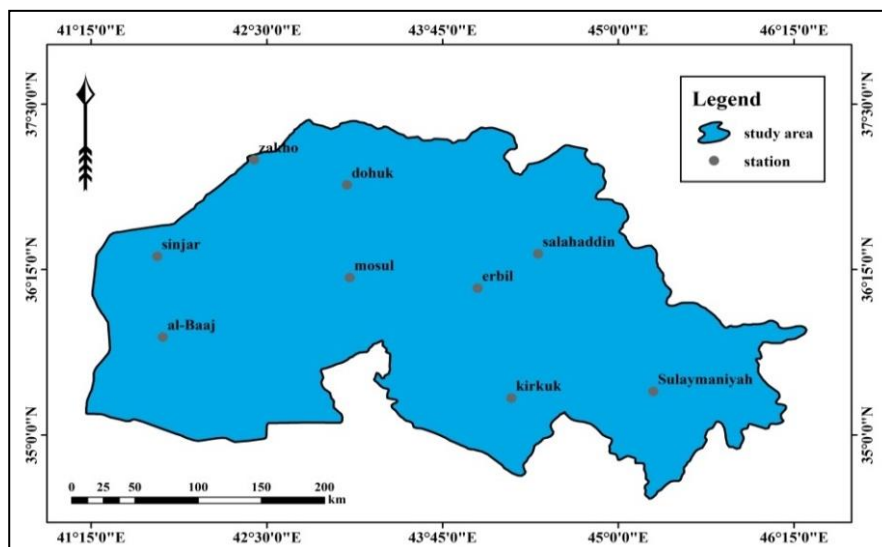
Table 1 stations of study area

station	altitude	Latitude	Longitude
Kirkuk	319	35.43	44.37
Sulaymaniyah	886	35.43	45.31
Al-Baag	301	36.06	41.87
Erbil	439	36.06	44.06
Mosul	288	36.06	43.12
Sinjar	522	36.37	41.87
Salahaddin	977	36.37	44.37
Dohuk	795	36.99	42.81
Zakho	835	37.31	42.50

2. Seasonality of Precipitation

By "seasonality of precipitation" meant the tendency for a place to have more rainfall in certain months or seasons than in others.

3. Precipitation Concentration

Which means the period that rain falls at a higher rate than the rest of the rainy season, and the concentration disappears if the rains of a region are falling distributed during the year without any drought period, and there is a huge concentration that rains fall in a certain area in one month of the year [1].

Precipitation concentration is measured to determine the rainiest period of the year, and it is based on a comparison of the monthly data of rains in the rainy seasons to give an idea of the rainiest season. Rainfall concentration can be measured at different levels, as it is measured at the annual level, as well as at the level of a specific season of the year.

To study the seasonal rain concentration, two equations were used to determine and measure this concentration in the study area due to the difference in the objectives of each method and based on the data of the precipitation series for 36 years from 1979-2014 to give the greatest clarity in determining the annual and seasonal rain concentration and its timing in each of the stations.

4. Method of Standard Vectors

(C.G. Markham) 1970 was the first to use it in determining the seasonal of Precipitation, the assumption can be made that mean monthly rainfall values are vector quantities with both magnitude and direction, magni- tude being the amount of rain, and direction being the month of the year expressed in units of arc. Vector direction for mean monthly rainfall is thus 15° for January, 44° for February, 74° for March, etc. [2]

The vector resultant is a measure of the seasonality of precipitation, its magnitude representing the degree of season- ality, and its direction representing the period of seasonal concentration. The ratio between the magnitude of the resultant and the total mean annual precipitation, expressed as a percentage, is here called the Seasonality Index. Large values show high seasonality, small values low. The maximum possible value for the Seasonality Index is 100 percent and would occur if all the precipitation came in a single month. The minimum value is zero percent, occurring if precipitation is evenly distributed throughout the year.

The resultant value is calculated by analyzing each vector into two components, the x component, and the y component, as in the equation:

$$R = \sqrt{\left(\sum_{i=1}^{12} vi \sin \emptyset i\right)^2 + \left(\sum_{i=1}^{12} vi \cos \emptyset i\right)^2}$$

R = summation value of all vectors.

vi = Monthly average of precipitation.

$\sin\emptyset$ = The sine of the angle made by the vector, which represents the Y component.

$\cos\emptyset$ = The cosine of the angle made by the vector, which represents the x component.

As for the angle made by the resultant, it can be estimated according to following equation:

$$\tan = \frac{\sum_{i=1}^{12} vi \sin \emptyset i}{\sum_{i=1}^{12} vi \cos \emptyset i}$$

Since tan represents the tangent of the angle made by the result with the x-axis, and through it the magnitude of the angle is found, while the context of the seasonal concentration is found through the following equation

$$\text{Concentration Index} = \frac{\text{summation value of all vectors}}{\text{Annual average of precipitation}} \times 100$$

It can be said that the pattern of rain concentration is determined by two factors, namely the percentage of rainfall concentration and its timing [3].

4-1. Equation application

Table 2 The date of precipitation concentration in the stations of the study area and the percentage of concentration

station	The period of concentration begins from				Concentration ratio
	day	Month	day	Month	
Kirkuk	18	january	1	february	61.03%
Sulaymaniyah	21	january	4	february	61.68%
Al-Baag	18	january	1	february	56.38%
Erbil	19	january	2	february	58.70%
Mosul	19	january	2	february	57.05%
Singar	20	january	3	february	53.94%
Salahadin	22	january	5	february	61.83%
Dohuk	20	january	3	february	59.66%
Zakho	23	january	6	february	59.29%

It is noticed that the period of rainy concentration in all stations of the study area shares the same period of concentration, which starts from late January to early February, and this is clear in the analysis of the angles that made by the summation value of all vectors with the axis of the years in each station, which showed one type of seasonal concentration This is due to the fact that there is a great similarity in the factors affecting rain fall in all stations of the study area, as the Mediterranean depressions are the main source of rain in the region, which often extends during this period to include all stations of the study area, in addition to the factor of smallness of the study area and similarity Climatic conditions.

As for the percentage of rain concentration, we find that the rates ranged between (61.8) in Salaheddin, which is the highest percentage, and (53.9) in the Sinjar station, which is the lowest percentage, and the rest of the stations are distributed between these two percentages, and this means that the rain is distributed between more than (6) months and less than (8) months (6.49-7.44), and the reason is due to the lack of influence of the altitude and the location of the stations in relation to the latitude circles in the period and timing of concentration, as there is no significant difference in the length of the rainy season between stations
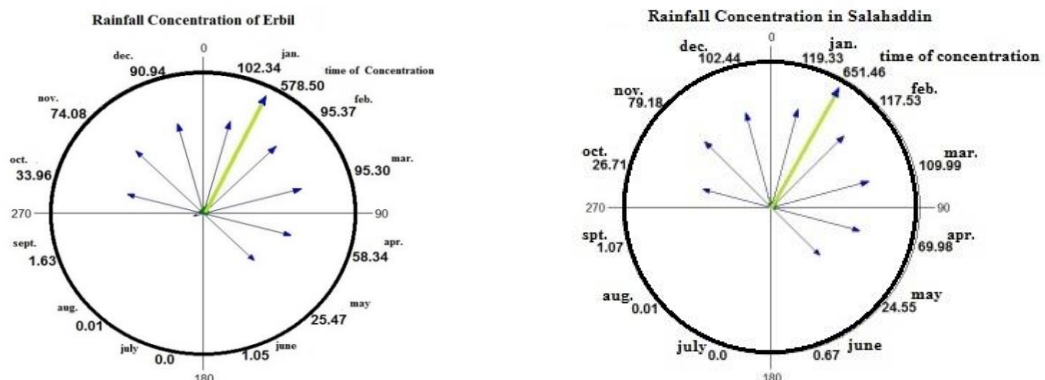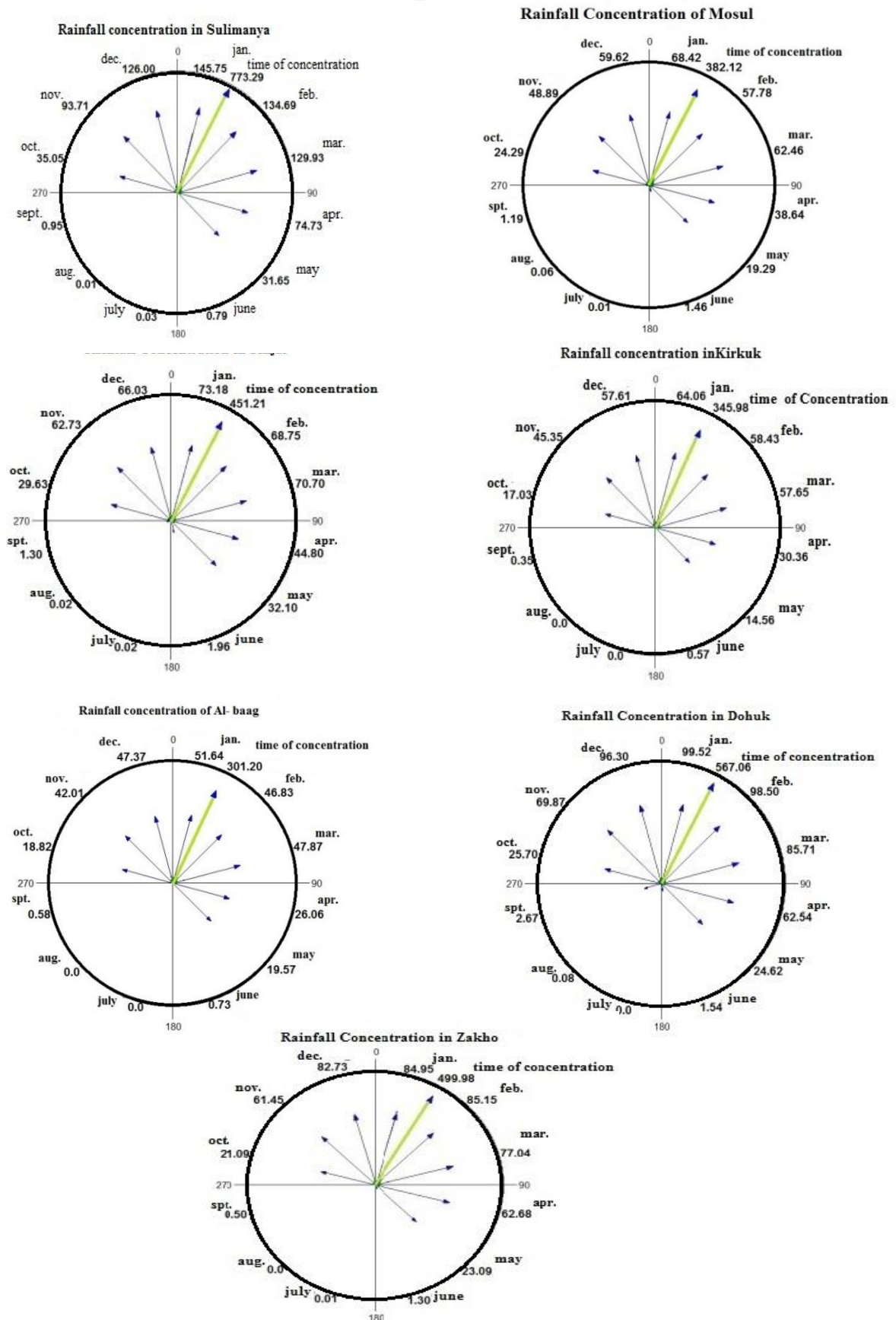
Figure 1 representation of Standard Vectors of rain concentration in all stations

5. Method of Precipitation Concentration Index (PCI)

Oliver 1980 was the first to suggest this indicator as an index of precipitation concentration and to measure the ability of rain to cause erosion [5], This index can measure the precipitation concentration at the annual level 12 months, the semi-annual level of 6 months, and the seasonal level 3 months, using the equations:

At the 12-month level

$$.100 \ PCI \ annual = \frac{\sum_{i=1}^{12} pi^2}{(\sum_{i=1}^{12} pi)^2}$$

At the level of 6 months

$$.50 \ PCI \ supra \ seasonal = \frac{\sum_{i=1}^{6} pi^2}{(\sum_{i=1}^{6} pi)^2}$$

At the level of 3 months

$$.25 \ PCI \ seasonal = \frac{\sum_{i=1}^{3} pi^2}{(\sum_{i=1}^{3} pi)^2}$$

$pi = $ The amount of rain in a month [4].

The precipitation concentration index is applied based on the monthly rates for a certain number of years, symbolized by PCI1, and on the monthly averages for each year, symbolized by PCI2[6].

It has been observed that, in general, there is no relationship between the results of the index of rain concentration and the amount of annual rain for a certain period of time because this index focuses on most is the pattern of rain distribution during the year or season [7].

Table 3 values classifications of the precipitation concentration index (PCI)

(PCI)	Rainfall system
10≤	Uniform precipitation distribution (low precipitation concentration)
15 - 11	Moderate precipitation concentration
16 - 20	Irregular distribution
20≥	Strong irregularity (high precipitation concentration)

5-1. Equation application

**Table 4** PCI for the monthly data of the area's stations rains from 1979-2014[8]

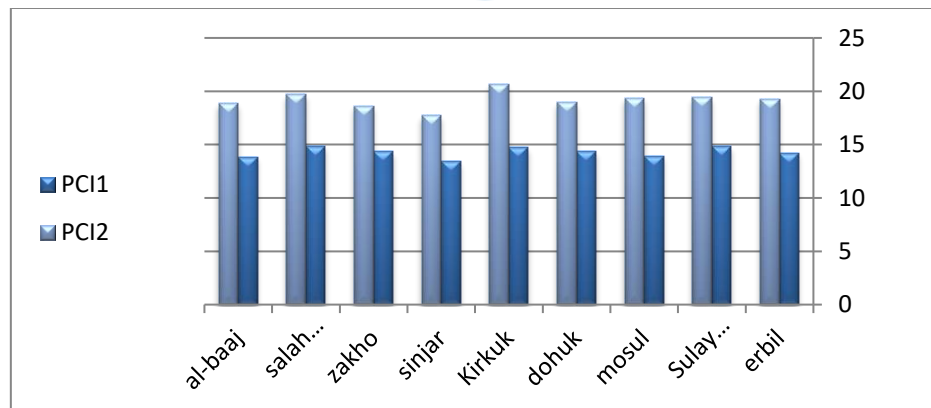| station	Annual level		
	PCI1	PCI2	PCI1/PCI2
Kirkuk	14.74	20.62	0.71
Sulaymaniyah	14.84	19.43	0.76
Al-baaj	13.85	18.88	0.73
Erbil	14.23	19.28	0.74
Mosul	13.92	19.39	0.72
Sinjar	13.41	17.74	0.76
Salahaddin	14.88	19.72	0.75
Dohuk	14.40	18.96	0.76
Zakho	14.37	18.61	0.77
PCI1=The rain concentration index for the averages of the whole period of study is 36 years. PCI2=Average rainfall concentration index for each year separately. PCI1/PCI2=The result of dividing the rain concentration index for the whole. period by the average concentration for each year.			

5-2. Annual level

From the analysis of the previous table of the values of the annual rain concentration index (PCI1) for the stations of the study area, was found that all the stations had a moderate average rain concentration, as the values in all the stations were close to each other, while the values of the annual concentration index (PCI2) for each year alone showed that Severe concentration in the Kirkuk station, while the rest of the stations showed a seasonal precipitation system and an uneven distribution

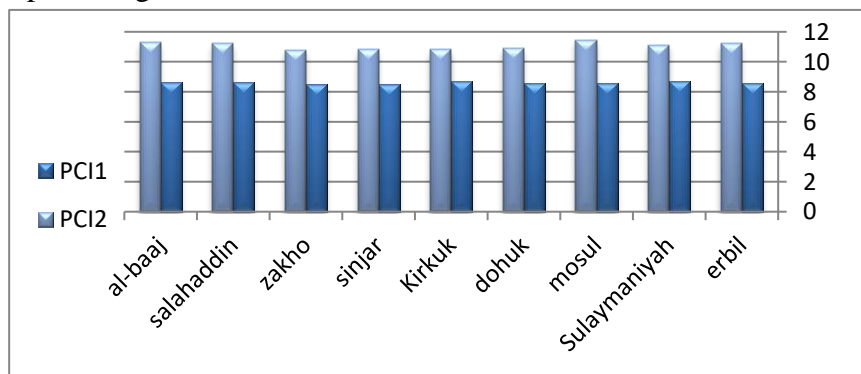**Map 2 Annual Rainfall Concentration Index (PCI1)**
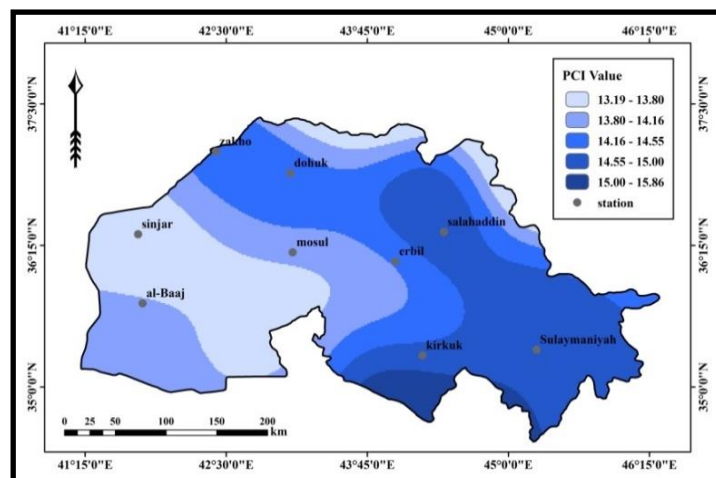
Figure 2 The difference between the values of the Precipitation Concentration Index (PCI1) and the values of the rain concentration index for years (PCI2) for the annual level

The result of dividing the index values of the averages on the index values for the years revealed a convergence in the concentration ratios. Zakho station recorded the highest percentage, while the Kirkuk station recorded the lowest concentration of the monthly amount of rain during the months of the year.

5-3. Semi-annual level

Regarding to the rainy season, which extends from November to April, the results of the PCI1 rainfall index showed that there is a clear parity in the distribution, as the amount of rain in this period is distributed over all months and this result included all the stations, as for the values of the annual rain concentration index (PCI2) It showed a moderate average in the concentration of rain in all stations of the study area.

The result of dividing the index values of the averages on the index values for the years during the rainy half. It indicated a similarity between the rain concentration ratios, while Kirkuk station recorded the lowest percentage, and both Sinjar, Dohuk and Zakho shared the highest concentration percentage.

Figure 3 The difference between the values of the average precipitation index (PCI1) and the values of the rain concentration index for the years (PCI2) for the semi-annual level
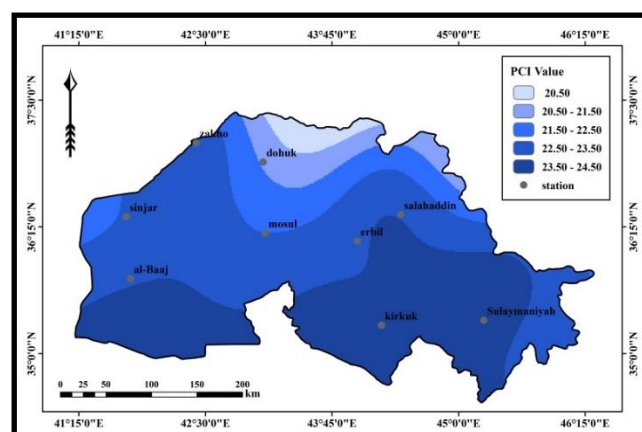
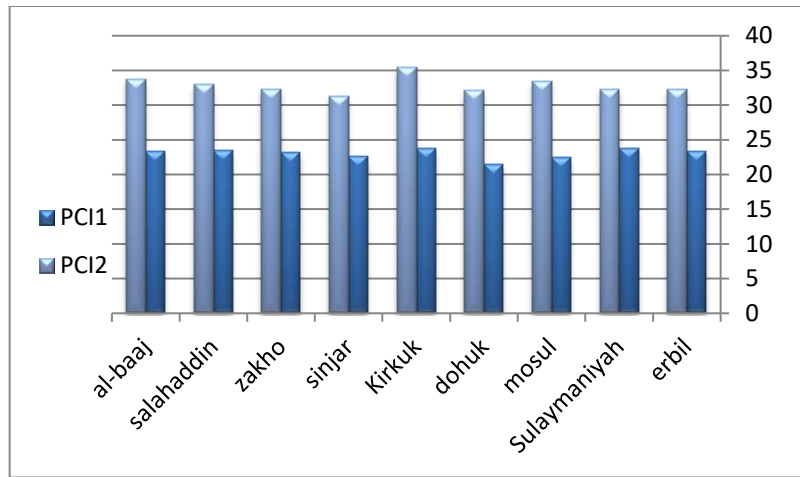**Map 3** Rainfall Concentration Index (PCI1) for the wet season
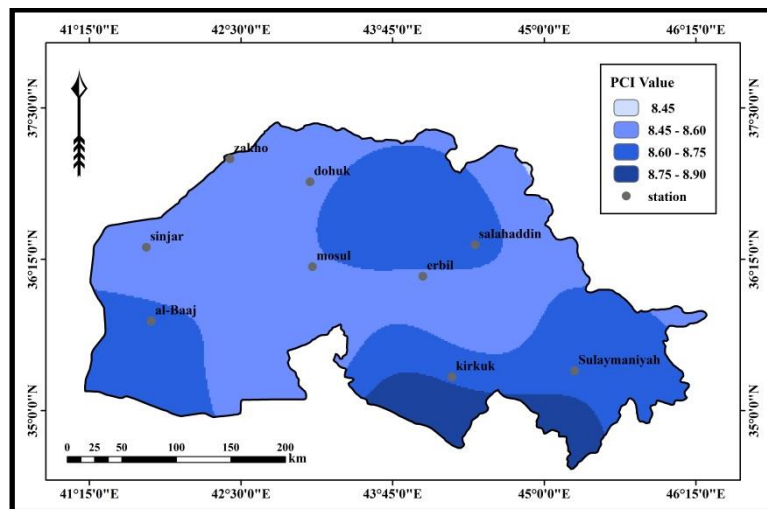
for the dry half, which extends from May to October, the results of the indicator ((PCI1) showed that all stations are similar in the classification of rain concentration in this season, which is represented by a clear irregularity in distribution and the presence of severe concentration in one or two months of this period, The same applies to the indicator of rain concentration for each year (PCI2) with the high concentration rates significantly, and this is due to the interruption of rain in the summer due to the change in the path of the depressions from the study area and the control of a system of high atmospheric pressure as the rains in this half of the year are concentrated in the late spring And early autumn, that is, the months of October and May.

. As for dividing the index values of rates on the index values for the years during the dry half, it indicated that the stations in Mosul, Dohuk and Kirkuk participated in the lowest concentration ratios, while the highest percentage of rain concentration was recorded in Sulaymaniyah station.

Map 4 Rainfall Concentration Index (PCI1) for the dry half year

Figure 4 The difference between the values of the average precipitation index (PCI1) and the values of the rain concentration index for the years (PCI2) for the semi-annual level

Table 5 The rain concentration index for the monthly data of the area's stations rains for the period from 1979-2014

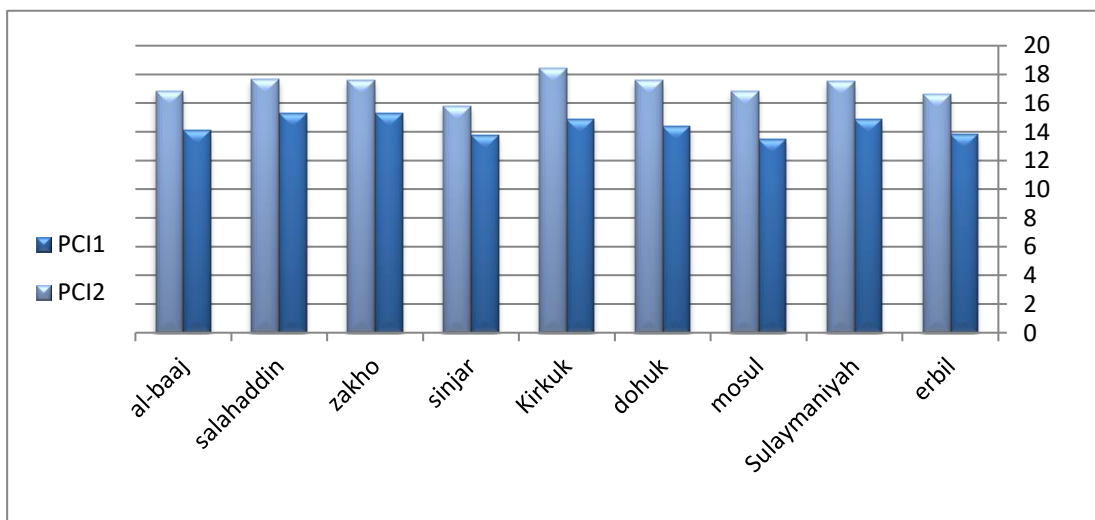| station	Rainy half of the year the			the dry half of the year		
	PCI1	PCI2	PCI1/PCI2	PCI1	PCI2	PCI1/PCI2
Kirkuk	8.72	10.82	0.74	23.76	35.40	0.67
Sulaymaniyah	8.71	11.12	0.78	23.80	32.32	0.74
Al-Baaj	8.64	11.27	0.77	23.40	33.77	0.69
erbil	8.59	11.22	0.77	23.39	32.24	0.73
mosul	8.58	11.42	0.75	22.52	33.47	0.67
sinjar	8.51	10.81	0.79	22.63	31.33	0.72
salahaddin	8.63	11.21	0.77	23.45	33.01	0.71
dohuk	8.57	10.91	0.79	21.39	32.14	0.67
zakho	8.48	10.79	0.79	23.17	32.31	0.72
PCI1=The rain concentration index for the averages of the whole period of study is 36 years. PCI2=Average rainfall concentration index for each year separately. PCI1/PCI2=The result of dividing the rain concentration index for the whole period by the average concentration for each year.						

5-4. Seasonal level

Autumn season

Which includes three months September, October, and November the results of the PCI1 index in **Table (7)** indicate that all stations in the study area are characterized by a moderate average in the concentration of autumn rains, although the values of the rain concentration index differ slightly from one station to another, but they remain within Same classification.,

As for the indicator values (PCI2), they indicated seasonality in the rainfall system and lack of moderation in distribution, and this result included all stations.

As for the result of dividing the index values of the rates on the index values for the years during the autumn season, it was found that the concentration ratios were high in all stations, and the rates were close to a large extent.

Table 7 PCI of the monthly data of the stations' rains in the study area for the period from 1979-2014

station	autumn			winter		
	PCI1	PCI2	PCI1/PCI2	PCI1	PCI2	PCI1/PCI2
Kirkuk	14.91	18.40	0.81	8.35	10.23	0.82
Sulaymaniyah	14.88	17.50	0.85	8.36	9.80	0.85
al-baaj	14.11	16.84	0.84	8.35	9.95	0.84
erbil	13.81	16.61	0.83	8.35	9.95	0.84
mosul	13.48	16.82	0.80	8.38	10.12	0.83
sinjar	13.72	15.80	0.87	8.35	9.94	0.84
salahaddin	15.26	17.63	0.87	8.37	9.79	0.85
dohuk	14.37	17.56	0.82	8.33	10.05	0.83
zakho	15.30	17.59	0.87	8.33	9.75	0.85
station	spring			PCI1=The rain concentration index for the averages of the whole period of study is 36 years. PCI2=Average rainfall concentration index for each year separately. PCI1/PCI2=The result of dividing the rain concentration index for the whole period by the average concentration for each year.		
	PCI1	PCI2	PCI1/PCI2			
Kirkuk	10.59	13.25	0.80			
Sulaymaniyah	10.51	12.55	0.84			
al-baaj	9.59	12.52	0.77			
erbil	10.24	12.48	0.82			
mosul	9.95	12.75	0.78			
sinjar	9.22	11.44	0.81			
salahaddin	10.52	12.68	0.83			
dohuk	9.92	12.04	0.82			
zakho	9.81	11.67	0.84			

Figure 5 The difference between the values of the average precipitation index (PCI1) and the values of the rain concentration index for years (PCI2) at autumn season
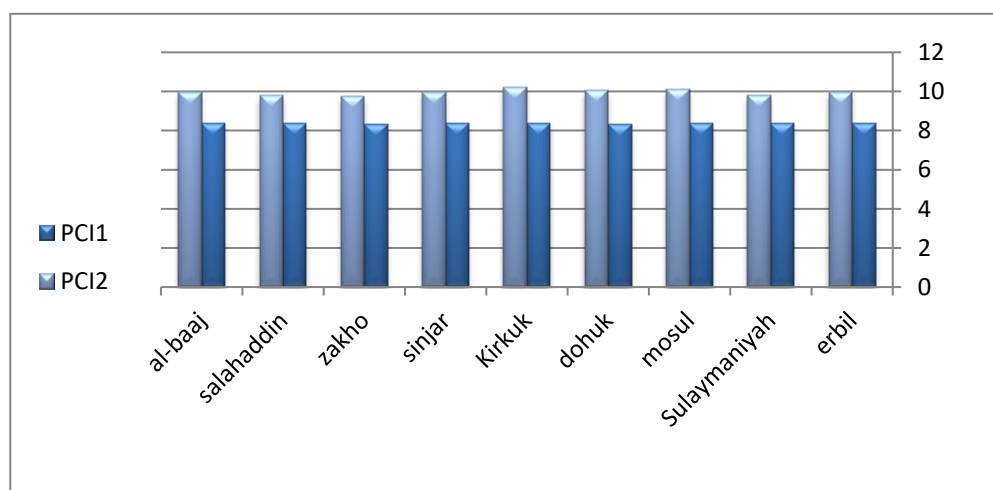
**Map 5** Rainfall Concentration Index (PCI1) for autumn
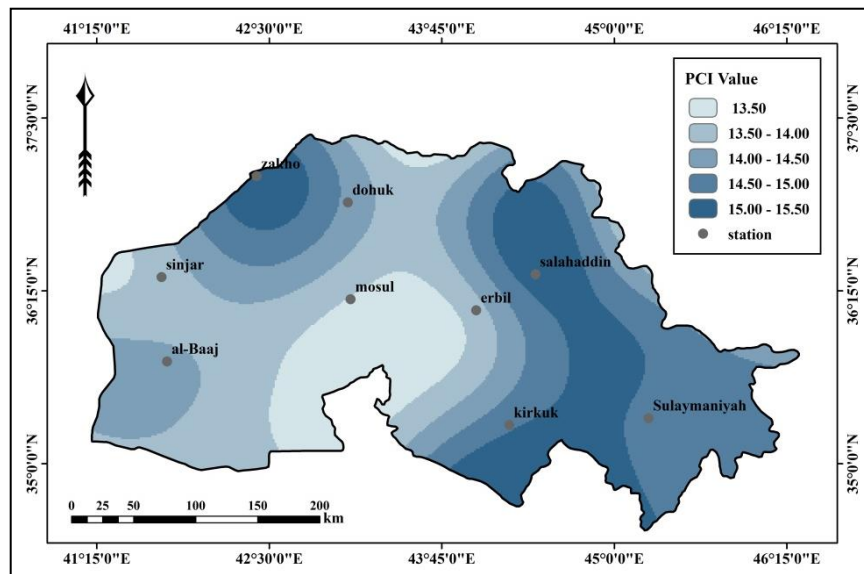
Winter season

Which includes the month of December, January and February, the index values showed that the results are very similar in the pattern of rain concentration (PCI1) in this season, which is a clear parity in the distribution, meaning that rain falls in all the months of winter, and this is despite the different amounts of rain from On the other hand, the same applies to the results of the concentration index for each year (PCI2), which showed a clear parity in the metric distribution during the season.

As for the result of dividing the index values for rates by the index values for the years during the winter season, high percentages were shown in all stations.

Figure 6 The difference between the values of (PCI1) and the values of (PCI2) at winter season
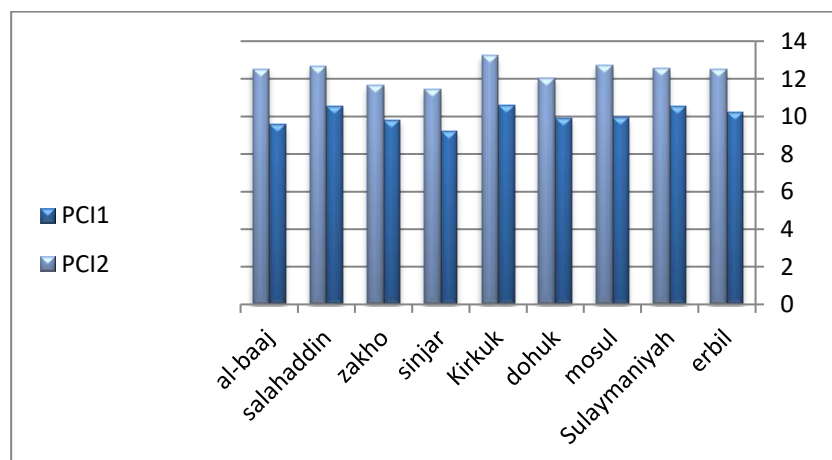
Map 6 Rainfall Concentration Index (PCI1) for the winter season
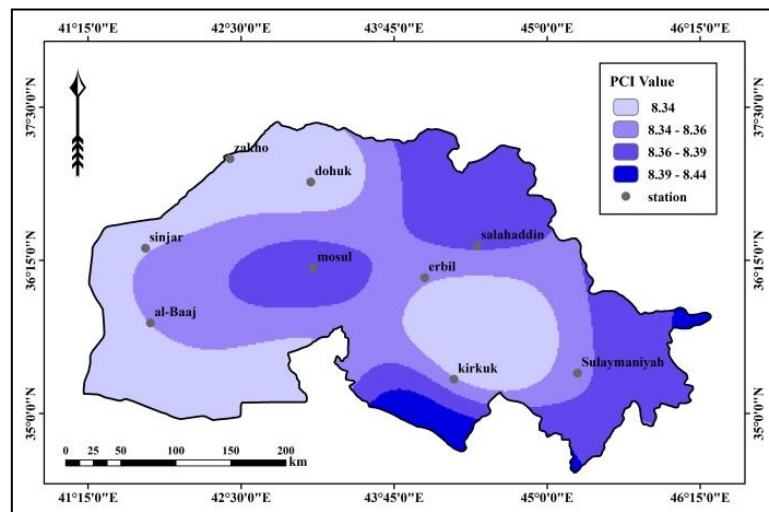
Spring season

Which includes the month of March, April and May. the analysis of the table we see that the concentration values (PCI1) showed in some stations (Erbil, Sulaymaniyah, Kirkuk, Salah al-Din) moderation in the distribution of rain in this season, as for the rest of the stations (Mosul, Zakho, Dohuk, Sinjar, Ba'aj). The concentration in it was clearly equal in the distribution of rain (ie, rain falls in all months). As for the values of concentration for each year, it indicated that there is an average moderation in the distribution of rain during the spring in all stations of the study area.

As for the result of dividing the index values of rates on the index values for the years during the spring season, it showed high concentration ratios in all stations, and the Dohuk station occupied the lowest rain concentration percentage in the region.

Figure 7 The difference between the values of the rain concentration index (PCI1) and the values of the rain concentration index for the years (PCI2) at spring season

Map 7 Rainfall Concentration Index (PCI1) for the spring season
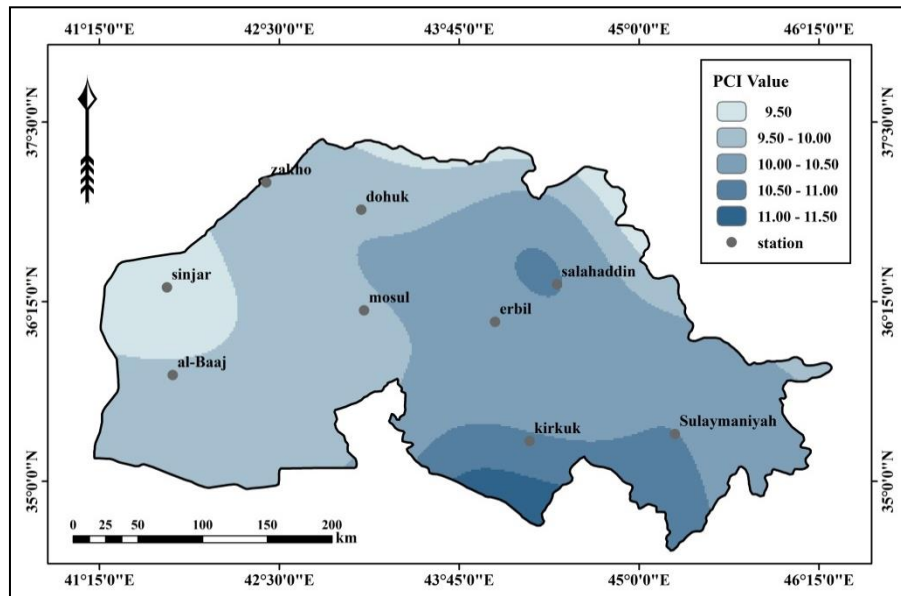
Conclusion:

1-The precipitation concentrated in the study area started from the end of January to the beginning of February, and this includes all stations.

2- The length of the rainy season varies from one station to another and ranges between more than six months in Sinjar and less than nine months in Salaheddin.

3- The results of the annual precipitation concentration index (PCI1) showed that all the stations in the study area had moderate concentrated rains. The results of the concentration index for each year showed a high concentration in the Kirkuk station, while the rest of the stations showed a seasonal precipitation system and no moderation in distribution.

4- for the results of semi-annual precipitation concentration, (PCI1) in the wet half showed that all the stations in the region were similar in the type of concentration, which is equal to the distribution over all months, while the values of (PCI2) showed moderate equilibrium in the distribution of rain, in the dry half , the concentration values indicated (PCI1) refers to presence of severe concentration and irregularity in the distribution in all stations, as the rains are concentrated in one or two months of this season, as well as for the values of the (PCI2) index with a high concentration rate

5- for the results of semi-annual rain concentration, (PCI1) in the wet half showed that all the stations in the region were similar in the type of concentration, which is equal to the distribution over all months, while the values of (PCI2) showed moderate equilibrium in the distribution of rain, in the dry half the concentration values indicated (PCI1) To the presence of severe concentration and irregularity in the distribution in all stations, as the rains are concentrated in a month or two of this season. Likewise, the values of the (PCI2) index with a high concentration rate

6- for the results of seasonal rain concentration, the concentration index (PCI1) in the autumn season showed a moderation in the distribution of rain during this season. As for the values of (PCI2), they indicated the seasonality of precipitation and this included all stations, while the winter season indicated the values of (PCI1 and PCI2 values) To the existence of a parity in the distribution of rain in all the months of the season, in the spring season the values of the index (PCI1) showed that the stations (Erbil, Sulaymaniyah, Kirkuk, Salah al-Din) are characterized by the presence of moderate moderation in the rain concentration, while the rest of the stations (Mosul, Dohuk, Zakho, Sinjar, Al-Baaj), it indicated a clear parity in the distribution of rain during this season. As for the index values for each year (PCI2), they showed moderate moderation in all stations

7-The study showed that applying the equations to measure the precipitation concentration in the study area It led to accurate identification of the seasonality of rain and the percentage of concentration in each season, in addition to an accurate determination time of the heaviest rainfall and number of rainy months in each station.

8-The concentration values for each year (PCI2) showed an increase in the concentration rates at the annual, semi-annual and seasons levels.

Reference

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