Analysis of Climatic Drought in Syria Using the Standardized Precipitation Index (SPI), 1993–2023

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Abstract:

This study analyzes drought periods at thirteen rainfall stations in Syria, which encompasses semi-humid and semi-arid climatic zones, using the Standardized Precipitation Index (SPI). Relative frequencies of drought categories were calculated, and produces GIS-based drought maps of these periods. Results show that >50% of years across all stations were normal. The study period was divided into three time periods to identify the driest period and assess the severity of the drought. It was observed that the moderate drought category was the most frequent during the three periods, with the highest frequency recorded during the first period (1993-2002) at Bouqa station at 40%, and 30.77% of the area affected by drought, which means partial regional drought. The highest frequency was recorded during the second period (2003-2012) at Qamishli station at 30%, and 23.08% of the area affected by drought which indicates local drought. During the third period (2013-2023), the highest frequency of moderate drought was recorded at Salkhad station at 27.3%, and 23.08% of the area affected by drought, whereas the frequency of severe and extreme drought was low, not exceeding 10%, in all stations with both semi-humid and semi-arid climates.

Keywords: Climatic Drought, Standardized Precipitation Index, Relative Frequency, Extreme drought, Severe drought.

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تحليل الجفاف المناخي في سوريا باستخدام المؤشر المعياري للهطل (SPI) للفترة (1993 – 2023)

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الملخص:

تهدف هذه الدراسة إلى تحليل فترات الجفاف في ثلاثة عشر محطة مطرية في سورية، تشمل مناطق مناخية شبه رطبة وشبه جافة، باستخدام المؤشر المعياري للهطل Standardized Precipitation Index، حُسبت التكرارات النسبية لفئات الجفاف، وأُنتجت خرائط جفاف باستخدام (GIS). تُظهر النتائج أن أكثر من 50 %من السنوات في جميع المحطات كانت طبيعية. قُسمت فترة الدراسة إلى ثلاث فترات زمنية لتحديد الفترة الأكثر جفافًا وتقييم شدة الجفاف. لوحظ أن فئة الجفاف المعتدل كانت الأكثر شيوعًا خلال الفترات الثلاث، حيث سُجل أعلى تكرار خلال الفترة الأولى (1993-2002) في محطة بوقا بنسبة 40% و30.77 % من المساحة المتأثرة بالجفاف، مما يعني جفافًا إقليميًا جزئيًا. سُجل أعلى تكرار خلال الفترة الثانية (2003-2012) في محطة القامشلي بنسبة 30% و23.08 % من المساحة المتأثرة بالجفاف، مما يشير إلى جفاف محلي. خلال الفترة الثالثة (2003 -2023) تم تسجيل أعلى معدل للجفاف المعتدل في محطة صلخد بنسبة 27.3% و23.08 % من المساحة المتأثرة بالجفاف، في حين كان معدل الجفاف الشديد والمتطرف منخفضاً، ولم يتجاوز 10% في جميع المحطات ذات المناخ شبه الرطب وشبه الجاف.

الكلمات المفتاحية: الجفاف المناخي، مؤشر الهطل المعياري، التكرار النسبي، الجفاف الشديد، الجفاف المتطرف.

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Drought is a condition of insufficient moisture caused by a deficit in precipitation over some time period. Difficulties are primarily related to the time period over which deficits accumulate and to the connection of the deficit in precipitation to deficits in usable water sources and the impacts that ensue (McKee et al, 1993). The length of the drought varies greatly from place to place. However, drought reaches its peak when water scarcity threatens to restrict human activities. Therefore, water conservation policies must be implemented to ensure its sustainability. Drought is an environmental disaster that can devastate regional agriculture, water resources and ecosystem services as well as human settlements .Globally, the frequency and intensity of extreme drought events are expected to increase (Mokhtar et al, 2017, p.503). According to the World Meteorological Organization, drought occurs when the total seasonal rainfall is less than 60% of the average for more than two consecutive seasons (Al-Nahlawi, 1991, pp.27-28).

Four types of drought can be distinguished based on the length and timing of the drought. The first type is permanent or continuous drought, which occurs when the amount of rainfall falls below the potential evapotranspiration, requiring irrigation of crops. The second type is sudden or flash drought, which occurs as a result of fluctuating rainfall, especially in humid and semi-humid regions. The third type is seasonal drought, where rainfall occurs during a particular season and not others, as is the case in the study area, where rainfall is concentrated in winter. The fourth type is unforeseen drought, in which air humidity and soil moisture are so low that they are insufficient for plant needs (Badawy, 2023, pp.58- 59).

Researchers have developed many mathematical indicators for measuring and evaluating drought incidents, and crop moisture index (CMI) (Palmer, 1968); Palmer Drought Severity Index (PDSI) (Palmer, 1965); Standardized Precipitation Index (SPI) (McKee et al.,1995). SPI is the number of standard deviations by which cumulative rainfall deviates from its climatic average for a given period of time (McKee et al, 1993), and it is one of the most reliable indicators are used for assessing meteorological drought, since its suitability and capabilities to assess on multiple temporal scales (1, 3, 6, 9, and 12-month timescales). However, SPI is a probabilistic index that used rainfall variability as a crucial indicator influencing drought severity and duration, ranges between -3 (severe drought) to +3 (wet conditions) (Chaitanya et al, 2022, p.4).

I. IMPORTANCE AND OBJECTIVES OF THE STUDY:

The importance of the research comes from its attempt to assess drought in Syria which has a great effect on agricultural and economic sides. This research uses the Standardized Precipitation Index (SPI) to identify periods of drought and wetness, as well as to estimate the severity and frequency of drought.

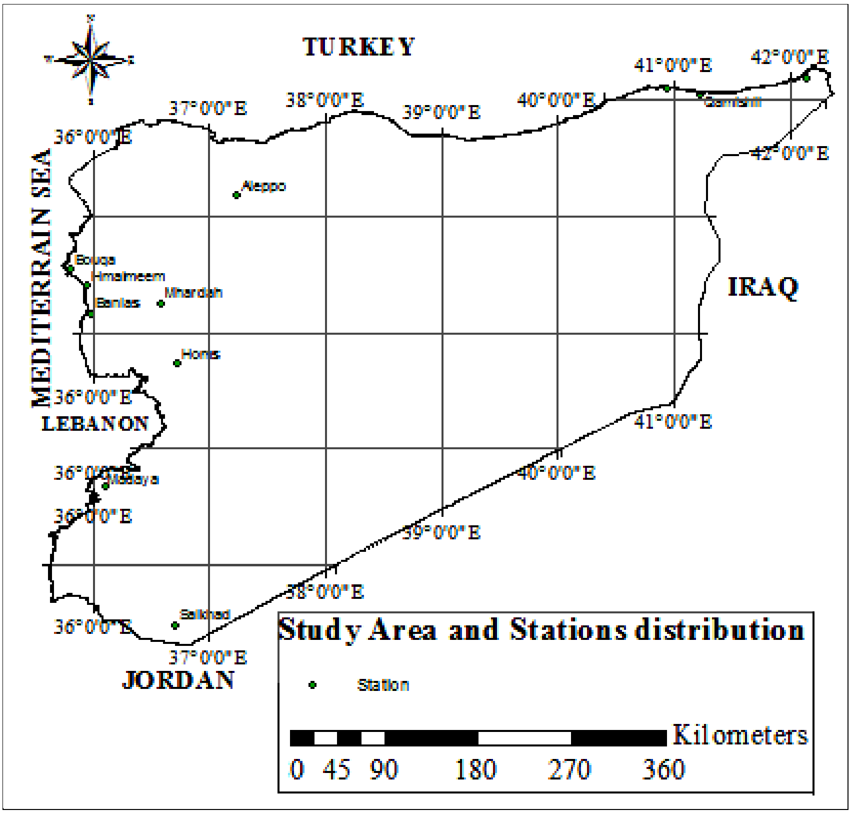
The most important objectives of this research is to calculate the SPI values for a 12-month timescales during the period 1993-2023, in addition to identifying periods of wetness and drought and classifying the severity and frequency of each one. It also aims to calculate the probability of drought and then estimate the percentage of area affected by drought.

II. STUDY AREA:

The Syrian Arab Republic has a surface area of 185.180 km2. This area is confined between latitudes of 32˚ and 37˚ N and longitudes 36˚and 42˚ E. Turkey, Iraq, Lebanon and Jordan bound Syria on the north, east, south and west respectively. The Eastern Coast of the Mediterranean Sea forms the western maritime boundary of Syria. The length of the Syrian Coast along the Mediterranean Sea is roughly 300 km (Shahin, 2007, p.5). This study only relied on stations representative of the semi-humid and semi-arid zones, according to the map prepared by the General Directorate of Meteorology, which shows the five bioclimatic zones in Syria (semi-humid, humid, semi-arid, arid, and very arid) according to the Emberger formula*.

*Emberger's formula depends on the ratio between the annual precipitation rate (p) and the temperature range (M-m) and the mean temperature ($\frac{M+m}{2}$), according to this formula, the climatic regimes in Syria are: humid, semi-humid, semi-arid, dry, and very dry (semi-desert)(Abdul Salam et al, 2004, p.306).

Figure 1: **The study area and distribution of meteorological stations.**



Source: Prepared by researchers**.**

Table 1: **Coordinates of the study area stations**

Station	Long. (Y)	Lat.(X)
Lattakia	35˚ 46′ 45	35˚ 31′ 25
Bouqa	35° 48′ 19″	35° 32′ 25″
Humaimeem	35° 56′ 33″	35° 24′ 28″
Tartous	35˚ 52′ 57	34˚ 52′ 16
Banias	35˚ 18′	35˚ 95′
Homs	36˚ 43′ 30	34˚ 43′ 45
Aleppo	37˚ 14′ 25	36˚ 10′ 30
Qamishli	41˚ 13′ 40	37˚ 03′ 20
Almalkiah	42˚ 08′	37˚ 11′
Amouda	40˚ 56′	37˚ 06′
Salkhad	36˚ 42′	32˚ 29′
Madaya	36˚ 06′	33˚ 41′
Mhardah	36˚ 35′	35˚ 15′

Source: General directorate of meteorology, climate department, Damascus.

III. Previous Studies:

Several local and Arab studies have addressed climatic drought using the standard precipitation index. Among the most important studies that have been utilized are:

1. The study by Fayad, R., & Ali, Y., (2024), titled "**Spatiotemporal Variations of Rainfall at Lattakia Governorate Using the Standardized Precipitation Index (SPI),"** analyzed periods of drought and humidity at Lattakia Governorate, northwestern Syria, and studied their spatial and temporal distribution using the SPI during the period 1993-2023 for 3- and 6-month periods. It also calculated the frequency of drought periods. The results showed that the stations at higher altitudes (Slenfeh and Kassab) experienced localized drought during a 6-month period, with rates ranging from 10% to 25%, while the drought was less severe at other stations, with rates less than 10%.
2. A study by Michel, S., and Mathbout, Sh., (2024), entitled **"Drought Analysis in the Syrian Jazira Region Using the Standardized Precipitation Index (SPI)"** which estimate the severity, frequency, and spatial extent of seasonal and annual droughts in the Jazira region of Syria using the Standardized Precipitation Index. One of its most prominent findings was a high frequency of drought, exceeding 20%, across all studied stations, albeit to varying degrees.
3. A study by Al-Hasnawi, A. A, D., (2023), entitled "**Changing Aridity and Humidity Maps in Iraq",** aimed to illustrate changes in aridity and humidity maps in Iraq using several indicators, most importantly the SPI index. It also sought to identify the most influential climatic elements on aridity and humidity values in Iraq and to describe their characteristics and trends. The study revealed that Iraq's climatic characteristics have a significant impact on determining aridity levels, with temperature having a direct proportional effect on aridity. There is also a difference in the distribution of climatic regions between the stations of northern and southern Iraq, and the Najaf station had the highest rates of drought.
4. A study by Mathbout et al., (2018), titled **"Spatiotemporal Analysis of Drought Variability Across Multiple Timescales in Syria During the Period 1961–2012,"** found,

through the application of the SPI and SPEI indices, that three regions in Syria experienced severe drought in the 1990s, a phenomenon previously unseen in the country. Furthermore, the drought period from 2007 to 2010 was the most severe.

5. A study By Rashid, M, M, A., (2010), entitled **(Analysis of Rainfall Drought Periods in Northern Iraq Using the Standardized Precipitation Index (SPI)**, aimed to use the Standardized Precipitation Index in analyzing rainfall data in nine climatological stations in northern Iraq during the period (1941-2002) and drawing digital maps showing the rates of drought severity and the drought severity classes at the study site. One of its most prominent results was that the percentage of dry years that the region went through constitutes approximately 56% of the study period.

IV. MATERIAL AND METHODS:

1. DATA SOURCES:

The research used monthly rainfall data recorded over 31 years for the period of 1993- 2023 at 13 rainfall monitoring stations in Syria (*Figure.1*). This data was obtained from the General Directorate of Meteorology.

- Standardized Precipitation Index (SPI):

The Standardized Precipitation Index- SPI was used to measure the severity of drought in Syrian bioclimatic regimes over varying time periods. The SPI is commonly calculated for 1-, 3-, 6-, and - 12 month timescales, but in this study, it will be measured for 12 months during the period (1993-2023). The statistical analysis using the standardized Precipitation index is based on the principle of transforming the gamma distribution of the data series into a normal distribution. Therefore, the mean value of the standardized Precipitation index data is zero, while positive values of the standardized Precipitation index indicate an excess of rainfall above the general average; i.e., wet years. Negative values of the standardized Precipitation index indicate a deficiency of rainfall compared to the general average. That is, dry years. To calculate the standardized Precipitation index, the gamma distribution of the rainfall data series for each rain station is calculated using the distribution function shown in the following equations(Khamaj & Al-Miloudi, 2019, p.6):

$$g\ (x)= \frac{1}{\beta^{\alpha}\tau(\alpha)}\ x^{\alpha-1}e^{-x/\beta}$$

$$\tau(\alpha) = \int_{0}^{\infty} y^{\alpha-1}e^{-y}dy$$

The SPI calculation formula based on the Γ fitting function is as follows:

$$\text{SPI}=\text{S}\ \frac{t-(c_2t+c_1)t+c_0}{[(d_3t+d_2)]t+d_1]t+1.0}$$

$$\text{t} = \sqrt{In(\frac{1}{G(x)^2})}$$

The G(x) is calculated using the Γ distribution function probability density integral formula (Chen et al, 2022, p.6):

$$\text{G}(x)= \frac{1}{\beta^{\gamma}\ \Gamma(\gamma)} \int_{0}^{x} x^{\gamma-1}\ e^{-\frac{x}{\beta}}\,dx, \quad \text{for } x > 0$$

Where: S is the positive and negative coefficient of the probability distribution. (c_0, c_1, c_2, d_1, d_2, d_3) the calculated parameters of the 6-digit distribution function are converted to the simplified approximate solution formula for the cumulative frequency.(x) is the probability of the rainfall distribution associated with the general distribution function. X is the amount of rainfall at which the general distribution is to be evaluated.

Table 2 shows the Standardized precipitation index drought and wet class classification criteria.

***Table 2*: Standardized Precipitation Index (SPI) Categories**

Classification	SPI
Extremely wet	>2.0
Very wet	1.5 to 1.99
Moderately wet	1.0 to 1.49
Near normal	-0.99 to 0.99
Moderately dry	-1.0 to -1.49
Severely dry	-1.5 to -1.99
Extremely dry	2->

Source: Allaby, 2007, p151.

For the spatial and temporal variation characteristics of regional drought, the relative frequency of drought (F_i) and the drought area ratio (P_i) were calculated to assess the impact of drought in the region using the following equation:

$$F_i = \frac{m_i}{M} \times 100$$
$$p_j = \frac{n_j}{N} \times 100$$

Where (M) is the total number of years, (m_i) is the number of drought years for the various index categories during the time period of study, N is the total number of grids, and n_j is the number of grids that experienced drought in the year. When: $p_j \geq 50\%$ drought covers a large area at the regional level, $33\% \leq p_j < 50\%$ is a regional drought, $25\% \leq p_j < 33\%$ is a partial regional drought, $10\% \leq p_j < 25\%$ is a local drought, and $p_j < 10\%$ is no significant drought. (Chen et al, 2022, p.6)

V. Results and Discussion:

1. Climate of the Study Area :

Syria's climate belongs to the Mediterranean basin or subtropical climate with dry summers, according to Köppen climate classification. The following two models are prevalent: The Central Region: The Mediterranean coastal climate model with **warm** summers. Seawater, stratus clouds, and fog moderate summer temperatures, keeping the average temperature of the hottest month below 22°C. This model prevails along the coast and its immediate vicinity and does not extend far into the central region. The Mediterranean climate model with **hot** summers: This model is generally found far from the coast and away from the influences of seawater. Summer temperatures are high, and winter temperatures are cold. Precipitation and temperature are the two factors that determine the distribution of climatic zones in Syria. *Table 3* shows that the highest annual rainfall was recorded at Tartous station at 887.1 mm, and the lowest at Salkhad station at 299.5 mm. The table also shows that the variance coefficient increases at Mhardah and Amouda stations to 38.5% and 38.4%, respectively. Therefore, crops in the areas served by these two stations require supplemental irrigation, and rainwater alone cannot be relied upon for irrigation.

Table 3: **Characteristic's rainfall at the studied stations**

Station	N. years	Aver.	Min	Max	Std. D	Cv
		mm	mm	mm		%
Tartous	31	**887.1**	465.4	1724.7	310.7	35.0
Lattakia	31	745.4	441.3	1320.1	223.4	30.0
Banias	31	844.3	505.0	1525.0	262.0	31.0
Bouqa	31	854.8	461.8	1752.2	315.8	36.9
Humaimeem	31	830.1	527.3	1673.5	272.6	32.8
Almalkiah	31	521.0	249.5	937.3	200.4	32.0
Mhardah	31	359.3	127.0	597.0	115.0	**38.5**
Aleppo	31	371.2	109.3	785.5	134.4	36.2
Qamishli	31	358.6	167.8	667.2	125.3	34.9
Amouda	31	366.8	148.0	718.3	141.0	**38.4**
Homs	31	404.6	143.0	672.0	117.7	29.1
Madaya	31	448.7	165.0	823.8	118.4	26.4
Salkhad	31	**299.5**	193.5	454.0	73.7	24.6

Source: Prepared by researchers.

2. Calculate Standardized Precipitation Index (SPI12):

The Standardized Precipitation Index (SPI) reflects long-term precipitation patterns. These time ranges are the cumulative result of shorter periods in which precipitation may be above or below average, the longer-term standard precipitation indices tend to approach zero unless a distinct wet or dry trend occurs. The indices in these time ranges are usually correlated with stream flows, reservoir levels, and even groundwater levels over longer time ranges. (WMO, 2012, p.8).

The Standardized Precipitation Index -SPI is a relative index for classifying dry and wet periods, dealing with each climatic station individually from the others, and The average of rainfall is the dividing line between wet and dry periods at a station (Al-Esawi, 2020, p.23). Therefore, the term "drought" is not associated with stations that have low rainfall rates, nor is the term "wet" associated with stations that have high rainfall rates (Rashid, 2010, p.61). For example, The average rainfall at Tartous station is 887.1 mm. Any year with rainfall average less than this is considered a drought year. Similarly, the average of rainfall at Salkhad station is 299.5 mm. If this average is exceeded, the year is considered rainy.

Applying the Standardized Precipitation Index (SPI) to the rainfall data from the stations shows that the number of normal years ranges between 18 and 26, with the highest number recorded at Almalkiah station, followed by Aleppo and Madaya stations. The highest number of severe drought years was recorded at

Mhardah station, with two years. The number of very severe drought years was two at Mhardah, Qamishli, Amouda, and Homs, and one year each at Tartous, Lattakia, Almalkiah, Aleppo, and Salkhad. Banias recorded the highest number of moderate drought years, with six. Regarding very wet years, two years were recorded at the semi-humid stations Bouqa and Humaimeem, and one year at the remaining stations, excluding Mhardah, Almalkiah, and Salkhad, where no years were recorded. The number of very wet years was three at Almalkiah and Amouda stations, while the humidity was moderate for five years of the study period at Mhardah station and four years at Almalkiah.

***Table 4*: Number of years according to the SPI categories during the period (1993 - 2023)**

Station	**Extremely dry**	**Severely dry**	**Moderately dry**	**Near normal**	**Moderately wet**	**Severely wet**	**Extremely wet**
	-2 >	**-1.5 > - 1.99**	**- 1 > - 1.49**	**0.99 > - 0.99**	**1.49 > 1**	**1.99 > 1.5**	2 <
Tartous	0	1	4	21	2	2	**1**
Lattakia	0	1	3	21	3	2	**1**
Banias	0	0	6	20	2	2	**1**
Bouqa	0	0	4	23	1	1	**2**
Humaimeem	0	0	2	25	2	0	**2**
Mhardah	2	2	2	19	5	1	**0**
Almalkiah	0	1	5	18	4	3	**0**
Aleppo	1	1	0	26	1	1	**1**
Qamishli	0	2	3	23	0	2	**1**
Amouda	0	2	3	20	2	3	**1**
Homs	1	2	2	23	1	1	**1**
Madaya	1	0	0	26	2	1	**1**
Salkhad	0	1	5	20	2	3	**0**

Source: Prepared by researchers.

Relative frequencies for moderate, severe, extreme drought, and wet conditions were calculated from the data shown in *table 4.* The computed relative frequencies are displayed in *table 5.*

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Table 5: **Relative frequency of years according to the SPI index during the period (1993-2023)**

Station	Extremely dry	Severely dry	Moderately dry	Near normal	Moderately wet	Severely wet	Extremely wet
Lattakia	0.0	3.23	9.68	67.74	9.68	6.45	**3.23**
Bouqa	0.0	0.0	12.9	74.19	3.23	3.23	**6.45**
Humaimeem	0.0	0.0	6.45	80.65	6.45	0.0	**6.45**
Tartous	0.0	3.23	12.9	67.74	6.45	6.45	**3.23**
Banias	0.0	00.	19.35	64.52	6.45	6.45	**3.23**
Homs	3.23	6.45	6.45	70.97	3.23	3.23	**3.23**
Aleppo	3.23	3.23	0.0	83.87	3.23	3.23	**3.23**
Qamishli	0.0	6.45	9.68	74.19	0.0	6.45	**3.23**
Almalkiah	0.0	3.23	16.13	58.06	12.9	9.68	**0.0**
Amouda	0.0	6.45	9.68	64.52	6.45	9.68	**3.23**
Salkhad	0.0	3.23	16.13	64.52	6.45	9.68	**0.0**
Madaya	3.23	0.0	0.0	83.87	6.45	3.23	**3.23**
Mhardah	6.45	6.45	6.45	61.29	16.13	3.23	**0.0**

Source: Prepared by researchers.

3. Classification of Drought Intensity:

Based on the Standardized Precipitation Index (SPI), years were classified according to the severity of drought (moderate- severe- extreme), and their relative frequency was calculated over three time periods: the first period (1993-2002), the second period (2003-2012), and the third period (2013-2023) to determine the driest period.

A. Classification of Drought Categories During the First Period (1993-2002):

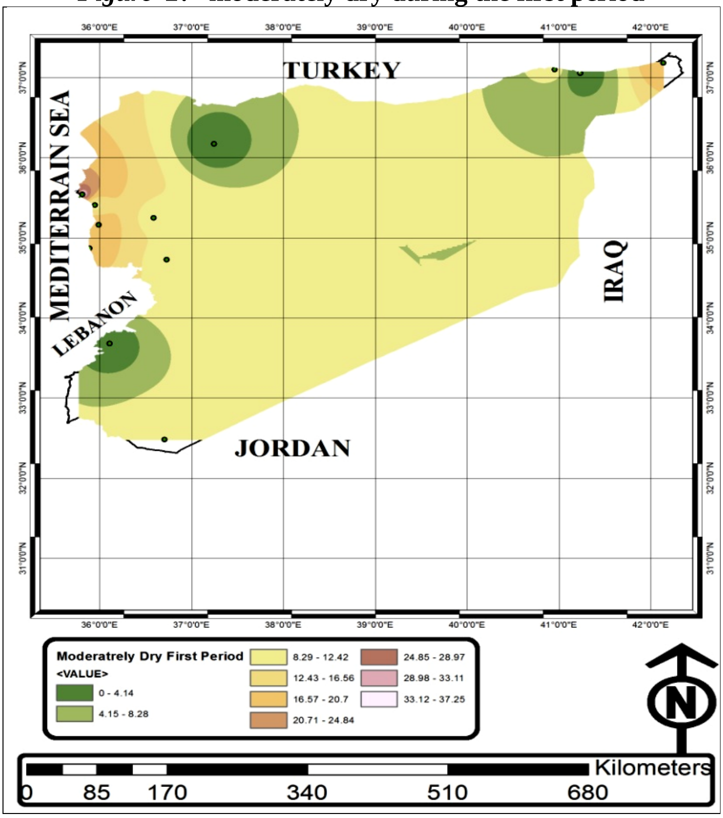
During the first period, moderate drought years were observed at Bouqa station with a high relative frequency of 40% and 30.77% of the area affected by drought, and a low relative frequency at Humaimeem, Homs, Amouda, Salkhad, and Mhardah stations with relative frequency 10% and 7.69% of the area affected by drought. Whereas, Aleppo, Qamishli and Madaya stations showed no occurrence of moderate drought years.

Table 6: **Relative frequency of moderately dry years during the first period**

Station	Period	Drought Type	SPI. Value	Years N.	Relative. F	P%
Lattakia	1993-2002	Moderately dry	- 1 > - 1.49	1	10	7.69
Bouqa			- 1 > - 1.49	4	40	**30.77**
Humaimeem			- 1 > - 1.49	1	10	7.69
Tartous			- 1 > - 1.49	2	20	15.38
Banias			- 1 > - 1.49	2	20	15.38
Homs			- 1 > - 1.49	1	10	7.69
Aleppo			- 1 > - 1.49	0	0	0.00
Qamishli			- 1 > - 1.49	0	0	0.00
Almalkiah			- 1 > - 1.49	2	20	15.38
Amouda			- 1 > - 1.49	1	10	7.69
Salkhad			- 1 > - 1.49	1	10	7.69
Madaya			- 1 > - 1.49	0	0	0.00
Mhardah			- 1 > - 1.49	1	10	7.69

Source: Prepared by researchers.

***Figure 2*:** **moderately dry during the first period**



Source: Prepared by researchers.

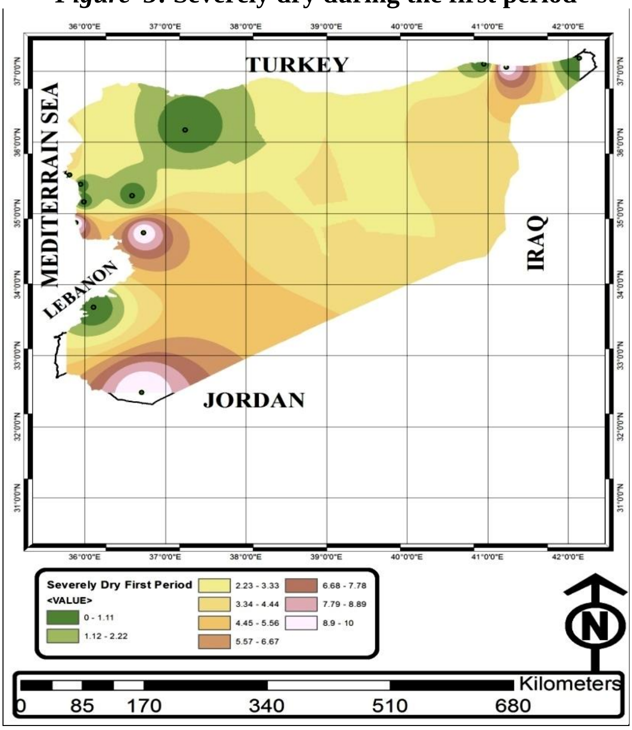
During the first period, severe drought years were observed at Lattakia, Tartous, Homs, Qamishli, and Salkhad stations with a relative frequency of 10% and 7.69% of the area affected by drought ,whereas the remaining stations showed no occurrence of Severe drought years.

***Table 7*: Relative frequency of severe dry years during the first period**

Station	Period	Drought Type	SPI. Value	N. Years	Relative. F	P%
Lattakia	1993-2002	Severely dry	-1.5 > - 1.99	1	10	**7.69**
Bouqa			-1.5 > - 1.99	0	0	0.00
Humaimeem			-1.5 > - 1.99	0	0	0.00
Tartous			-1.5 > - 1.99	1	10	**7.69**
Banias			-1.5 > - 1.99	0	0	0.00
Homs			-1.5 > - 1.99	1	10	**7.69**
Aleppo			-1.5 > - 1.99	0	0	0.00
Qamishli			-1.5 > - 1.99	1	10	**7.69**
Almalkiah			-1.5 > - 1.99	0	0	0.00
Amouda			-1.5 > - 1.99	0	0	0.00
Salkhad			-1.5 > - 1.99	1	10	**7.69**
Madaya			-1.5 > - 1.99	0	0	0.00
Mhardah			-1.5 > - 1.99	0	0	0.00

Source: Prepared by researchers.

***Figure 3*: Severely dry during the first period**



Source: Prepared by researchers.

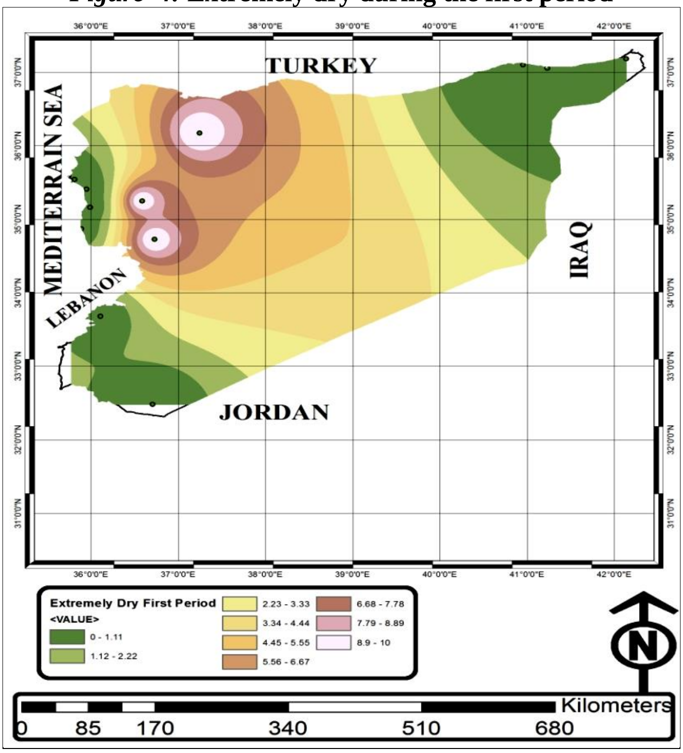
During the first period, extreme drought years were observed at Homs, Aleppo, and Mhardah stations with a relative frequency of 10% and 7.69% of the area affected by drought, whereas the remaining stations showed no occurrence of extreme drought years.

Table 8 **: Relative frequency of extreme dry years during the first period**

Station	Period	Drought Type	SPI. Value	N. Years	Relative. F	P%
Lattakia			-2 >	0	0	0.00
Bouqa			-2 >	0	0	0.00
Humaimeem			-2 >	0	0	0.00
Tartous			-2 >	0	0	0.00
Banias			-2 >	0	0	0.00
Homs			-2 >	1	10	**7.69**
Aleppo	**1993-2002**	**Extremely dry**	-2 >	1	10	**7.69**
Qamishli			-2 >	0	0	0.00
Almalkiah			-2 >	0	0	0.00
Amouda			-2 >	0	0	0.00
Salkhad			-2 >	0	0	0.00
Madaya			-2 >	0	0	0.00
Mhardah			-2 >	1	10	**7.69**

Source: Prepared by researchers.

Figure 4: **Extremely dry during the first period**



Source: Prepared by researchers.

B. Classification of Drought Categories During the Second Period (2003-2012):

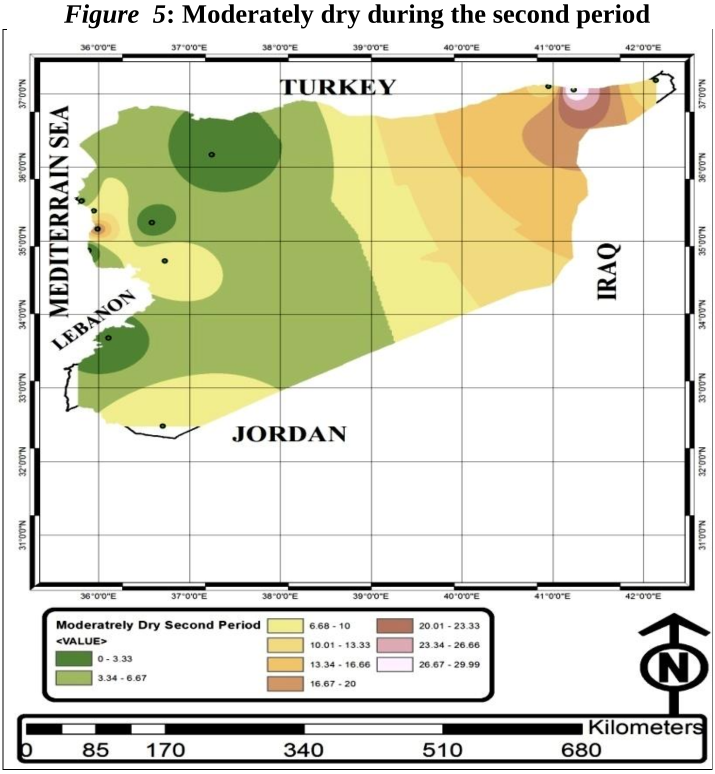
During the second period, moderate drought years were observed at Qamishli station with a high relative frequency of 30% and 23.08% of the area affected by drought, and a low relative frequency at Lattakia, Humaimeem, Homs, Almalkiah, Amouda, and Salkhad stations at 10% and 7.69% of the area affected by drought. Whereas the remaining stations showed no occurrence of moderate drought years.

Table 9 **: Relative Frequency of Moderate Drought Years During the Second Period**

Station	Period	Drought Type	SPI. Value	N. Years	Relative. F	P%
Lattakia			- 1 > - 1.49	1	10	**7.69**
Bouqa			- 1 > - 1.49	0	0	0.00
Humaimeem			- 1 > - 1.49	1	10	**7.69**
Tartous			- 1 > - 1.49	0	0	0.00
Banias			- 1 > - 1.49	2	20	15.38
Homs			- 1 > - 1.49	1	10	**7.69**
Aleppo	**2003-2012**	**Moderately dry**	- 1 > - 1.49	0	0	0.00
Qamishli			- 1 > - 1.49	3	30	**23.08**
Almalkiah			- 1 > - 1.49	1	10	**7.69**
Amouda			- 1 > - 1.49	1	10	**7.69**
Salkhad			- 1 > - 1.49	1	10	**7.69**
Madaya			- 1 > - 1.49	0	0	0.00
Mhardah			- 1 > - 1.49	0	0	0.00

Source: Prepared by researchers.

Figure 5**: Moderately dry during the second period**



Source: Prepared by researchers.

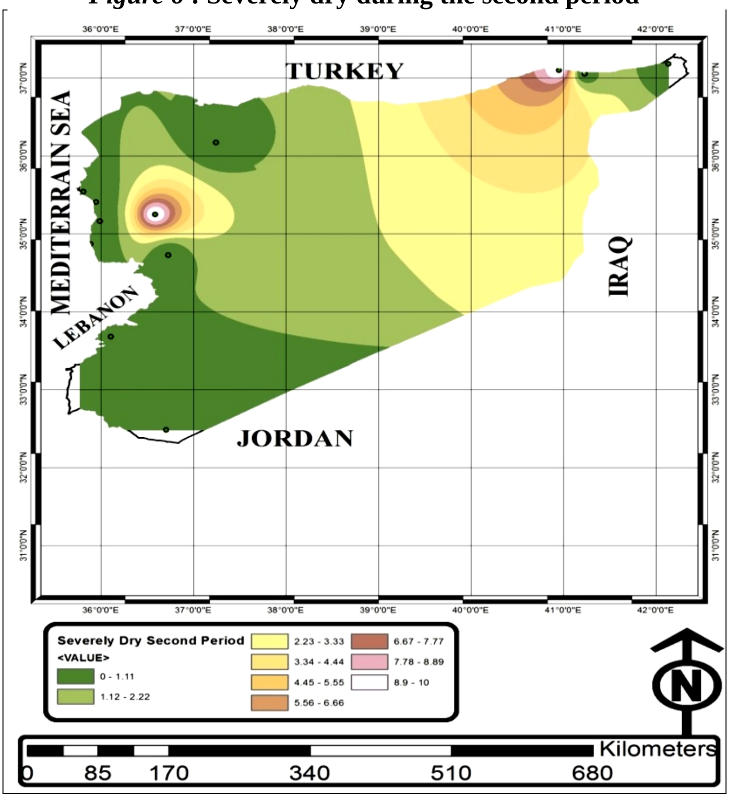
During the second period, severe drought years were observed at Amouda and Mhardah stations with a frequency of 10% and 7.69% of the area affected by drought, whereas the remaining stations showed no occurrence of severe drought years.

***Table 10*: Relative frequency of severe dry years during the second period**

Station	Period	Drought Type	SPI. Value	N. Years	Relative. F	P%
Lattakia	2013-2023	Severely dry	-1.5 > - 1.99	0	0	0
Bouqa			-1.5 > - 1.99	0	0	0
Humaimeem			-1.5 > - 1.99	0	0	0
Tartous			-1.5 > - 1.99	0	0	0
Banias			-1.5 > - 1.99	0	0	0
Homs			-1.5 > - 1.99	0	0	0
Aleppo			-1.5 > - 1.99	0	0	0
Qamishli			-1.5 > - 1.99	0	0	0
Almalkiah			-1.5 > - 1.99	0	0	0
Amouda			-1.5 > - 1.99	1	10	**7.69**
Salkhad			-1.5 > - 1.99	0	0	0
Madaya			-1.5 > - 1.99	0	0	0
Mhardah			-1.5 > - 1.99	1	10	**7.69**

Source: Prepared by researchers.

***Figure 6* : Severely dry during the second period**



Source: Prepared by researchers.

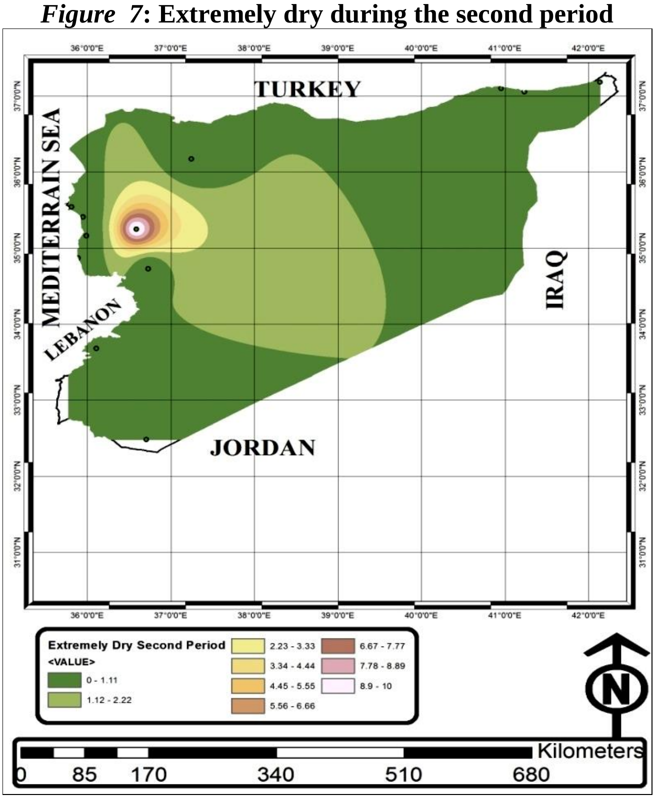
During the second period, extreme drought years were observed at Mhardah station with a relative frequency of 10% and 7.69% of the area affected by drought, whereas the remaining stations showed no occurrence of extreme drought years.

Table 11: **Relative Frequency of Extreme Dry Years During the Second Period**

Station	Period	Drought Type	SPI. Value	N. Years	Relative. F	P%
Lattakia			-2 >	0	0	0.00
Bouqa			-2 >	0	0	0.00
Humaimeem			-2 >	0	0	0.00
Tartous			-2 >	0	0	0.00
Banias			-2 >	0	0	0.00
Homs			-2 >	0	0	0.00
Aleppo	**2003-2012**	**Extremely dry**	-2 >	0	0	0.00
Qamishli			-2 >	0	0	0.00
Almalkiah			-2 >	0	0	0.00
Amouda			-2 >	0	0	0.00
Salkhad			-2 >	0	0	0.00
Madaya			-2 >	0	0	0.00
Mhardah			**-2 >**	**1**	**10**	**7.69**

Source: Prepared by researchers.

***Figure 7*: Extremely dry during the second period**



Source: Prepared by researchers.

C. Classification of Drought Categories During the Third Period (2013-2023):

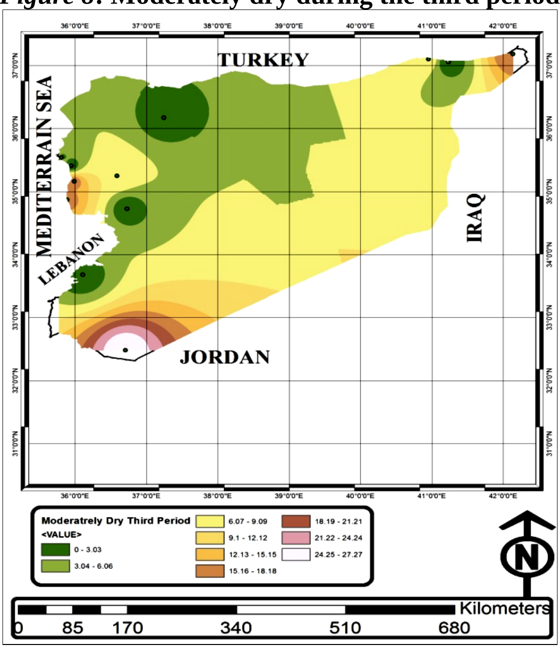
During the third period, moderate drought years were observed at Salkhad station with a frequency of 27.27% and 23.08% of the area affected by drought, and a low relative frequency at Lattakia, Amouda and Mhardah stations with a frequency 9.09% and 7.69% of the area affected by drought. Whereas the remaining stations showed no occurrence of moderate drought years.

Table 12 **: Relative Frequency of Moderate Dry Years During the Third Period**

Station	Period	Drought Type	SPI. Value	N. Years	Relative. F	P%
Lattakia			- 1 > - 1.49	1	9.09	**7.69**
Bouqa			- 1 > - 1.49	0	0.00	0.00
Humaimeem			- 1 > - 1.49	0	0.00	0.00
Tartous			- 1 > - 1.49	2	18.18	15.38
Banias			- 1 > - 1.49	2	18.18	15.38
Homs			- 1 > - 1.49	0	0.00	0.00
Aleppo	**2013-2023**	**Moderately dry**	- 1 > - 1.49	0	0.00	0.00
Qamishli			- 1 > - 1.49	0	0.00	0.00
Almalkiah			- 1 > - 1.49	2	18.18	15.38
Amouda			- 1 > - 1.49	1	9.09	**7.69**
Salkhad			**- 1 > - 1.49**	**3**	**27.27**	**23.08**
Madaya			- 1 > - 1.49	0	0.00	0.00
Mhardah			- 1 > - 1.49	1	9.09	**7.69**

Source: Prepared by researchers.

Figure 8**: Moderately dry during the third period**



Source: Prepared by researchers.

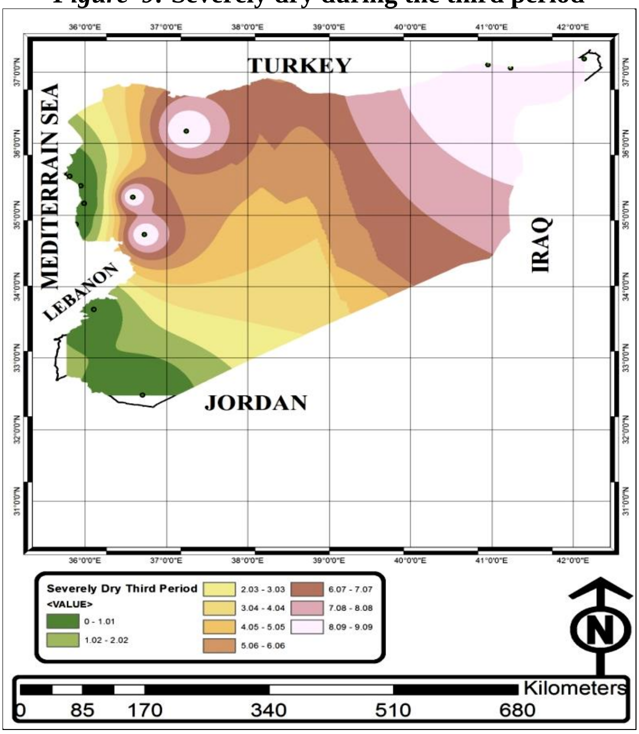
During the third period, severe drought years were observed Homs, Aleppo, Qamishli, Almalkiah, Amouda, and Mhardah stations with a frequency of 9.09% and 7.69% of the area affected by drought, whereas the remaining stations showed no occurrence of no severe drought years.

***Table 13*: Relative Frequency of Severe Dry Years During the Third Period**

Station	Period	Drought Type	SPI. Value	N. Years	Relative. F	P%
Lattakia			-1.5 > - 1.99	0	0.00	0.00
Bouqa			-1.5 > - 1.99	0	0.00	0.00
Humaimeem			-1.5 > - 1.99	0	0.00	0.00
Tartous			-1.5 > - 1.99	0	0.00	0.00
Banias			-1.5 > - 1.99	0	0.00	0.00
Homs			-1.5 > - 1.99	1	9.09	**7.69**
Aleppo	**2013-2023**	**Severely dry**	-1.5 > - 1.99	1	9.09	**7.69**
Qamishli			-1.5 > - 1.99	1	9.09	**7.69**
Almalkiah			-1.5 > - 1.99	1	9.09	**7.69**
Amouda			-1.5 > - 1.99	1	9.09	**7.69**
Salkhad			-1.5 > - 1.99	0	0.00	0.00
Madaya			-1.5 > - 1.99	0	0.00	0.00
Mhardah			-1.5 > - 1.99	1	9.09	**7.69**

Source: Prepared by researchers.

***Figure 9:* Severely dry during the third period**



Source: Prepared by researchers.

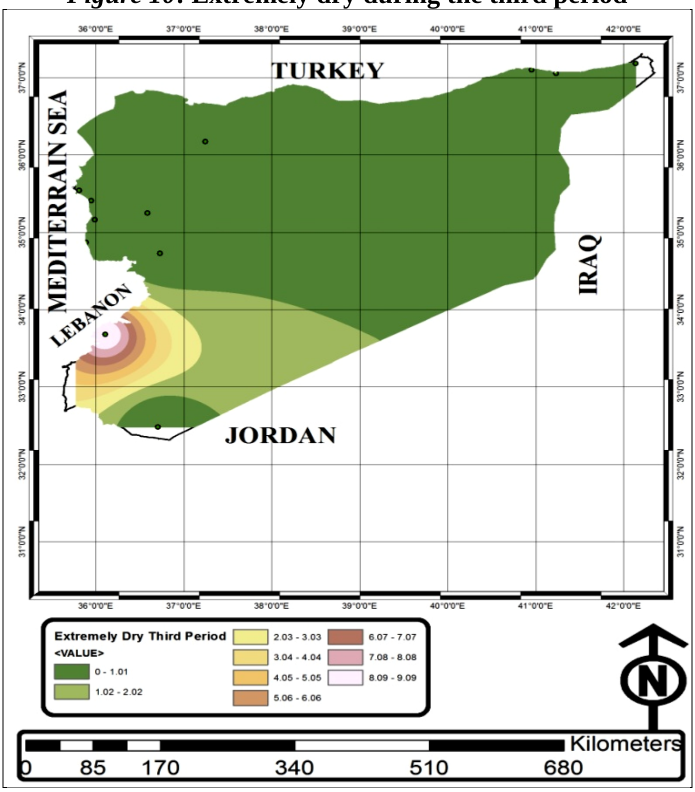
During the third period, extreme drought years were observed at Madaya station with a frequency of 9.09% and 7.69% of the area affected by drought, whereas the remaining stations showed no occurrence of extreme drought years.

***Table 14*: Relative Frequency of Extreme Drought Years During the Third Period**

Station	Period	Drought Type	SPI. Value	N. Years	Relative. F	P%
Lattakia			-2 >	0	0	0
Bouqa			-2 >	0	0	0
Humaimeem			-2 >	0	0	0
Tartous			-2 >	0	0	0
Banias			-2 >	0	0	0
Homs			-2 >	0	0	0
Aleppo	**2013-2023**	**Extremely dry**	-2 >	0	0	0
Qamishli			-2 >	0	0	0
Almalkiah			-2 >	0	0	0
Amouda			-2 >	0	0	0
Salkhad			-2 >	0	0	0
Madaya			**-2 >**	**1**	**9.09**	**7.69**
Mhardah			-2 >	0	0	0

Source: Prepared by researchers.

***Figure 10*: Extremely dry during the third period**



Source: Prepared by researchers.

Conclusion:

Analysis of rainfall series data in Syria during the period 1993–2023, using the Standardized Precipitation Index (SPI), showed that more than 50% of the years across all stations were classified as normal. Extreme drought was recorded exclusively at Mhardah station, occurring in two years. Severe drought was observed at four stations each one experiencing two years. Moderate drought was most frequent at Banias station, with six years of occurrence. In terms of humid conditions, two years of extreme humidity were recorded at Bouqa and Humaimeem stations. Extreme humidity was also observed at three stations each one with a three year occurrence. Moderate humidity was recorded at two stations Mhardah (4 years) and Almalkiah (5 years). In addition, The study period was divided into three sub-periods to identify the driest interval and assess drought severity, during the First period (1993–2002), the highest frequency of moderate drought was recorded at Bouqa station with a relative frequency of 40%, and 30.77% of the area affected by drought. Severe drought occurred at five stations (Lattakia, Tartous, Homs, Qamishli, and Salkhad) with a relative frequency of 10% and 7.69% of the area affected by drought. Extreme drought was recorded at three stations with a relative frequency of 10% and 7.69% of the area affected by drought, with no extreme drought at the remaining stations. During the Second period (2003–2012), the highest frequency of moderate drought was recorded at Qamishli station with a relative frequency of 30% and 23.08% of the area affected by drought. Severe drought was observed at Amouda and Mhardah stations with a relative frequency of 10% and 7.69% of the area affected by drought). Extreme drought was recorded only at Mhardah station with a relative frequency of 10% and 7.69% of the area affected by drought, with no extreme drought at the other stations. During the third period (2013–2023) the highest frequency of moderate drought was recorded at Salkhad station with a relative frequency of 27.3% and 23.08% of the area affected by drought. Severe drought and extreme drought were recorded with a relative frequency of 9.09% and 7.69% of the area affected by drought for each one. Therefore, the moderate drought is the most dominant type during the three period, but the other two types of drought observed during less than 10% of the years.

References

- Abdul Salam, A., Al-Sheikh, M. I., & Halima, A. K. (2004). *Syrian physical geography*. Tishreen University Publications.

- Al-Essawi, K. K. I. (2020). Analysis of the impact of climatic droughts on vegetation in Al-Anbar Governorate (Al-Jazira Region) using GIS. *Al-Iraqia University*.

- Allaby, M. (2007). *Encyclopedia of weather and climate.* (2nd ed). New York.

- Al-Miloudi, A. M., & Khamaj, A. I. (2019). Analysis of climatic drought using the standardized precipitation index for some areas in the Jfara plain for the period between 1962 and 1999. *Libyan Journal of Agricultural Sciences*, *24*(1).

- Al-Nahlawi, M. (1991). Damascus rainfall characteristics, probability and relationship to drought and the general trend. *Journal of Agriculture and Water*, *12*.

- Badawy, H. D. S. (2023). Long-term changes in climate drought during the period 1901–2020 in northern Egypt using the standardized precipitation-evaporation-transpiration index (SPEI). *Scientific Journal of the Faculty of Arts*, 12(3), 110–55.

- Chen, X., Lu, Y., Sun, Z., Zhang, J., Guan, T., Jin, J., Liu, C., Wang, G., & Bao, Z. (2022). Centennial precipitation characteristics change in Haihe River Basin, *China Atmosphere*, *13*, 1025. https://doi.org/10.3390/atmos13071025

- McKee, T. B., Doesken, N. J., & Kleist, J. (1993). *The relationship of drought frequency and duration to time scales*. In Proceedings of the 8th Conference on Applied Climatology (Vol. 17, No. 22, pp. 179-183). Boston, MA: American Meteorological Society.

- Mokhtar, A., Jalali, M., Nabi, A., Elbeltagi, A., Al-Ansari, N., Alsafadi, K., Abdo, H. Gh., Sammen, S. H., Gyasi-Agyei, Y., & Rodrigo-Comino, J., (2021). Estimation of SPEI meteorological drought using machine learning algorithms. *China. IEEE ACCESS*, *9*, https://doi.org/10.1109/ACCESS.2021.3074305

- Pande, C. B., Kushwaha, N. L., Orimoloye, I. R., Kumar, R., Abdo, H. Gh., Tolche, A. D., & Elbeltagi, A. (2023). Comparative assessment of improved SVM method under different kernel functions for predicting multi-scale drought index. *Springer*. https://doi.org/10.21203/rs.3.rs-2052671/v1

- Rasheed, A. M. M. (2010). Analysis of rainfall drought periods in the north of Iraq using standardized precipitation index (SPI). *Al-Rafidain Engineering*, *18*(2).

- Shahin, M. (2007). *Water resources and hydro-meteorology of the Arab region*. (Vol. 59). Springer.

- World Meteorological Organization. (2012). *User's guide to the standardized precipitation index, (*Print No. 1090). Geneva, Switzerland.