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RESEARCH ARTICLE

Investigation of drought in the northern Iraq region

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Drought is a phenomenon of climate and is one of the catastrophic events that cause much damage on each occurrence. One of the ways of drought adjustment, evaluation and drought monitoring is based on indicators that can be used to determine its extent and continuity in a region. In this study, drought analysis (the duration and severity of drought) in the north Iraq region was studied by using the Standardized Precipitation Index (SPI) for time intervals of 1, 3, 6, 9 and 12 months. That feature of this method helps to compare the drought events in different places and scales. To observe dry and wet periods and the severity and length of drought monthly rainfall data of 15 meteorological stations of the northern Iraq provinces from 1979 to 2013 were used. Calculations were performed on the SPI by using the SPI code in MATLAB computer software. The results of the study showed that the continuity of dry periods in the 6, 9 and 12 month periods was higher than in the 1 and 3 month time intervals. Moreover, according to the calculation, the driest year was observed in 2008. This analysis is essential because it gives full information about the longest dry and wet periods for all stations of the region.

KEYWORDS
drought, drought duration, drought severity, northern Iraq, standard precipitation index

1 | INTRODUCTION

Natural disasters such as floods, thunderstorms, drought are characteristics of our environment. These disasters make a negative impact and irreparably damage human life. According to the literature, the number and incidence of these events have increased over the past 30 years. About 25% of them are events related to climatic factors. Drought is one of the main causes of these events, perhaps the most influential (Kogan, 1990).

Drought is one of the significant hazards associated with meteorology. This natural hazard affects all aspects of our life. At the international level, there is no single definition of drought that is universally accepted. In general, drought occurs when there is a decrease in water, both at the site and at a specific time (Correia *et al.*, 1991). Each drought is characterized by three characteristics: intensity, length and width. There are a variety of types of drought due to the length of the drought, and they are defined as meteorological, agricultural, hydrological and socioeconomic drought.

It should also be noted that the effects of rainfall reduction on soil moisture, water reservoirs, surface currents of rivers and groundwater levels are shown at different time scales (Lloyd-Hughes and Saunders, 2002).

Drought definitions, especially regarding the impact on the natural and social environment, are always changing. It seems reasonable to relate drought to a large scale with time, period length and location of its occurrence (Tsakiris and Vangelis, 2003).

In advanced stages of drought, water resources encounter a severe shortage. In most areas of the world, groundwater resources have been exploited as a source for public consumption as well as agricultural activities (Scheidleder *et al.*, 1999); this means that the reaction of groundwater to drought has become important (Calow *et al.*, 1999). Although underground is one of the most critical water

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sources in the world, it is not considered in many studies of drought.

In any case, for quantitative analysis of drought, the existence of a specific indicator for the accurate determination of wet and dry periods is essential (Silva, 2003).

The efficiency of drought monitoring systems is profoundly influenced by the accuracy of the selection of indicators that provide a detailed description of the actual state of drought conditions. In recent years, several indicators have been proposed for the study of drought. Moreover, necessarily each of these indicators is related to one of four types of drought (Mendicino *et al.*, 2008), e.g. the Palmer Drought Severity Index (PDSI), the Shafer and Dezmann Surface Water Supply Index, the Ball and Mole Index, the Johnville and others index, and the Standardized Precipitation Index (SPI) which was introduced by McKee and others in 1993 (McKee *et al.*, 1993).

After a general evaluation of the literature, it can be seen that drought analysis is critical for any region to understand its daily condition and to design some water structures or plan water management. Beside this, there is no detailed study on drought in the northern Iraq region, an essential part of Iraq which has important rivers. This situation encouraged the preparation of this study.

2 | LITERATURE STUDY

Palmer (1965) proposed the PDSI which is based on production and demand for water balance. After that, some researchers realized that an index is easy to calculate and statistically relevant and meaningful. Moreover, the understanding that a deficit of precipitation has different impacts on groundwater, reservoir storage, soil moisture, snowpack and streamflow led scientists like McKee to develop the SPI in 1993. This was used for western Kansas, central Iowa and Colorado, United States (Shafer and Dezman, 1982; McKee *et al.*, 1993), and in Hungary (Szalai *et al.*, 2000).

Drought severity characteristics using the SPI were studied by Hayes *et al.* (1999), in Catalonia, Spain, by Lana *et al.* (2001), in China (Wu and Hayes, 2001), in Cordoba, Argentina (Lloyd-Hughes and Saunders, 2002), in Greece (Loukas *et al.*, 2004), in the Aegean region, Greece (Pamuk *et al.*, 2004), in Trakya, Turkey (Çaldağ *et al.*, 2004), in Şanlıurfa, Turkey (Tonkaz *et al.*, 2005), in the Awash River basin, Ethiopia (Edossa *et al.*, 2010), in Albania (Merkoci *et al.*, 2013), in Iraq (Al-Timimi *et al.*, 2013), in Antakya-Kahramanmaraş, Turkey (Karabulut, 2015), in Şanlıurfa, Turkey (Gümüs and Basak, 2017), in the Seyhan–Ceyhan river basins, Turkey (Gümüş and Algın, 2017), and in northern Iraq (Awchi and Kalyana, 2017).

The aim of this study was to find the longest dry and wet periods and their severity for different meteorological stations in the northern Iraq region. A drought analysis of the area under consideration was carried out by using long-term monthly total rainfall data collected from 15 meteorological observation stations. The SPI which is widely accepted throughout the world was used to determine the drought. Temporal drought values were evaluated according to 1, 3, 6, 9 and 12 month time scales for determining the dry and wet periods.

The main difference between this and previous studies for northern Iraq's drought is the data used (Awchi and Kalyana, 2017). These are more accurate, because the amount of missing data is less than in previous work. Thus, the result is more accurate. The longest dry and wet periods for all stations were found in this study. All situations for all time scales are shown on the maps by using ArcMap software. The percentages of all situations for all time scales were found. Also the number of stations is more than in previous studies.

3 | MATERIALS AND METHODS

3.1 | Study area

The study area of northern Iraq has an area of 40,643 km^2. North Iraq is at 36 ° N and 44 ° E. The southern parts of Iraq are located in the tropics and its northern parts are in semi-arid regions. Figure 1 shows the study area. There are four main rivers in northern Iraq, the Euphrates, Tigris, Diyala and the Lower Zab.

The Euphrates is one of the two major rivers in Asia and the Middle East. It is the longest river in the region with a length of 1,700 miles (2,800 km). The Tigris is the second largest river in Iraq with a length of 1,150 miles (1,850 km). They come from the eastern mountains of Turkey. The Tigris river arrives in Iraq, where it connects with the Euphrates to form the Shat Al-Arab River.

The Diyala river is the third highest river in Iraq at 277 miles (445 km). This river comes from the Zagros Mountains in western Iran and flows to Iraq through the lowlands. The Lower Zab, also known as the Little Zab, comes from the Zagros Mountains in Iran, where it is tied to the Tigris. The river is 249 miles (400 km) long. It passes through different environmental zones that result in the growth of different plants (Sawe, 2017).

3.2 | Data

Meteorological data are used in this study. Rainfall is the main parameter of the evolution of a meteorological drought, so rainfall data were collected from the meteorological observation stations in different cities of northern Iraq (Meteorological Organization of North Iraq and Global Weather Data) and the software needed was available in the laboratory of the Civil Engineering Department of Harran University. Table 1 gives the general information of the stations used in the drought analysis. According to this,

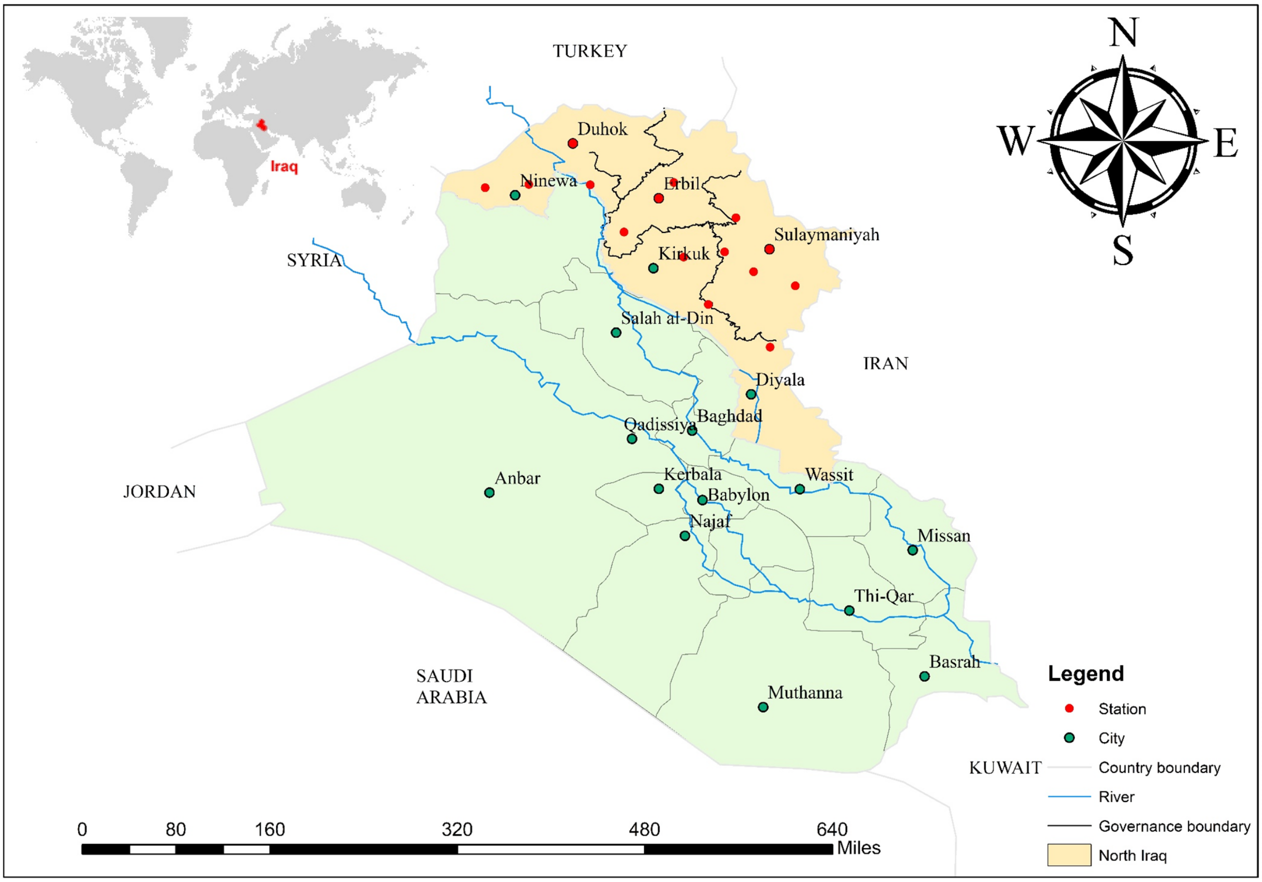

FIGURE 1 Study area [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 The climatic and geographical characteristics of all stations

Station no.	Station ID	Station name	Longitude	Latitude	Height (m)	Available years range
1	361441	Erbil	44.009167	36.191111	439	1979–2013
2	358434	Makhmur	43.58102	35.774954	252	1979–2013
3	364441	Pirmam	44.196151	36.385931	507	1979–2013
4	354453	Sulaymaniyah	45.375611	35.564112	886	1979–2013
5	351456	Darbandikhan	45.695272	35.110939	532	1979–2013
6	354447	Chamchamal	44.821728	35.529211	859	1979–2013
7	351453	Sangaw	45.179867	35.285127	770	1979–2013
8	361450	Dokan	44.962103	35.949559	529	1979–2013
9	370428	Duhok	42.948857	36.867905	795	1979–2013
10	364419	Sinjar	41.865044	36.322072	1,067	1979–2013
11	354444	Kirkuk	44.316667	35.466667	319	1979–2013
12	345453	Khanaqin	45.383938	34.354254	188	1979–2013
13	348447	Tuz Khurma	44.620763	34.880964	197	1979–2013
14	364431	Mosul	43.164	36.356648	233	1979–2013
15	364425	Tal Afar	42.403672	36.362358	485	1979–2013

Sulaymaniyah (354453) had the highest rainfall amount of the studied stations, and Makhmur (358434) had the least amount of rainfall. Average annual precipitation values range from 765 to 241 mm at all stations.

In this research, the annual rainfall of 15 synoptic stations at Erbil, Sulaymaniyah, Duhok, Darbandikhan, Chamchamal, Sangaw, Kirkuk, TuzKhurma, Makhmur, Pirmam, Dokan, Sinjar, Tal Afar, Mosul and Khanaqin during a 34 year statistical period (from 1979 to 2013) from the Meteorological Organization of North Iraq and Global Weather Data was obtained.

After initial data analysis, incomplete data in the monthly series were constructed by the ratio method using the statistics of the adjacent station. To reconstruct some of the statistical deficiencies in the Erbil, Sulaymaniyah and Duhok stations, the synoptic stations of Chamchamal and Sangaw were used, but in some stations no long-term statistical period could cover long distances; these years were eliminated from the calculations. Monthly rainfall data in northern Iraq stations were collected from 1979 to 2013. Fifteen stations were selected. They were obtained from the Meteorological Organization of North Iraq and Global Weather Data. Some of the climatic and geographical characteristics of the stations are presented in Table 1. The location of the meteorological precipitation stations is given in Figure 2.

3.3 | Methods

3.3.1 | Standardized Precipitation Index (SPI) method

The SPI is used for investigation of drought. One of the main criteria for the evaluation of drought using the SPI is that the calculation requires the average and long-term standard deviation of rainfall data during the period of study (Bonaccorso *et al*., 2003). This measure is provided primarily to define and monitor drought and rain (Tsakiris *et al*., 2003) and allows the analysis to define and identify the number of dry and wet periods for any described time (McKee *et al*., 1993). Since the index is dimensionless, that information can help to compare different areas. Moreover, produce drought range with higher accuracy (Agnew, 2000) one of the other advantages of this indicator, its ability to detect extreme droughts and extreme wet in the region, to do a lot of analysis on it (Livada and Assimakopoulos, 2006). Details of the SPI method can be found in Gumus and Algin (2017).

The SPI values have been classified by Edossa *et al*. (2010) into eight classes that vary within the range from extreme wet to extreme drought as shown in Table 2. The general statistics of the data are given in Table 3.

TABLE 2 The SPI classification

SPI classes	Period classification
$SPI \leq -2$	Extreme drought
$-2 < SPI \leq -1.5$	Severe drought
$-1.5 < SPI \leq -1$	Moderate drought
$-1 < SPI \leq 0$	Mild drought
$0 < SPI \leq 1$	Mild wet
$1 < SPI \leq 1.5$	Moderate wet
$1.5 < SPI \leq 2$	Wet
$SPI > 2$	Extreme wet

With this index, first the amount of monthly rainfall is calculated at each station for each time scale (1, 3, 6, 9, 12 months). For example, at the 3 month scale each of the rainfalls in April, May and June make up the precipitation index in June; the total rainfall of May, June and July is an indicator of July. At the 6 month time scale the total rainfall of the last month and 5 months before will be an index of rainfall *per* month. Similar to other measures, cumulative rainfall time series are calculated for each month. Thus, for example, for the 6 month time scale there is not a specific period of 6 months *per* year (first or second 6 months), but all the intervals of 6 months in the period are included. Then, the cumulative rainfall *per* month is fitted with a gamma probability distribution. After calculating the cumulative probability scale at any time scale and for each month of the year this possibility becomes a normal random variable, i.e. is the same standard *Z*.

The SPI, due to the simplicity of calculation, has the ability to calculate for any period the most appropriate

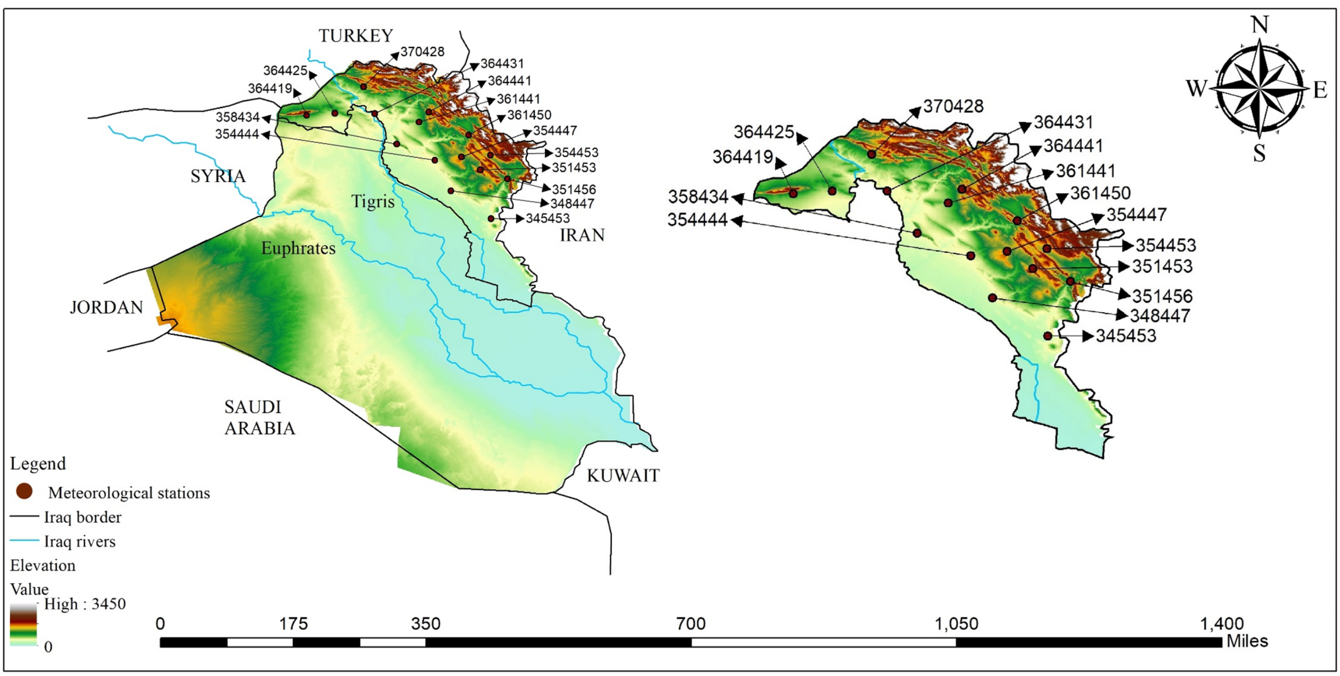

FIGURE 2 The regional distribution of long-term average annual precipitation of all used stations [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 3 The general statistics of the data for the stations

Station no.	Station ID	Station name	Mean	Min	Max	Annual precipitation (mm)
1	361441	Erbil	548.91	216.79	872.82	577
2	358434	Makhmur	260.16	109.80	523.57	298
3	364441	Pirmam	568.15	228.24	600.66	601
4	354453	Sulaymaniyah	778.18	244.65	1,304.30	765
5	351456	Darbandikhan	546.11	170.95	783.19	505
6	354447	Chamchamal	554.66	171.09	874.58	555
7	351453	Sangaw	669.67	205.07	943.92	631
8	361450	Dokan	619.78	254.75	1,012.93	670
9	370428	Duhok	552.06	222.26	988.72	572
10	364419	Sinjar	456.29	162.47	727.81	452
11	354444	Kirkuk	321.67	105.64	568.87	347
12	345453	Khanaqin	228.03	97.67	370.82	241
13	348447	TuzKhurma	337.15	134.00	583.75	354
14	364431	Mosul	535.57	199.73	1,045.88	598
15	364425	Tal Afar	442.68	153.35	741.87	450

indicator for monitoring the meteorological drought. Positive values of the SPI index indicate that rainfall is more than average and negative values have the inverse meaning. According to this method, a period of drought occurs when the SPI is continuously negative and reaches −1 or less and ends when it is positive. Therefore, the duration of the drought is determined by the start and end of negative values, and the cumulative amounts of the SPI also indicate the magnitude and severity of the drought (Hayes *et al*., 1999):

$$G(x) = \frac{1}{\beta_{\text{pro}}^{a_{\text{pro}}}\Gamma(a_{\text{pro}})}\int_0^x x^{a\text{pro}-1} e^{-\frac{1}{\beta_{pro}}} dx \tag{1}$$

when:

$$a_{\text{pro}} = \frac{1}{4A}\left(1+\sqrt{1+\frac{4A}{3}}\right) \tag{2}$$

$$A = \ln(x_{\text{sr}}) - \frac{\sum_{i=1}^{n}\ln(x_i)}{n} \tag{3}$$

$$\beta_{\text{pro}} = \frac{x_{\text{sr}}}{a_{\text{pro}}} \tag{4}$$

x_{sr} shows the mean amount of precipitation, n is the number of precipitation measurements and x_i is the quantity of precipitation in the sequence of data.

When $x = 0$, then the cumulative probability function becomes $H(x) = q + (1 - q)G(x)$; q is the probability of no precipitation.

$$\text{SPI} = \begin{cases} -\left(t - \dfrac{c0 + c1t + c2t2}{1 + d1t + d2t2 + d3t3}\right) & 0 < H(x) \le 0.5 \\ +\left(t - \dfrac{c0 + c1t + c2t2}{1 + d1t + d2t2 + d3t3}\right) & 0.5 < H(x) \le 1.0 \end{cases} \tag{5}$$

$$t = \begin{cases} \sqrt{\ln\dfrac{1}{\{H(x)\}\hat{}2}} & 0 < H(x) \le 0.5 \\ \sqrt{\ln\dfrac{1}{\{1-H(x)\}\hat{}2}} & 0.5 < H(x) \le 1 \end{cases} \tag{6}$$

where $H(x)$ is the cumulative probability of the observed precipitation and c0, c1, c2, d1, d2 and d3 are constants:

$$c0 = 2.515517 \quad c1 = 0.802853 \quad c2 = 0.010328$$
$$d1 = 1.432788 \quad d2 = 0.189269 \quad d3 = 0.001308$$

4 | FINDINGS AND DISCUSSION

Drought analyses were conducted by using monthly rainfall data for all meteorological stations. They were measured continuously between 1937 and 2013. For drought analysis, a code prepared by MATLAB software was used. Moreover, the SPI values were calculated after the precipitation data were fitted to a gamma distribution. Monthly and annual total precipitation was used for determining the temporal distribution of the 1, 3, 6, 9 and 12 month SPI values. The calculated SPI values were taken as a single period between 1979 and 2013.

For Kirkuk station (as an example) the temporal distribution of SPI values for dry and wet situations according to the 1, 3, 6, 9 and 12 month SPI, the longest dry and wet periods according to the 1, 3, 6, 9 and 12 month SPI and the distribution of SPI values for dry and wet situations according to the 1, 3, 6, 9 and 12 month SPI are given in Figures 3 and 4 and Table 4, respectively. The calculations were made for all the other stations but they are not given here because of length.

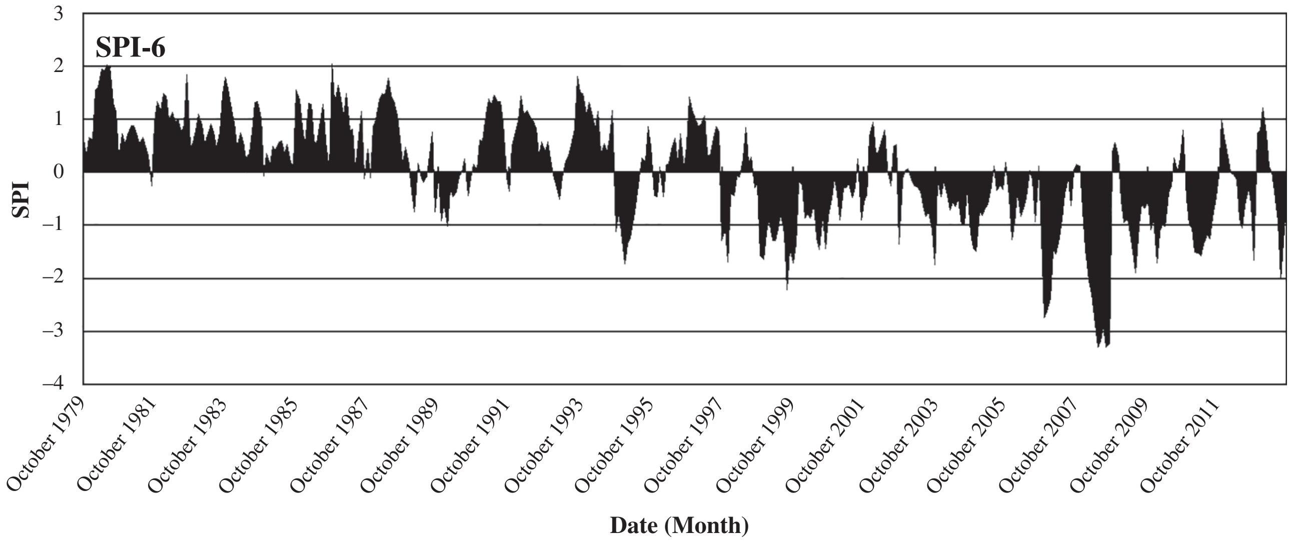

FIGURE 3 The temporal distribution of SPI values for dry and wet situations in Kirkuk station according to the 1, 3, 6, 9 and 12 month SPI

4.1 | Temporal variation of drought

The values of the temporal SPI according to the seasonal periods (1) SPI-3 December, (2) SPI-3 March, (3) SPI-3 June, (4) SPI-3 September, (5) SPI-6 March, (6) SPI-6 September, (7) SPI-12 for 1979–2013 are given in Figure 5. The occurrence of drought and wet events according to SPI-3 values are given in Figure S1.

4.2 | Discussion on the drought situation of the northern Iraq region

4.2.1 | Dry periods

Examining the dry periods, according to the SPI-1 values the highest percentage of dry months in the long-term data is found in Erbil, Pirmam, Duhok and Mosul with 40%, while Kirkuk was the highest of extremely dry months with 2.86%. Erbil had the highest severe dry percentage with 4.52%, and the highest moderate dry percentage was Mosul with 6.9%. Duhok had the highest mild dry percentage with 29.7%.

According to the SPI-3 values, the highest percentage of dry months in the long-term data is found in Duhok with 50%. It is seen that Makhmur is the highest with 3.43% of extreme dry months. Darbandikhan and Dokan had the highest severe dry percentage with 5.15%, Duhok a moderate dry percentage of 9.31% and Erbil had the highest mild dry percentage with 35.78%.

According to the SPI-6 values, the highest percentage of dry months in the long-term data is found in Makhmur, Khanaqin and Mosul with 50%. It is seen that Darbandikhan is the highest of the extreme dry months with 4.17%. For the severe dry percentage, Erbil and Sinjar with 5.88% were highest, for moderate dry percentage Duhok with 12.25%, and for the highest mild dry percentage Khanaqin with 34.56%.

According to the values of the 9 month SPI (SPI-9), Makhmur has the highest percentage of dry months with 54%. The station with the highest percentage of extreme dry months was Tuz Khurma with 7.35%, Pirmam with 6.95% for severe dry months; when the middle months are examined, it is seen that the highest percentage of moderate dry months was in Duhok with 13.97%. Also, Makhmur is determined to be the station with the highest rate of mild arid months with 36.52%.

When the 12 month values are examined, the percentage of dry months in all months is highest at Makhmur with 56%. The highest percentage of extreme dry months in these months is Sinjar and Tuz Khurma with 3.68%. Makhmur is observed as the highest severely dry station with 6.62%. The highest percentage of moderate dry months is 14.95% in Duhok, and the highest percentage of mild dry months is 40.44% in Makhmur. Dry months and percentages of the SPI-1, SPI-3, SPI-6, SPI-9 and SPI-12 values of all stations considered are given in Tables S1–S5.

4.2.2 | Wet periods

The monthly highest wet percentages for the SPI -1 values are 67% for Darbandikhan, Kirkuk and Khanaqin; in wet months, the highest percentage of extreme wet months is 2.38% in Erbil and Makhmur. The highest percentage of severe wet months is 4.76% in Mosul. The highest percentage (24.52%) of moderate wet months is observed in Tuz Khurma. The maximum percentage of mild wet months is determined at Sulaymaniyah with 48.81%.

For SPI-3 values the highest percentage of wet months is in Darbandikhan and Kirkuk with 55%. Erbil and Makhmur have the largest amount of extreme wet months with 2.21%. For severe wet percentage, the highest is in Makhmur with 5.15%. The highest percentage of moderate wet months is in Sulaymaniyah with 10.78%. The highest percentage of mild wet months is determined to be Darbandikhan with 48.77%.

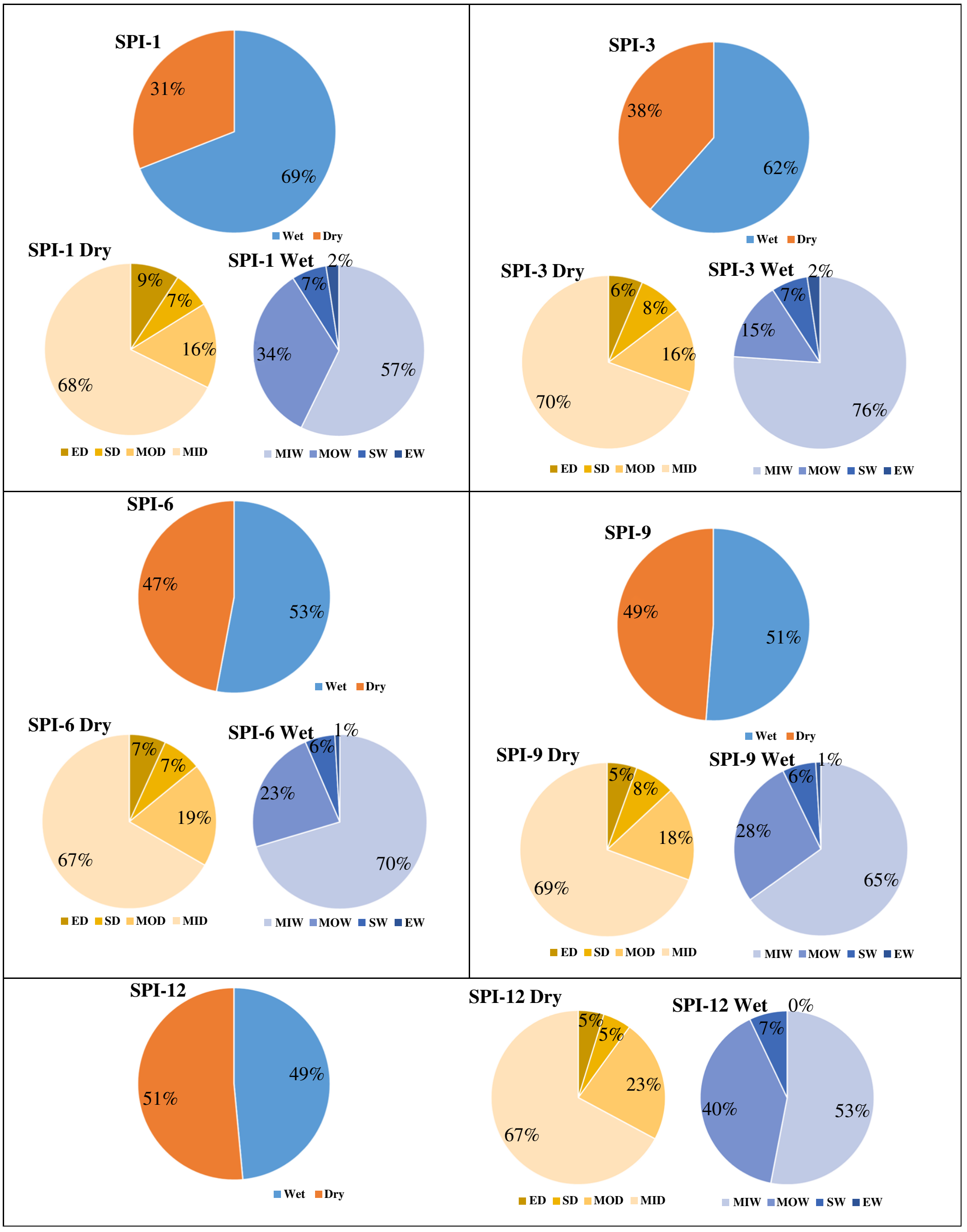

FIGURE 4 The distribution of SPI values for dry and wet situations according to the 1, 3, 6, 9 and 12 month SPI [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 4 The longest dry and wet periods in Kirkuk station according to 1, 3, 6, 9 and 12 month SPI

	Dry period			Wet period		
	Start	Finish	Time	Start	Finish	Time
SPI-1	December 8–9	May 9–10	6 months	December 88–April 91	November 89–March 92	12 months
SPI-3	October 98–99	July 99–00	10 months	February 86	May 87	16 months
SPI-6	September 98	July 1	35 months	October 81	October 84	37 months
SPI-9	October 6	September 10	48 months	October 79	December 88	112 months
SPI-12	March 3	December 12	118 months	October 79	March 89	115 months

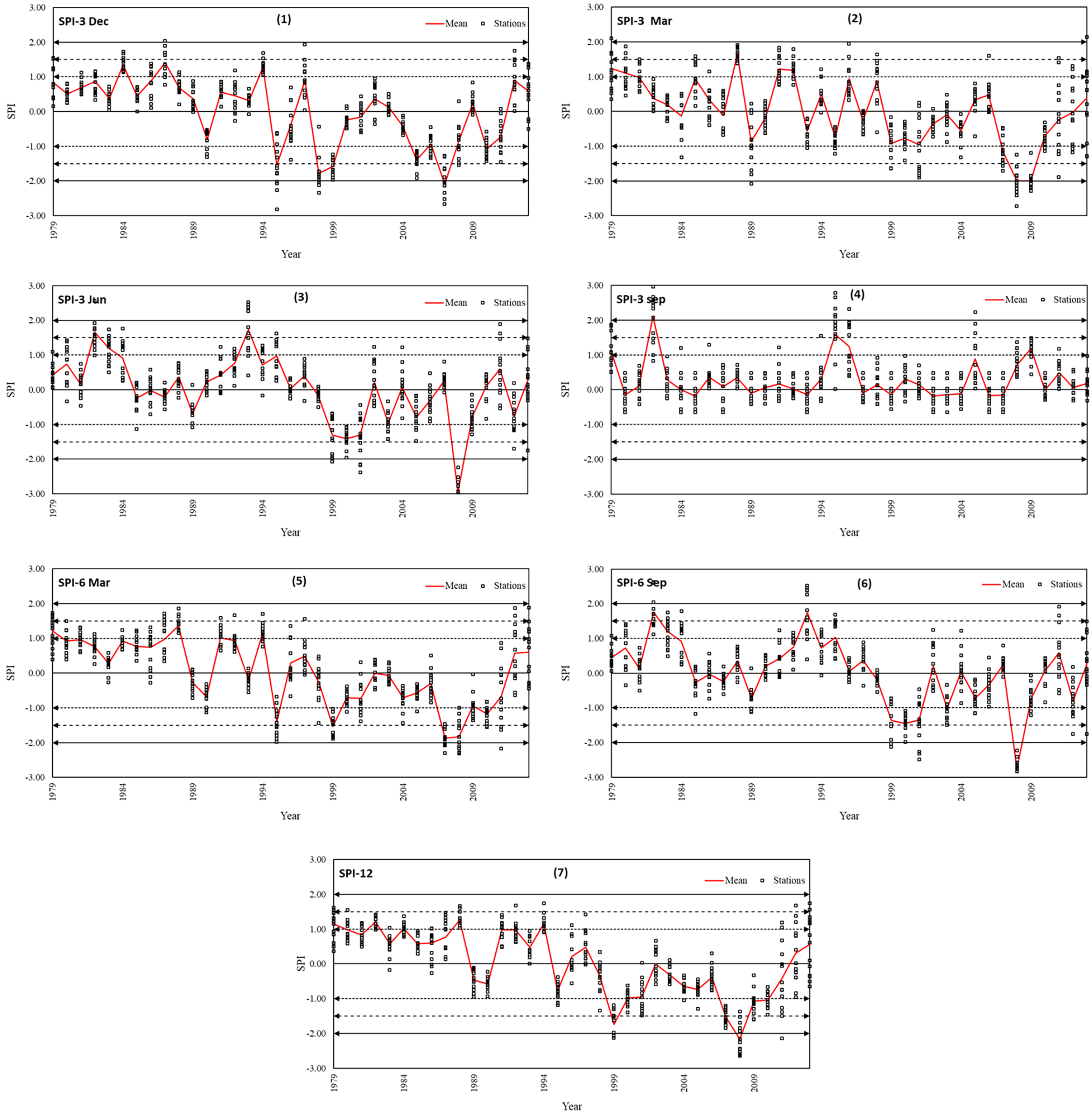

FIGURE 5 The values of temporal SPI according to the seasonal periods for 1979–2013: (1) SPI-3 December, (2) SPI-3 March, (3) SPI-3 June, (4) SPI-3 September, (5) SPI-6 March, (6) SPI-6 September, (7) SPI-12 [Colour figure can be viewed at wileyonlinelibrary.com]

For the SPI-6 values and wet months, the percentage of wet months is about 55% for Tuz Khurma compared to all station data. The highest percentage of extreme wet months is 1.96% in Makhmur, and the highest percentage of severe wet months is in Tuz Khurma with 5.39%. The highest percentage of moderate wet months is in Mosul with 15.69%. Tuz Khurma is determined to have the highest percentage of mild wet months with 40.69%.

For the SPI -9 values and wet months, the percentage of wet months is about 55% for Sangaw compared to all station data. The highest percentage of extreme wet months is 0.98% in Makhmur and Pirmam, and the highest percentage of severe wet months is in Tuz Khurma with 6.13%. The highest percentage of moderate wet months is in Tal Afar with 18.63%. Sulaymaniyah is determined to have the highest percentage of mild wet months with 38.24%.

For the SPI-12 values and wet months, the percentage of wet months is about 56% for Sangaw compared to all station data. The highest percentage of extreme wet months is 0.98% in Duhok, and the highest percentage of severe wet months is in Makhmur with 6.37%. The highest percentage of moderate wet months is in Tal Afar with 21.57%. Sulaymaniyah is determined to have the highest percentage of mild wet months with 35%. Wet months and percentages of the SPI-1, SPI-3, SPI-6, SPI-9 and SPI-12 values of all stations considered are given in Tables S6–S10.

5 | CONCLUSIONS

In this study, drought analysis of the northern Iraq area was carried out using long-term monthly total rainfall data measured at 15 meteorological observation stations in the Erbil, Sulaymaniyah, Duhok, Kirkuk and Mosul provinces.

Due to the final results of this study, temporal drought values for different time scales in the northern Iraq region were examined in detail. Based on the findings from the present drought analysis in the northern Iraq region by using monthly precipitation time series, the following conclusions may be drawn.

Considering the spatial and climatic characteristics of focal points in all three characteristics studied in a drought, among the 50 stations Makhmur station has the highest frequency of drought occurrence on a 12 month time scale with 227 drought occurrences. Kirkuk station has the highest frequency of wet occurrence on a 1 month time scale with 290 wet occurrences. Regarding the second feature studied, Erbil station has the longest duration of drought on all five time scales. Kirkuk and Chamchamal stations have the longest duration of wet on all five time scales. The third characteristic is drought severity. Makhmur station has a value of 40.44%, which is the highest dry Standardized Precipitation Index (SPI) value in the 12 month time series. Sulaymaniyah station has a value of 48.81%, the highest wet SPI in the 1 month time series. The results obtained from this study have been extracted as focal points of the three characteristics studied.

The SPI method was used to determine the temporal drought and the data were evaluated according to 1, 3, 6, 9 and 12 month time scales. When the SPI-1 values of the stations are examined, the longest dry periods for Arbil, Makhmur, Pirmam, Sulaymaniyah, Darbandikhan and Chamchamal stations were 162, 131, 97, 93, 60 and 125 months respectively, with 58 months for Sangaw station, 107 months for Dokan station and 62 months for Duhok station. For Sinjar, Kirkuk and Khanaqin stations the longest dry periods were 86, 118 and 48 months, respectively. Tuz Khurma, Mosul and Tal Afar stations were 82, 118 and 93 months respectively. The start dates of the longest dry periods of all the stations examined were generally between 1997 and 2012, according to the SPI-12 values.

The drought has a direct and indirect impact on life and the socioeconomic and environmental structure, so, the impact can be divided into two groups: direct and indirect. It can also be arranged in first order and second order (Paul, 1998). In societies where their economies are based on agriculture, the direct effects of the first batch of drought arise as a decrease in food production due to reduced crops and yields (Krannich *et al*., 1995). Reducing employment and income levels is one of the indirect and second-order effects in these communities, the main reasons for which are the reduction of land use, the reduction of operations (irrigation) and harvesting. As a result of reduced food production, food prices usually increase rapidly as a result of drought. Decreasing food production abnormally leads to rising food prices, and lack of access to appropriate jobs reduces the access of rural people to food; the occurrence of such problems, especially for small farmers and landless workers, is clear (Paul, 1998). So, in a time of drought, unpleasant and unusual uses of existing water resources, along with the weakness of water distribution systems, exacerbate the crisis (Karami and Keshavarz, 2010).

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Conflict of interest

The authors declare that they have no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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