Rainfall Analysis in Lattakia (Syria) During the Period 1993–2024

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Abstract:

Rainfall is one of the most important and vital climatic elements. This research aimed to analyze the general trend of rainfall at several rain stations in Lattakia Governorate for the period 1993–2024, using the Mann–Kendall nonparametric test to identify temporal variations in rainfall. The results indicated a significant increasing trend in annual rainfall at Bouqa and Wadi Qandeel stations, where the calculated test values exceeded the critical table value (1.96). A significant increasing trend was also observed in January at all stations, except Alhaffah station. The Standardized Precipitation Index (SPI) was calculated for the six rainy months, and the years were classified according to their humidity and aridity levels based on index categories. The results showed that the majority of years were normal. Coefficients of variation (CV) were also computed, and a map of CV classes was prepared, with the highest value recorded at Bouqa station (37%). Additionally, an isohyetal map was prepared for the same period, showing that the study area was distributed between rainfall lines of <800 mm and >1150 mm, with approximately 71.2% of the area lying between 900 mm and 1000 mm.

***Keywords*:** General trend, Sen's slope, Mann–Kendall test, SPI, coefficient of variation, isohyetal method.

تحليلات الهطل المطري في اللاذقية (سوريا) خلال الفترة (1993- 2024)

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الملخص:

يُعد الهطل المطري من أهم العناصر المناخية وأكثرها حيوية. لذا يهدف هذا البحث إلى تحليل الاتجاه العام للهطل المطري في عدد من المحطات المطرية في محافظة اللاذقية للفترة (1993-2024) باستخدام أحد أهم الاختبارات اللامعلمية وهو اختبار مان-كيندال لتوضيح التغيرات الزمنية في هطول الأمطار. أظهرت نتائج الاختبار اتجاهاً متزايداً ملحوظاً في الهطل المطري السنوي في محطتي بوقا ووادي قنديل، حيث كانت قيمة الاختبار المحسوبة أكبر من القيمة الجدولية (1.96) كما لوحظ اتجاه تصاعدي ملحوظ خلال شهر يناير في جميع المحطات باستثناء محطة الحفة. تم حساب مؤشر SPI للأشهر الستة المطيرة، ثم تم تصنيف السنوات وفقاً لمستويات الرطوبة والجفاف بناءً على فئات المؤشر. أظهرت النتائج أن غالبية السنوات كانت طبيعية. كما تم حساب قيم معامل التباين (CV) وإعداد خريطة لفئة معامل التباين، حيث كانت أعلى قيمة في محطة بوقا (37٪). كما تم إعداد خريطة لخطوط تساوي الهطل لنفس الفترة، وتوزعت منطقة الدراسة بين خطي هطل (800-1150<) ملم وحوالي 71.2٪ من منطقة الدراسة موزعة بين خطي هطل (900 و1000 ملم).

الكلمات المفتاحية: الاتجاه العام، ميل الانحدار، اختبار مان-كيندال، مؤشرSPI ، معامل التباين، طريقة خطوط تساوي الهطل.

I. INTRODUCTION:

Precipitation is the primary source of water in the continental component of the hydrological cycle (Ward, 1974) and represents the sole source of traditional renewable water resources. Consequently, any changes in the spatial and temporal distribution of precipitation can have varying impacts on the environment and its components. Climate change can affect the hydrological cycle, leading to significant alterations in the amount and distribution of precipitation in different regions of the world, including the Mediterranean (Philandras et al., 2011). This may result in water scarcity, as well as increased frequency of floods and droughts, thereby affecting natural ecosystems, society, and the economy (Kamal & Pachauri, 2018).

The Intergovernmental Panel on Climate Change (IPCC) distinguishes between climate variability, which refers to changes in climate elements resulting from natural variations within the climate system, and climate change, which refers to changes driven by direct and indirect external factors, such as human activities and alterations in land use patterns over time (Bryson et al., 2008). IPCC reports further indicate that climate change, associated with global warming, may lead to an increased frequency and severity of droughts, particularly in the Mediterranean region, while extreme rainfall events are expected to become more frequent and intense in many regions (IPCC, 2021).

II. STUDY OBJECTIVES:

The main objective of this research is to determine the general trend of rainfall in the study area by applying simple linear regression and calculating the Mann–Kendall coefficient at both monthly and annual levels. Additionally, the coefficient of variation is employed to assess the need for supplementary irrigation in the area. The Standardized Precipitation Index (SPI) was also calculated to analyze temporal rainfall variability. The significance of this study lies in its application of statistical methods to evaluate rainfall trends and variations over time, which is particularly important for an area of both agricultural and touristic significance in Syria.

III. STUDY AREA:

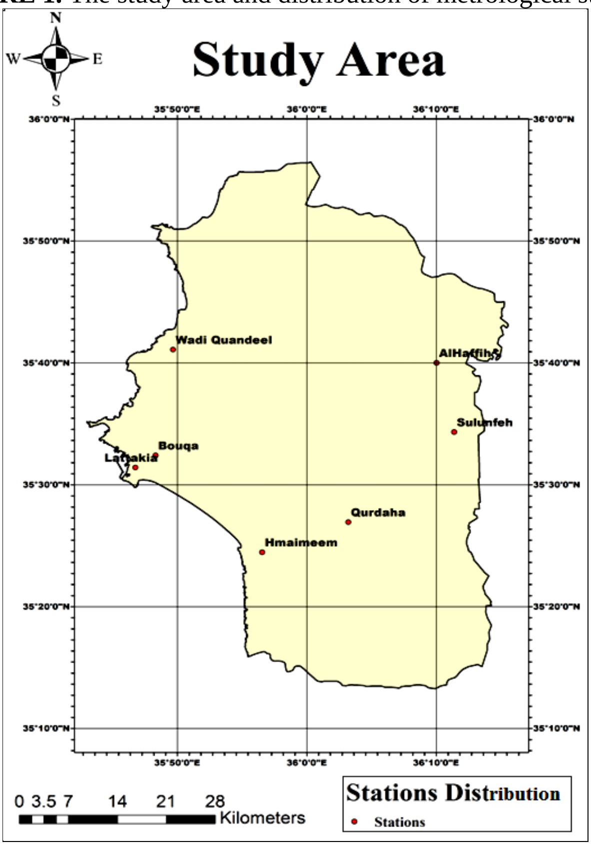
The study area covers approximately 2,300 km² and is located in the western region of the Syrian Arab Republic, between latitudes 35°13′ and 35°56′ N and longitudes 35°43′ and 36°16′ E. It is bordered by Hama Governorate to the east, the Mediterranean Sea to the west, Tartous Governorate to the south, and Turkey to the north. Figure 1 illustrates the study area and the distribution of meteorological stations used in this research.

TABLE. (1) characteristics of Stations in the Study Area

Station	Lat.(X)	Long. (Y)	Altitude above sea level	Period of study
Lattakia	35° 31′ 25″	35° 46′ 45″	7	1993- 2024
Bouqa	35° 32′ 25″	35° 48′ 19″	40	1993- 2024
Humaimeem	35° 24′ 28″	35° 56′ 33″	45	1993- 2024
Qurdaha	35° 26′ 56″	36° 03′ 12″	300	1993- 2024
Alhaffah	35° 40′ 01″	36° 10′ 01″	330	1993- 2024
Wadi Qandeel	35° 88′	35° 71′	150	1993- 2024
Sulunfeh	35° 34′ 20′	36° 11′ 23′	1100	1993- 2024

Source: General Directorate of Meteorology, Climate Department, Damascus

FIGURE 1. The study area and distribution of metrological stations



IV. MATERIAL AND METHODS:

A. DATA SOURCES:

The research used rainfall data recorded over 32 years for the period of 1993- 2024 at seven meteorological-rain stations distributed according to elevation: Lattakia, Bouqa, Qurdaha, Alhaffah, Wadi Qandeel, Humaimeem, and Sulunfeh (Figure 1). This data was obtained from the General Directorate of Meteorology, which relied on rainfall amounts recorded during the year (from January to December).

B. LINEAR REGRESSION:

The rainfall series data were examined by using the simple linear regression approach, where the slope represents the average temporal change in the variable under consideration.

C. MANN-KENDALL TEST:

The Mann-Kendall (MK) test is used in climate studies to assess the trend of climate variables, particularly temperature and rainfall. It is a non-parametric test, meaning it does not assume a normal distribution of the data or a linear relationship between the variables. This test is based on the null hypothesis (H_0), which indicates the absence of a trend that is, the data are independent and randomly arranged and this is tested against the alternative hypothesis (H_a), which assumes the presence of a trend. So, it was adopted to analyze the time changes of rainfall in the study area. The equation used is (Agbo, E. P., & Ekpo, C., 2021):

$$S = \sum_{k=1}^{n-1} \sum_{j=k=1}^{n} sgn\ (x_j - x_k) \qquad \textbf{(1)}$$

Where X_j and X_k are the annual values in years' j and k, j>k, respectively.

$$sgn(x_{j\_}x_k) = \begin{Bmatrix} 1, & x_{j\_}x_k > 0 \\ 0, & x_{j\_}x_k = 0 \\ -1, & x_{j\_}x_k < 0 \end{Bmatrix} \qquad \textbf{(2)}$$

The test statistics τ can be computed as;

$$\boldsymbol{\tau} = \frac{\mathbf{s}}{\mathbf{n-(n-1)/2}} \qquad \textbf{(3)}$$

It is necessary to compute the probability associated with S and the sample size n, to statistically quantify the significance of the trend. The calculating formula of variance S is denominating as;

$$\text{VAR (s)}: \frac{1}{18}\ [(n-1)(2n+5) - \sum_{k=1}^{p} qk(qk-1)(2qk-1)(2qk+5)] \textbf{(4)}$$

Where p is the total number of linkage groups in the data, and qk is the number of data points in the k-set (Shah, A. Sh., and Kiran, M., 2021).

The values of S and VAR(S) are accustomed to calculate the test statistics Z which is following as;

$$Z=\begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if\ S>0 \\ 0 & if\ S=0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if\ S<0 \end{cases} \quad \textbf{(5)}$$

Z score follows a normal distribution. at a choice of α =0.05 (95% confidence interval) and two-sided alternative, the critical values of 0.025 are equal to -1.96 to 1.96. the trend is said to be decreasing if Z is negative and the absolute value is greater than the level of significance, while it is increasing if Z is positive and greater than the label of significance. if n≤10 the normal approximation test is used and a statistically significant trend is computed exerting the Z score. Mann-Kendall & Sen's slope estimator test the z score significance level at α:0.001, 0.05, and 0.1.

D. COEFFICIENT OF VARIANCE:

$$CV= \gamma/\bar{X} \times 100$$

Where CV is coefficient of variance, γ standard deviation, $\bar{X}$ average of annual precipitation.

E. ISOHYETAL METHOD:

Rainfall was calculated using the isohyetal method, following the following steps: Drawing an isohyetal map based on rainfall data obtained for the period 1993-2024 using a GIS program, then calculating the area enclosed between each two adjacent rain lines, in addition to calculating the average rainfall between them. Then, calculate the rainfall volume for each area bounded by two rain lines by multiplying the area bounded by the two rain lines (km^2) by the average rainfall between them. Considering that every 1 mm of rainfall is equivalent to 1000 cubic meters per 1 square kilometer or:

$$V = a \times d$$

Where **V** is volume of rainfall (m^3), **a** area of surface recipient(km^2), and **d** is depth of rainfall (m). Then, add the rainfall volume for each area bounded by the two rain lines to obtain the total rainfall volume for the study area (m^3).

F. Standardized Precipitation Index (SPI):

This indicator was calculated for the six rainy months, then the years during the hole period were classified according to the indicator's categories. **Table** (2).

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, M., 2007, p151.

RESULTS AND DISCUSSIONS:

a) RAINFALL CHARACTERISTICS DURING 1993- 2024:

The climate of Syria belongs to the hot temperate zone of the Mediterranean climate which is generally characterized by a rainy winter and a hot dry summer, and spring and autumn as transitional seasons, and The coastal zone can be represented by locations such as Lattakia (study area, This zone is characterized by heavy winter rain and a dry, moderate summer (Shahin, M., 2007).

Rainfall in the study area is characterized by seasonality and fluctuations. Heavy rainfall is concentrated during the winter months, while a small amount is concentrated during the summer. This negatively impacts water supplies, reduces river and dam levels, and impacts many sectors, particularly agricultural sectors, based on the amount of water supplies received by the governorate. **Table.3** shows the monthly rainfall average in the study area during the period (1993-2024)., the biggest quantity was observed in December (253.4mm in Sulunfeh station) and January (227mm in Qurdaha station), while the lower quantity was in June, July, August.

TABLE. 3 Average of Monthly Rainfall during 1993- 2024

Station	Jan	Feb.	mar	Apr	may	Jun	Jul	Aug	sep	Oct	Nov	Dec
Lattakia	160.3	117.3	69.7	42.8	17.7	7.1	0.8	4.0	21.3	57.4	90.4	166.8
Bouqa	182.9	136.4	79.8	49.0	23.5	6.7	1.7	4.6	18.0	72.8	98.8	194.9
Humaimeem	188.9	133.5	83.9	50.1	24.3	7.3	0.0	2.7	16.1	56.3	89.7	186.3
Qurdaha	219.5	175.3	122.7	70.6	42.1	6.3	0.6	3.7	26.5	72.2	117.4	227.0
Alhaffah	191.7	140.8	102.8	66.3	35.7	12.2	0.3	0.7	32.5	63.5	111.1	196.4
WadiQandeel	170.9	127.2	86.2	50.4	34.7	8.1	0.9	1.0	26.4	67.5	103.8	179.8
Sulunfeh	253.4	198.3	173.2	88.1	43.0	14.8	0.7	3.7	25.7	59.1	111.6	215.1

Source: Prepared by researchers.

Table.4 also shows the percentage of seasonal rainfall. The highest percentage of winter rainfall was recorded in Humaimeem station (60.6%), and the spring rainfall in Sulunfeh station (25.6%). The highest percentage of autumn rainfall was recorded in Lattakia station (22.4%), and the highest percentage of summer rainfall was recorded both in Lattakia and Sulunfeh stations (1.6%). The rainfall ranges in the studied stations between (755.8-1186.8) mm, the first in Lattakia (coastal station 7 m above sea level) and the second in Sulunfeh (mountainous station 1100 m), where the role of the height factor above sea level in increasing the amount of rainfall is highlighted.

TABLE. 4 Percentage of Seasonal Rainfall

Station	Winter	Spring	Summer	Autumn	Aver
Lattakia	58.8%	17.2%	1.6%	**22.4%**	755.8
Bouqa	59.2%	17.5%	1.5%	21.8%	869.2
Humaimeem	**60.6%**	18.9%	1.2%	19.3%	839.1
Qurdaha	57.4%	21.7%	1.0%	19.9%	1083.9
Alhaffah	55.4%	21.5%	1.4%	21.7%	954.1
Wadi Qandeel	55.8%	20.0%	1.2%	7.9%	856.9
Sulunfeh	56.2%	**25.6%**	**1.6%**	16.6%	**1186.8**

Source: Prepared by researchers.

The Simple Linear Regression method was used for the general trend of rainfall. **Table.5** shows a clear trend towards an increase in annual rainfall in all stations except for Sulunfeh station, which recorded a decrease in annual rainfall of 63.2 mm. The lowest increase was in Alhaffah station, 142.5 mm. However, this change was not significant except in Bouqa and Wadi Qandeel stations, where (Sig>0.05).

TABLE. 5 Results of Simple Linear Regression

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
Lattakia	7.7	4.2	0.3	1.8	.075	-0.8	16.3
Bouqa	**16.9**	**5.4**	**0.5**	**3.1**	**.004**	**5.8**	**28.0**
Humaimeem	8.3	5.1	0.3	1.6	.116	-2.1	18.7
Qurdaha	7.1	5.9	0.2	1.2	.245	-5.1	19.2
Alhaffah	4.5	4.7	0.2	0.9	.351	-5.1	14.1
Wadi Qandeel	**13.9**	**4.3**	**0.5**	**3.3**	**.003**	**5.2**	**22.7**
Sulunfeh	-2.0	5.0	-0.1	-0.4	.694	-12.1	8.2

a. Dependent Variables: Lattakia, Bouqa, Humaimeem, Qurdaha, Alhaffah, Wadi Qandeel, Sulunfeh.
Source: Prepared by researchers.

The significance test of the slope of the regression line is found to be significant in Bouqa and WadiQandeel stations, Where (P<Sig<0.05), indicating statistical significance. Therefore, the null hypothesis should be rejected and the alternative Hypothesis accepted.

TABLE. 6 Significance test results of the slope of the regression line

Station	Parameter	Null hypothesis	Alternative Hypothesis	t	P
Lattakia	a	$H_0: a = 0$	$H_1: a \neq 0$	-1.754-	.090
	b	$H_0: b = 0$	$H_1: b \neq 0$	1.843	.075
Bouqa	a	$H_0: a = 0$	$H_1: a \neq 0$	-3.027-	**.005**
	b	$H_0: b = 0$	$H_1: b \neq 0$	3.106	**.004**
Humaimeem	a	$H_0: a = 0$	$H_1: a \neq 0$	-1.539-	.134
	b	$H_0: b = 0$	$H_1: b \neq 0$	1.621	.116
Qurdaha	a	$H_0: a = 0$	$H_1: a \neq 0$	-1.094-	.283
	b	$H_0: b = 0$	$H_1: b \neq 0$	1.185	.245
Alhaffah	a	$H_0: a = 0$	$H_1: a \neq 0$	-.847-	.404
	b	$H_0: b = 0$	$H_1: b \neq 0$	.948	.351
WadiQandeel	a	$H_0: a = 0$	$H_1: a \neq 0$	-3.154-	**.004**
	b	$H_0: b = 0$	$H_1: b \neq 0$	3.254	**.003**
Sulunfeh	a	$H_0: a = 0$	$H_1: a \neq 0$	.515	.610
	b	$H_0: b = 0$	$H_1: b \neq 0$	-.397-	.694

Source: Prepared by researchers.

Figure.3, 4, 5, 6 shows the general trend of rainfall using simple linear regression. The value of the coefficient of interpretation (R^2) indicates a relationship between the time factor and the change in rainfall. The value of the coefficient ranged between 0.03 in Alhaffah station and 0.26 in Wadi Qandeel station, which indicating a significant relationship between the time factor and the change in rainfall at this station. Values less than 0.25 indicate that the trend is random and the correlation is due to chance.

FIGURE. 2 general trend of rainfall in Lattakia, Bouqa

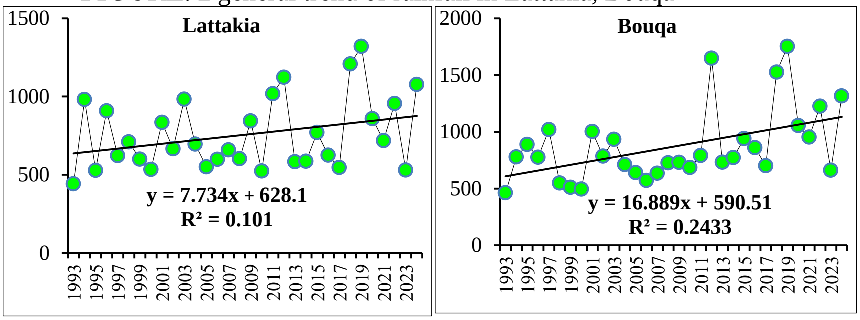


FIGURE.3 general trend of rainfall in Humaimeem, Qurdaha

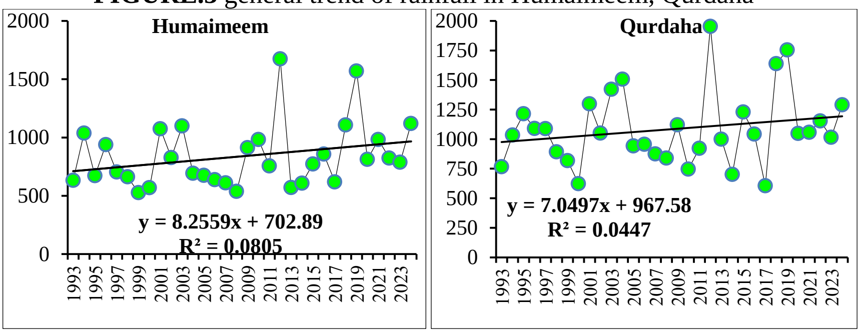


FIGURE.4 general trend of rainfall in WadiQandeel, , Alhaffah

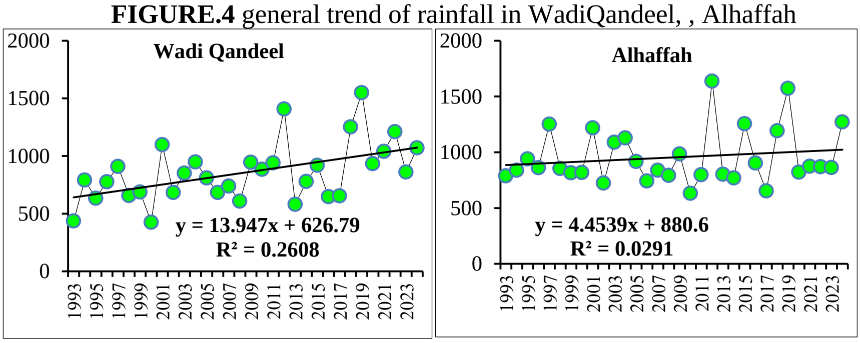
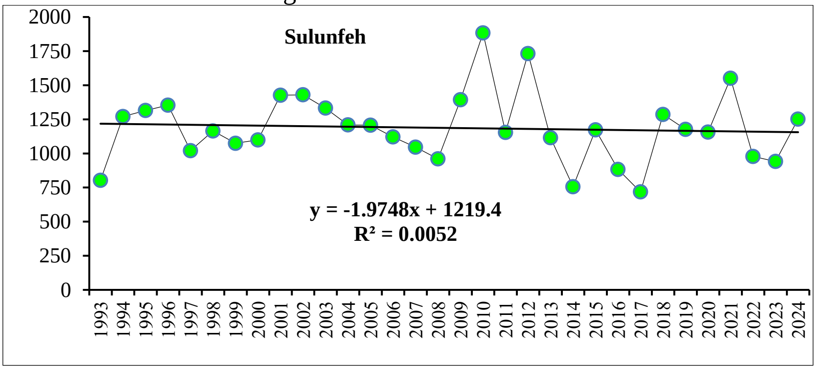


FIGURE.5 general trend of rainfall in Sulunfeh



b) COEFFICIENT OF VARIANCE CALUCULATION:

The coefficient of variation is commonly used in climate and hydrological studies to indicate the percentage deviation from the average, i.e., to determine the reliability of the average. It is also an important comparative tool for demonstrating the stability of the annual precipitation rate over multiple locations, which may be similar or dissimilar in their geographical characteristics. This contributes to the decision-making process in determining the economic activities that can be carried out in a given region. Some have suggested that when the coefficient of variation (CV) values exceed (37%), the possibility of depending on rainfall to provide the water needed for rain fed agriculture is negated, and crops require supplementary irrigation (Al-Shaer J., & Al-Mousa, F., 2006). Annual rainfall exhibits significant variability, as evidenced by the high values of the coefficient of variation (CV). The results, as shown in Table (7).

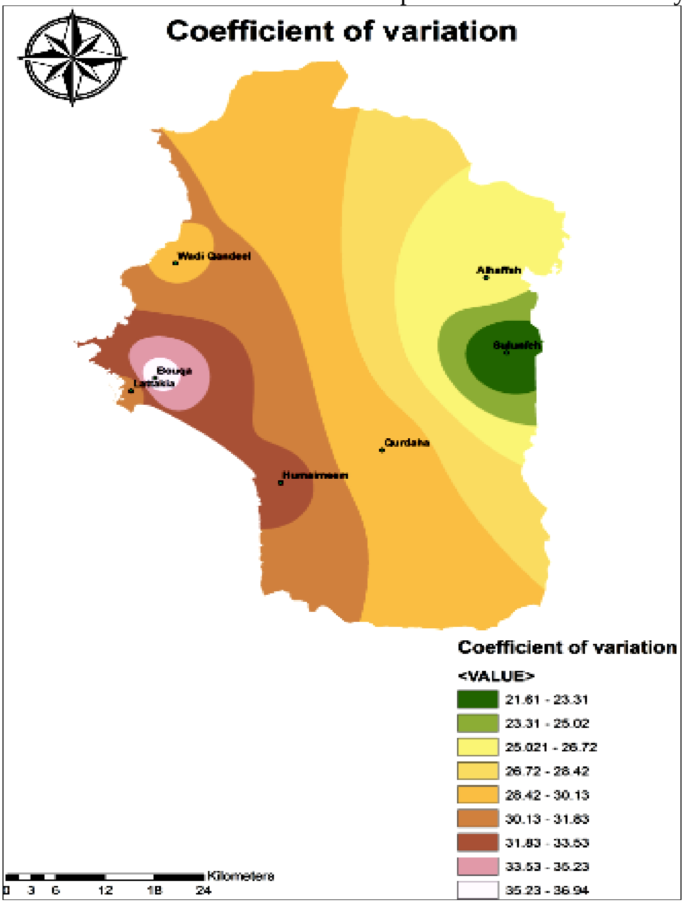
TABLE. 7 CV values for the period 1993- 2024 in study area

Station	Average	Median	γ	Cv%
Lattakia	755.8	679.8	227.5	30.1
Bouqa	869.2	776.75	321.2	**37.0**
Humaimeem	839.1	780.3	273.0	32.5
Qurdaha	1083.9	1044.7	312.8	28.9
Alhaffah	954.1	862	245.0	25.7
Wadi Qandeel	856.9	830.9	256.2	29.9
Sulunfeh	1186.8	1168.9	256.5	**21.6**

Source: Prepared by researchers

The CV values range between 21.6% in Sulunfeh station and 37% in Bouqa station. Therefore, in the geographical area of Bouqa station, crops may not rely solely on rainwater for irrigation, but will require supplementary irrigation. Furthermore, water resources must be managed and their consumption rationalized to ensure sustainability.

FIGURE.6 coefficient of variance for the period 1993–2024 in study area



c) ANNUAL MANN-KENDALL TEST RESULTS:

Mann-Kendall (MK) test was used for studying temporal changes in rainfall in the study area during 1993- 2024. **Table.8** shows the results of the Mann-Kendall test for annual rainfall values. A significant trend toward increasing rainfall was observed in Bouqa (Z= 2.64) and Wadi Qandeel stations (Z= 2.61), while no significant increase was recorded at the other stations: Lattakia, Humaimeem, Qardaha, Alhaffah, and Sulunfeh.

TABLE.8 Results of Mann-Kendall Test to the Average Annual Rainfall During 1993- 2024

Station	Sen's Slope	S	Z-Value	Trend
Lattakia	5.88	92.0	1.48	No Trend
Bouqa	**15.52**	**164.0**	**2.64**	**Increasing**
Humaimeem	6.05	94.0	1.51	No Trend
Qurdaha	7.04	62.0	0.99	No Trend
Alhaffah	2.01	44.0	0.70	No Trend
Wadi Qandeel	**11.97**	**162.0**	**2.61**	**Increasing**
Sulunfeh	-3.41	-40.0	-0.63	No Trend

Source: Prepared by researchers.

d) MOTHLY MANN-KENDALL TEST RESULTS:

Table.9 shows the results of the Mann-Kendall test during the months in Lattakia station. There is an increasing trend in rainfall during January but there is no trend during the other months.

TABLE. 9 Monthly Mann-Kendall test in Lattakia station

Station	Month	Sen's Slope	S	Z-Value	Trend
Lattakia	**Jan**	**2.96**	**116.0**	**1.87**	**Increasing**
	Feb.	1.33	58.0	0.92	No Trend
	mar	0.63	56.0	0.89	No Trend
	Apr	-0.32	-32.0	-0.50	No Trend
	may	0.03	11.0	0.16	No Trend
	Jun	0.00	8.0	0.11	No Trend
	sep	0.10	50.0	0.80	No Trend
	Oct	-1.17	-83.0	-1.33	No Trend
	Nov	1.13	52.0	0.83	No Trend
	Dec	3.13	84.0	1.35	No Trend

Source: Prepared by researchers

Table.10 shows the results of the Mann-Kendall test during the months in Bouqa station. There is an increasing trend in rainfall during January but there is no trend during the other months.

TABLE.10 Monthly Mann-Kendall test in Bouqa station

Station	Month	Sen's Slope	S	Z-Value	Trend
Bouqa	**Jan**	**4.99**	**167.0**	**2.69**	**Increasing**
	Feb.	1.59	68.0	1.09	No Trend
	mar	1.18	66.0	1.05	No Trend
	Apr	-0.03	-2.0	-0.02	No Trend
	may	0.12	24.0	0.37	No Trend
	Jun	0.00	-15.0	-0.23	No Trend
	sep	0.26	87.0	1.40	No Trend
	Oct	0.02	2.0	0.02	No Trend
	Nov	1.33	63.0	1.01	No Trend
	Dec	3.24	92.0	1.48	No Trend

Source: Prepared by researchers.

Table.11 shows the results of the Mann-Kendall test during the months in Humaimeem station. There is an increasing trend in rainfall during January but there is no trend during the other months.

TABLE. 11 Monthly Mann-Kendall test in Humaimeem station

Station	Month	Sen's Slope	S	Z-Value	Trend
Humaimeem	**Jan**	**3.57**	**109.0**	**1.75**	**Increasing**
	Feb.	-0.43	-18.0	-0.28	No Trend
	mar	1.14	49.0	0.78	No Trend
	Apr	0.43	59.0	0.94	No Trend
	may	0.25	59.0	0.99	No Trend
	Jun	0.00	-2.0	-0.02	No Trend
	sep	0.24	77.0	1.23	No Trend
	Oct	-0.21	-18.0	-0.28	No Trend
	Nov	0.39	17.0	0.26	No Trend
	Dec	2.34	70.0	1.12	No Trend

Source: Prepared by researchers.

Table.12 shows the results of the Mann-Kendall test during the months in Qurdaha station. There is an increasing trend in rainfall during January but there is no trend during the other months.

TABLE. 12 Monthly Mann-Kendall test in Qurdaha station

Station	Month	Sen's Slope	S	Z-Value	Trend
Qurdaha	**Jan**	**4.65**	**122.0**	**1.96**	**Increasing**
	Feb.	-0.44	-12.0	-0.18	No Trend
	mar	0.47	23.0	0.36	No Trend
	Apr	0.76	52.0	0.83	No Trend
	may	-0.02	-5.0	-0.07	No Trend
	Jun	0.00	42.0	0.67	No Trend
	sep	-0.12	-30.0	-0.47	No Trend
	Oct	-0.52	-31.0	-0.49	No Trend
	Nov	-0.10	-5.0	-0.07	No Trend
	Dec	1.48	32.0	0.50	No Trend

Source: Prepared by researchers.

Table.13 shows the results of the Mann-Kendall test during the months in Alhaffah station. There is no trend during all months.

TABLE. 13 Monthly Mann-Kendall test in Alhaffah station

Station	Month	Sen's Slope	S	Z-Value	Trend
Alhaffah	Jan	4.65	122.0	1.96	No Trend
	Feb.	-0.44	-12.0	-0.18	No Trend
	mar	0.47	23.0	0.36	No Trend
	Apr	0.76	52.0	0.83	No Trend
	may	-0.02	-5.0	-0.07	No Trend
	Jun	0.00	42.0	0.67	No Trend
	sep	-0.12	-30.0	-0.47	No Trend
	Oct	-0.52	-31.0	-0.49	No Trend
	Nov	-0.10	-5.0	-0.07	No Trend
	Dec	1.48	32.0	0.50	No Trend

Source: Prepared by researchers.

Table.14 shows the results of the Mann-Kendall test during the months in Wadi Qandeel station. There is an increasing trend in rainfall during January and December but there is no trend during the other months.

TABLE.14 Monthly Mann-Kendall test in WadiQandeel station

Station	Month	Sen's Slope	S	Z-Value	Trend
Wadi Qandeel	**Jan**	**4.7**	**178.0**	**2.9**	**Increasing**
	Feb.	1.1	46.0	0.7	No Trend
	mar	1.0	63.0	1.0	No Trend
	Apr	-0.1	-18.0	-0.3	No Trend
	may	0.4	25.0	0.4	No Trend
	Jun	0.0	-30.0	-0.5	No Trend
	sep	0.1	36.0	0.6	No Trend
	Oct	-0.2	-11.0	-0.2	No Trend
	Nov	0.8	33.0	0.5	No Trend
	Dec	**4.4**	**112.0**	**1.8**	**Increasing**

Source: Prepared by researchers.

Table.15 shows the results of the monthly Mann-Kendall test in Sulunfeh station. There is no trend of increase in all months. On the contrary, there is a significant decreasing trend in rainfall in April.

TABLE.15 Monthly Mann-Kendall test in Sulunfeh station

Station	Month	Sen's Slope	S	Z-Value	Trend
Sulunfeh	Jan	3.96	80.0	1.28	No Trend
	Feb.	-1.51	-69.0	-1.10	No Trend
	mar	1.55	51.0	0.81	No Trend
	Apr	**-2.98**	**-145.0**	**-2.34**	**Decreasing**
	may	0.00	0.0	0.00	No Trend
	Jun	0.00	7.0	0.10	No Trend
	sep	0.05	52.0	0.83	No Trend
	Oct	-0.64	-59.0	-0.94	No Trend
	Nov	-1.50	-64.0	-1.02	No Trend
	Dec	1.11	22.0	0.34	No Trend

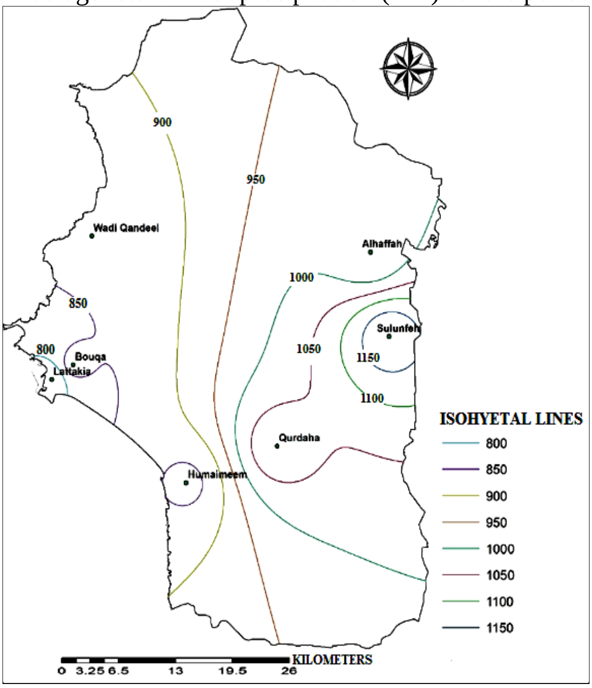
Source: Prepared by researchers.

e) ISOHYETAL METHOD:

Given the great importance of rainfall in the study area, a map was prepared that shows the annual rainfall Average over the study area during 1993- 2024 using isohyetal. Based on this map, the average annual atmospheric water income of precipitation was calculated.

Figure.7 shows the annual rainfall Average using the isohyetal lines method. The study area is distributed between the rainfall lines (<800 and >1150 mm), and is classified according to the Syrian Ministry of Agriculture's classification as the first agricultural stability zone. However, rainfall here is characterized by fluctuations from year to year, making agricultural crops uncertain.

FIGURE.7 Average total annual precipitation (mm) for the period 1993–2024



The isohyetal method was used to calculate rainfall volume. It was found that the area receives approximately 2,346,759,323 m³, with approximately 71.2% of the study area distributed between the 900 and 1000 isoprecipitation lines, contributing 69.3% of the total rainfall.(**Table.16**)

TABLE.16 Average annual rainfall volume over the study area

Rain line	Area between two rain lines	percentage of rainfall volume%	Rainfall volume
<800	0.5%	0.4%	8,617,699
850	3.9%	3.4%	79,725,148
900	21.4%	19.6%	460,051,486
950	21.3%	20.6%	483,049,150
1000	28.5%	29.1%	682,664,496
1050	12.9%	13.8%	323,387,741
1100	7.7%	8.7%	203,311,600
1150	2.3%	2.7%	62,912,717
>1150	1.5%	1.8%	43,039,286
			2,303,720,037

Source: Prepared by researchers.

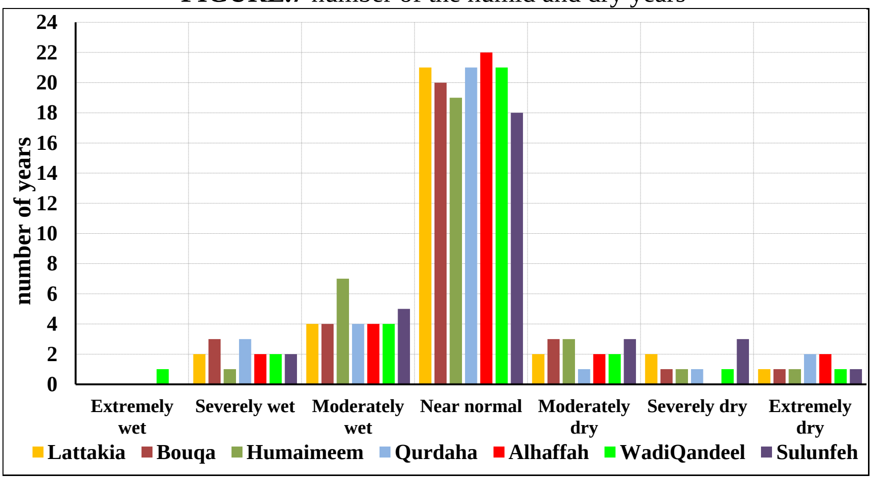
Applications of the SPI6 precipitation index for the months of October, November, December, January, February, and March to rainfall data from 1993 to 2024 revealed that the number of normal years ranged from 18 in Sulunfeh station to 22 in Qurdaha station. The number of years with moderate drought was two at both Qurdaha and Alhaffah stations. The highest number of years with severe drought was recorded at Sulunfeh station (3 years), indicating that it experienced more drought than other stations. One year of excessive rainfall was recorded at the Wadi Qandeel station, while no such year was recorded at any other station.

TABLE.17 Number of years according to the Standard Precipitation Index SPI6 categories during the period (1993 - 2024).

Station	Extremely dry	Severely dry	Moderately dry	Near normal	Moderately wet	Severely wet	Extremely wet
Lattakia	1	2	2	21	4	2	0
Bouqa	1	1	3	20	4	3	0
Humaimeem	1	1	3	19	7	1	0
Qurdaha	2	1	1	21	4	3	0
Alhaffah	2	0	2	22	4	2	0
WadiQandeel	1	1	2	21	4	2	1
Sulunfeh	1	3	3	18	5	2	0

Source: Prepared by researchers

FIGURE.7 number of the humid and dry years



V. CONCLUSION:

The analysis of the general trend of rainfall in the study area during 1993–2024, using the simple linear regression method, revealed an increasing trend in rainfall at all stations except

Sulunfeh, where a decreasing trend was observed. The trend was statistically significant at Bouqa and Wadi Qandeel stations ($R^2 > 0.25$), while it was not significant at the other stations.

The Mann–Kendall test confirmed an increasing trend in annual rainfall at Bouqa and Wadi Qandeel, where the calculated test values exceeded the critical table value ($Z > 1.96$). An increasing trend was also observed in January at all stations except Alhaffah. The coefficient of variation (CV) ranged from 21.6% at the mountainous Sulunfeh station to 37% at Bouqa station in the coastal plain.

The total rainfall volume for the study area was approximately 2,303,720,037 m^3. Spatially, the area is distributed between rainfall lines of <800 mm and >1150 mm, with about 71.2% of the area lying between 900 mm and 1000 mm, contributing on average 69.3% of the total rainfall volume. SPI analysis indicated that the majority of years were classified as normal.

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