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Deanship of Scientific Research

The Impact of Climate Changes on The Climatic Water Balance in The Syrian Coast Region During The Period (1980 to 2020)

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Abstract

Objectives: This study aimed to investigate and analyze the impact of temporal changes in climatic elements (temperature, precipitation, relative humidity, solar radiation, wind, and reference evapotranspiration) on the climatic water balance in the Syrian coastal region from 1980 to 2020. This will be achieved by using statistical indicators and equations to elucidate the relationship between precipitation, reference evapotranspiration, and climate change indicators, utilizing five climate stations distributed in the region (Tartous, Safita, Latakia, Al-Kurdaha, and Slunfah).

Methods: The study used the Mann-Kendall equation to verify the hypothesis of temporal temperature changes at the studied stations. The Climatic Water Deficit (CHD) was evaluated using monthly and annual climate data (temperature and relative humidity) to calculate reference evapotranspiration values at the stations based on the Ivanov equation. This represents the difference between precipitation (P) and reference evapotranspiration (ET0) calculated using the Penman-Monteith method, for the period from 1980 to 2020. Additionally, drought and surplus years were identified using the decadal method.

Results: The study results showed a significant upward trend in reference evapotranspiration at all stations over the study period, with a water deficit observed at all stations except Slunfah. Analysis of the drought index revealed that precipitation was less than 30% of expected precipitation in 15 years during the study period.

Conclusions: The general trend of rainfall in the Syrian coast was analyzed, along with the study of agricultural drought years and periods of water surplus based on decadal categories. Additionally, the study evaluated the climatic water balance during the period (1980-2020), shedding light on the variations and challenges faced due to natural factors and site characteristics.

Keywords: Climate change, Climatic water balance, Climatic water deficit, Drought index, the Syrian coastal region.

أثر التغيرات المناخية في الموازنة المائية المناخية في إقليم الساحل السوري خلال الفترة الممتدة بين (1980-2020)

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ملخّص

الأهداف: تهدف هذه الدراسة إلى دراسة وتحليل أثر التغيرات الزمنية في العناصر المناخية (درجة الحرارة، والهطول، والرطوبة النسبية، والإشعاع الشمسي، والرياح، والتبخر النتح-المرجعي) على الموازنة المائية المناخية في منطقة الساحل السوري من عام 1980 إلى عام 2020.وذلك استخدام المؤشرات الإحصائية والمعادلات لتوضيح العلاقة بين الهطول والتبخر-النتح المرجعي ومؤشرات تغير المناخ، وذلك باعتماد خمس محطات مناخية موزعة في المنطقة (طرطوس، صافيتا، اللاذقية، القرداحة، وصلنفة).

المنهجية: تم التأكد من فرضية تغيرات درجة الحرارة زمانيا في المحطات المدروسة باستخدام معادلة مان-كيندال. وتم تقييم العجز المائي المناخي(CHD)، باستخدام البيانات المناخية الشهرية والسنوية (درجة الحرارة والرطوبة النسبية) لحساب قيم التبخر -النتح المرجعي في المحطات بناءً على معادلة إيفانوف. الذي يمثل الفرق بين الهطول (P) وتبخر المرجع (ET0) المحسوب بطريقة بينمان-مونتيث، للفترة من عام 1980 إلى عام 2020. وكذلك تم تحديد سنوات الجفاف والفائض المائي باستخدام طريقة العشريات.

النتائج: أظهرت نتائج التبخر-النتح المرجعي اتجاهًا صاعداً ملحوظًا في جميع المحطات على مدى فترة الدراسة، مع وجود عجز مائي في جميع المحطات باستثناء صلنفة. كشف تحليل مؤشر الجفاف أن الهطول كان أقل من 30٪ من الهطول المتوقع في 15 عامًا خلال فترة الدراسة.

الخلاصة: تم تحليل الاتجاه العام لهطول الأمطار في الساحل السوري، إلى جانب دراسة سنوات الجفاف الزراعي وفترات الفائض المائي على أساس الفئات العقدية. بالإضافة إلى ذلك، قامت الدراسة بتقييم الميزان المائي المناخي خلال الفترة (1980-2020)، وتسليط الضوء على التغيرات والتحديات التي واجهتها بسبب العوامل الطبيعية وخصائص الموقع.

الكلمات الدالة: التغير المناخي، الموازنة المائية المناخية،العجز المائي المناخي،مؤشر الجفاف،إقليم الساحل السوري.

1. Introduction:

Peripheral Water Balance refers to the relationship between precipitation and evaporation in a given area or ecosystem. It is a measure of the availability of water in an area, and it is an important factor in determining the water resources and general climate of any area. Climate change over the past century has caused significant modifications in the main climatic elements, especially temperature, precipitation, and evapotranspiration which play an essential role in the energy and mass cycles of the global atmospheric system (Sellers et al, 1997; Thomas, 2000; Fisher et al, 2008), and changes in evaporation values were caused mainly by thermal changes. In addition, other important factors (solar Radiation, wind, water vapor pressure, etc….) play an essential role in changing the balance of the Hydro-climatic Cycle (Jhajharia et al., 2009; Bandoc and Golumbeanu, 2010; Bandoc, 2012a; Bandoc et al., 2013; Xu et al., 2013; Prăvălie et al, 2014b; Zhao and Zhao, 2014). Identifying, evaluating and managing the impact of Climate Change on living components is of great importance, through systematically identifying and studying the negative effects of climate change on ecosystems and determining the best strategies for adapting to it. This includes assessing the current state of the ecosystem and awareness of scenarios to assess the impact of Climate Change on ecosystems, as well as determining the best strategies for adapting ecosystems and mitigating their impact (Bandoc et al, 2009). Studies have shown that drylands occupy about 41% of the Earth's surface, which is home to more than a third of the world's population (Mortimore et al, 2009). Knowledge of how human Climate Change will affect the extent of global drylands is essential for managing water resources and land use in these regions (Mortimore et al, 2009; Reynolds et al, 2007). Ecosystems in dry areas are fragile and sensitive to climate change (Reynolds et al., Solomon et al, 2007; Reed et al, 2012), as all studies and model simulations indicate that continued global warming will make the Earth's dry areas drier (Overpeck, 2010; Seager et al, 2007; Held and Soden, 2006; Solomon et al, 2007), leading to increased water balance deficits in many regions (IPCC, 2007), For example, a study published in the Nature journal in 2018 showed that rising temperatures could increase evaporation by up to 28% by 2100 in some dry areas of the world. Drought is an insidious natural hazard. It is related to the reduction in the amount of precipitation received over an extended period of time (Mishra and Singh 2010) In the context of the dynamics of the two climatic parameters, the expansion of global drylands has been observed during the past six decades (arid, semi-arid, and humid-dry areas). It is possible that the world's drylands will increase by 10% by the end of this century over the climatic norm for the period from 1961 to 1990 (In terms of precipitation and referential evaporation) (Feng and Fu, 2013), The occurrence of drought makes the land incapable of cultivation throughout the year and this situation renders harsh and inhospitable environmental condition for human being, livestock population and biomass potential and plant species (Dutta et al. 2015) . Syria is a region that is greatly exposed to Climate Change, as indicated by the report of the Arab Forum for Environment and Development (AFED, 2009). A study has shown that 75% of the area of Syria receives less than 500 mm of rain (Al Mousa, 2007), and the area of the territories with rainfall not exceeding 1000 mm (5%), and this percentage is concentrated in the highlands of humid areas. (Kaniewski et al, 2012) also indicates that the Northeastern Region of Syria went through severe drought conditions during the period from 2007-2010, which led to a decline in agricultural productivity and large population migration in what was the most severe drought period that the eastern region has ever experienced. The report of the Arab Water Council (2009) indicates expected difficulties in securing water in Syria, which is one of the most important agricultural countries, as agriculture contributes about 19.2% to the gross domestic product. The results of the study conducted in the Latakia region (Ibrahim et al., 2022) indicated that there is a temporal change in the monthly, seasonal and annual maximum temperatures in the study area and a positive upward curve during the period (1960-to 2021).

Objectives of Study:

This research aims mainly to:

1. Study and analysis of the general annual and seasonal trends in temperatures (C°) for the Syrian Coastal Region during the period (1980-to 2020).
2. Study and analysis of the general annual and seasonal trends in rainfall amounts (mm) of the Syrian Coast Region during the period (1980-to 2020).
3. Analysis of annual changes in Referential Evapotranspiration values in the Syrian coastal region

during the period (1980- to 2020)

4. Study and evaluation of the current Climatic Water Deficit in the Syrian Coastal Region during the period (1980-to 2020)
5. Study and evaluation of the severity and succession of drought episodes in the study areas using the decadal index to detect drought based on the climatic data available in the five stations studied, and a comparison between these locations in terms of the percentage and succession of drought episodes in them during the period (1980-to 2020).

Problem of Study:

The problem of this study is centered upon the fact that the study area is one of the regions with the highest precipitation rates in Syria and is agriculturally active in relation to various crops in addition to other economic activities that depend mainly on water.

This study attempts to research the Water Balance of the Syrian coast region and determine its merits as well as the impact of Climate Change on the Climatic Water Balance in the Syrian Coast Region, Climate Change and identifying the potential challenges that may face the Syrian Coastal Region to find solutions for adaptation and future planning

Materials and Methods:

1.2. *Study Area*:

The Syrian coastal region extends between two latitudes (34.31°-35.57°) North, and two longitudes (35.43°-36.26) East. It is bordered by Jabal Al-Aqra' to the North and the Akkar Plain and Buqaa's Depression to the South. It is confined between the peaks of the Coastal Chain to the East (the water dividing line between the Orontes Basin and Sahel Basin) and the Coastal Strip on the Mediterranean Sea to the West, thus forming the Northwestern part of the Syrian Arab Republic, thus occupying an area an estimated land area of 5086 Km^2 (Halima, 2001), see Figure 1

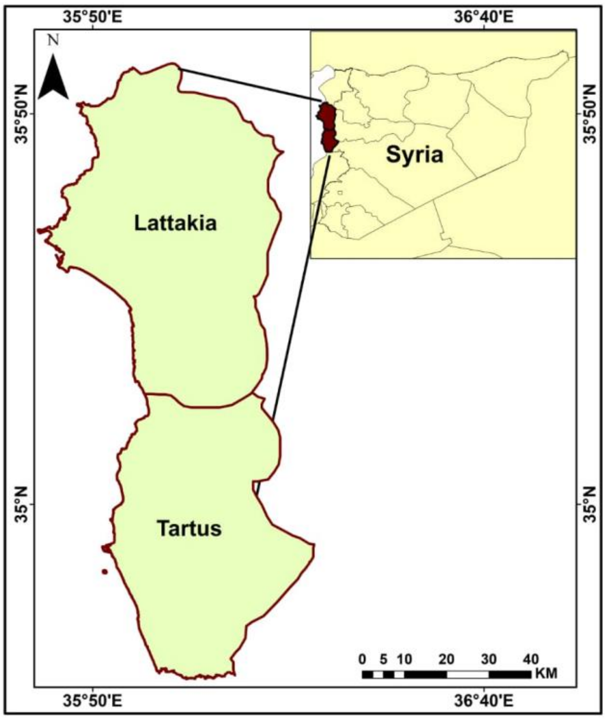


Figure 1: The location of the study area

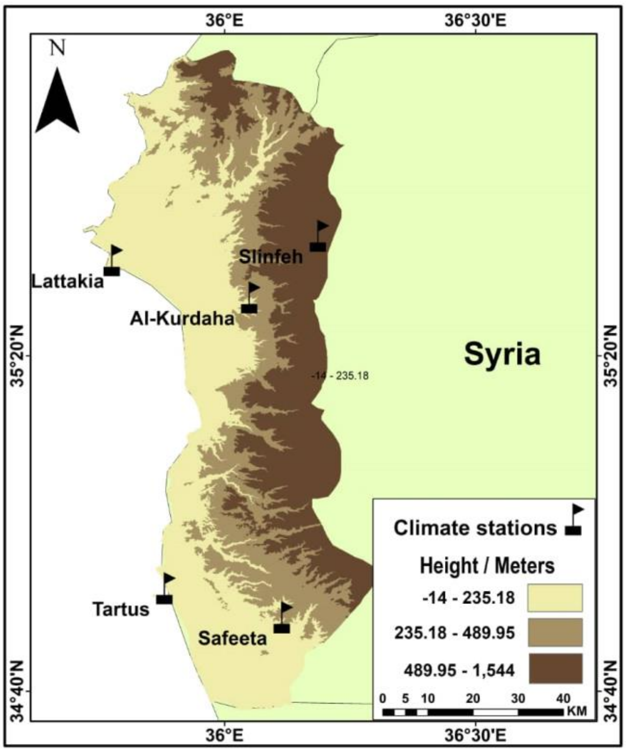


Figure 2: Distribution of climate stations according to altitude in the study area

1.3. Research tools:

The study relied on data on climate elements (temperatures, rainfall amounts, winds, relative humidity, and solar Radiation) from meteorological records for five stations representing the Syrian Coastal Region during the study period (1980 to2020) (Figure2). This data was processed and analyzed. Statistically, studying the relationships among them according to the nature of the data, statistical programs were used: Microsoft Excel was used to format tables, draw graphs and trend lines and produce results. SPSS statistical package program was used to process and analyze data and test hypotheses.

(Standard Deviation and Coefficient of Variation) were used to determine the value and percentage of deviation and difference of annual temperature averages for the study period (1980-to 2020) from the general long-term average, using the following two mathematical formulas (Darkzanli et al, 2004)

$$.S = \sqrt{\frac{(X-\bar{X})}{n}} \quad (1)$$

Where:

S: Standard deviation

Σ: Sum

X: Annual temperatures average

$\bar{X}$: Temperatures average

n: Number of years in which X was calculated

$$Cv = \frac{S}{\bar{X}}100 \quad (2)$$

where:

S: Standard Deviation

Cv: Coefficient of variation

$\overline{X}$:Annual temperatures average

2.2.1 Quantitative statistical analysis:

1. Normal distribution test: Through the statistical package program SPSS, the One-Sample Kolmogorov-Smirnov Test was utilized to ensure the normal distribution and randomness of the data used through the significance of the test value, where the data is normally distributed if the value of “Sig” indicates that (Sig>0.05), but if the value of “Sig” indicates that (Sig<0.05) then the distribution is deemed dispersed .

2. Deviations of monthly average temperatures for the study period (1980-to 2020) from monthly average temperatures for the standard period (1960-1990), to determine the general trends of the climate elements adopted during the studied period.

3. The Mann–Kendall (MK) test was used to evaluate trends in rainfall which is based on the null hypothesis (H0) that there is no trend – the data are independent and randomly are variationd – and this is checked against the alternative hypothesis (Ha), which assumes there is, in fact, a trend. The true slope (change per unit time) was predicted using the Sin Slope (SS) value. The results of the MK test are likely to be affected by the presence of autocorrelation in the time series data so a serial correlation test was performed before MK. It was by calculating the lag-1 r1 serial correlation coefficient at a 5% significance level using the XSTAT program which was applied to the annual values of precipitation trends for 40 years without interruption.

2.2.2 Calculating referential evapotranspiration:

Monthly and annual climate data (temperature and relative humidity) were used to calculate the Referential Evapotranspiration at the study stations during the period based on the Ivanov equation, which is written in the following form Ivanov method (Cunha et al., 2017) :

ETP = 0.0018(25 + T)2 (100 - A) K (3)

Where:

ETP: Evaporation-transpiration (reference) (mm/day)

T: Average daily temperature.

A: Average relative humidity.

K: Climate factor.

2.2.3 **Calculating Climatic Water Deficit (CHD):**

For a given area, the Climatic Water Deficit (CHD) represents the difference between precipitation P (mm) and the Referential Evapotranspiration ET0 (mm) calculated by the Penman-Monteith method) Allen et al., 1998)

$$ET0 = \frac{0.408\Delta\,(R_n - G) + y\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + (1 + 0.34U_2)}$$

Where:

$ET_{o:}$ reference evapotranspiration [mm day^{-1}],

R_n :net radiation at the crop surface [MJ m^{-2} day^{-1}],

G :soil heat flux density [MJ m^{-2} day^{-1}],

γ = Psychrometric constant (kPa/°C)

T: mean daily air temperature at 2 m height [°C],

u2: wind speed at 2 m height [m s-1],

es: saturation vapor pressure [kPa],

ea: actual vapor pressure [kPa],

es :- ea saturation vapor pressure deficit [kPa],
D :slope vapor pressure curve [kPa °C-1],
g psychrometric constant [kPa °C-1].Water Deficit (CHD) calculated by: CHD=$\sum_{i=1}^{n}(P - ET0)$ (4)

Where:
CHD : Cumulative Hydrological Deficit
P: amount of rainfall in period *i*
*ET*0 : Reference Evapotranspiration
n i: number of time periods over which the deficit is calculated

2.2.4 **Calculating the Drought Index:**

Drought in the study area was studied annually during the period approved by the study using the Deciles Method, which is one of the methods for monitoring drought. Developed by (Gibbs and Maher, 1967), this technique is based on dividing the distribution of rainfall frequency recorded over a long period in Deciles of the distribution. After arranging the data in ascending order, each of these categories is called a Decimals. The first Decimals represents the amount of precipitation that does not exceed 10% of the smaller rainfalls within the distribution. The second decimal represents the amount of precipitation that does not exceed 20% of the smallest rainfall, and so on, and the tenth decimal indicates the maximum amount of precipitation during the measurement period. If precipitation falls into the lowest 20% (deciles 1 and 2), it is classified as much below normal. Deciles 3 and 4 (20–40%) indicate below normal precipitation, deciles 5 and 6 (40–60%) indicate near normal precipitation, 7 and 8 (60–80%) indicate above normal precipitation and 9 and 10 (80–100%) indicate much above normal precipitation (Karinki, & Sahoo, 2019). These Deciles are grouped into five categories (Table 1).

Table 1. Classification of drought based on deciles (adapted from Gibbs and Maher 1967).

Class	Percent	Period
Decile 1–2	20% lower	Much below normal
Decile 3–4	20% following	Below normal
Decile 5–6	20% medium	Near normal
Decile 7–8	20% following	Above normal
Decile 9	20% more high	Much above normal

3.Results and Discussion:

3.1 Studying the climatic factors affecting the Climatic Water Balance during the period (1980-2020):

3.1.1 **Temperature**:

The distribution of the annual average dry temperature in the Syrian Coastal Region is affected by natural circumstances, such as altitudes above sea level, lines of latitude, marine and continental factors, and terrain. All of which appear in the distribution of annual, seasonal, and monthly temperature averages. It is clear from the data that the annual temperature averages during the studied period were distributed in the study area as follows: Tartos 19.8°C, Latakia 19.9°C, Al-Kurdaha 18.8°C, Safita 18.5°C and Slunfah 13.4°C. As for the monthly averages: January records the lowest average dry temperature in the study area, 9.8°C, then the average begins to rise, reaching its peak in August, 25.1°C, and then decreases again until December, 10.1°C. Thus, the summer months (June, July, and August) record the highest average temperatures in the region. The winter months (December, January, and February) have the lowest average temperatures, and the averages converge in the transitional seasons of spring and fall (Figure 3).

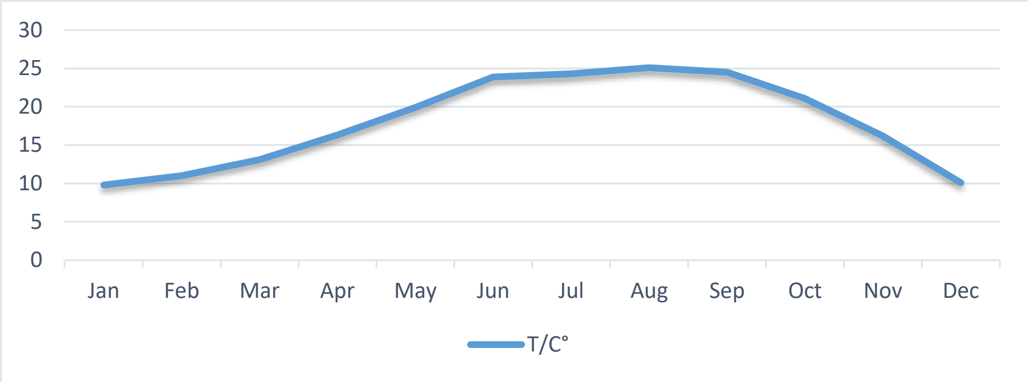


Figure 3. The monthly dry temperature/C° averages during the period of observational recordings in the study area (1980-to 2020).

3.1.2 Seasonal and Annual Temperature Variation:

The Seasonal and Annual Temperature Variation reflects the extent of temperature variation between parts of the studied region as a result of variations in external and internal factors during the year. It is made clear from the analysis of seasonal temperature data that the temperature Variation in the summer (JJA) Variations between (3.2-3.6 C°) in Latakia and Tartos, (2.5-3 C°) in Al-Kurdaha, and (2.3-2.5 C°) in both Slunfah and Safita. The Variation in the lowland areas of the region is higher than it is in areas of higher altitude. This is due to the sea effect, delaying the period of maximum heat until the second half of the season, as well as the nature of the region, as the high areas of the region have an increased density of vegetation which reduces thermal variation. In the winter, the conditions associated with low weather prevail over most parts of the region, which reduces the impact of local factors and the temperature decreases in general (see Figure 4)

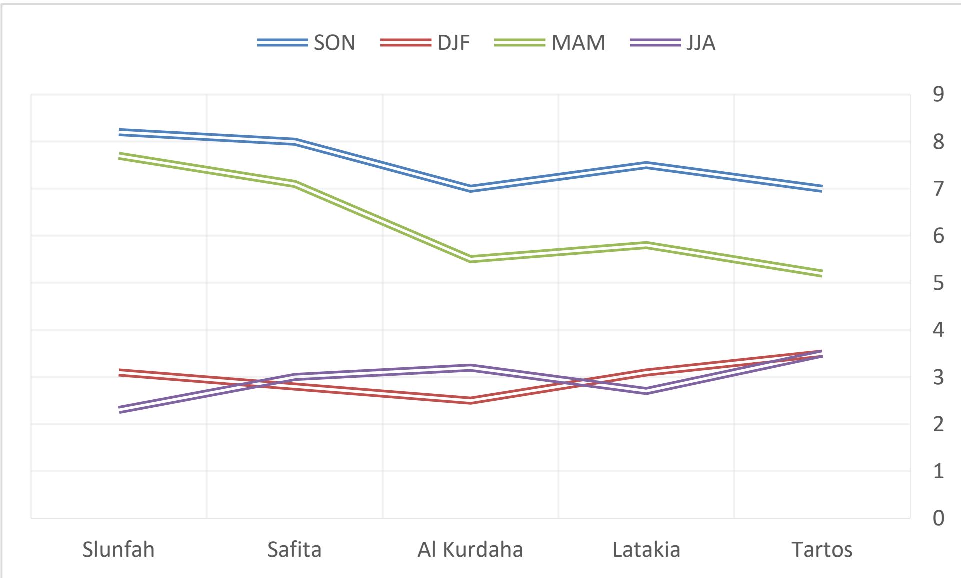


Figure 4. Seasonal Temperature/C° Variation during the period (1980-2020) at stations representing the study area

During the transitional seasons of Spring and Fall, most of the weather conditions in the region change as these periods are transitional between the cold and hot seasons. In the fall, temperatures begin to gradually decrease but both extremities increase at the beginning and end of the season. The Average Temperature Variation in the Coastal Region Variations between (6.8 C°) in Tartos and (7.2 C°) in Latakia. Meanwhile, the average in plateaus and inland areas of the region

Variations between (6.9 C°) in Al-Kurdaha, (7.9 C°) in Safita and 8.2 in the mountains in Slunfah. In the spring, The Average Temperature Variations between (5.1°C) in Tartos and (5.7°C) in Latakia. In the lowland region, said Variation is situated between (7°C) in Safita and (7.9°C) in Slunfah in the inland region, (See Figure 4).

1.1.1. Annual Temperatures Variation:

Analysis of temperature data in the Syrian Coastal Region shows that the average annual temperature Variation in the study area changes during the year from one region to another in the region due to the effects of external and internal factors and terrain conditions. The role of marine effects appears in reducing thermal extremes and adjusting the temperature. The temperature variation was recorded. During the period (1980-2020) in Latakia (15.7 C°) and in Tartos (15.6 C°). As for the inland regions, the Annual Temperature variation increases as we move further within said regions. This is due to continental factors which are reflected in a rise in temperatures during the summer and a subsequent decrease during the following winter, increasing the Annual Temperature variation. In Safita (16.8 C°), it is noted that the temperature variation increases in high-altitude areas, especially during the winter season, as a result of the significant decrease in temperature, in Slunfah (17.8 C°), (see Figure 5).

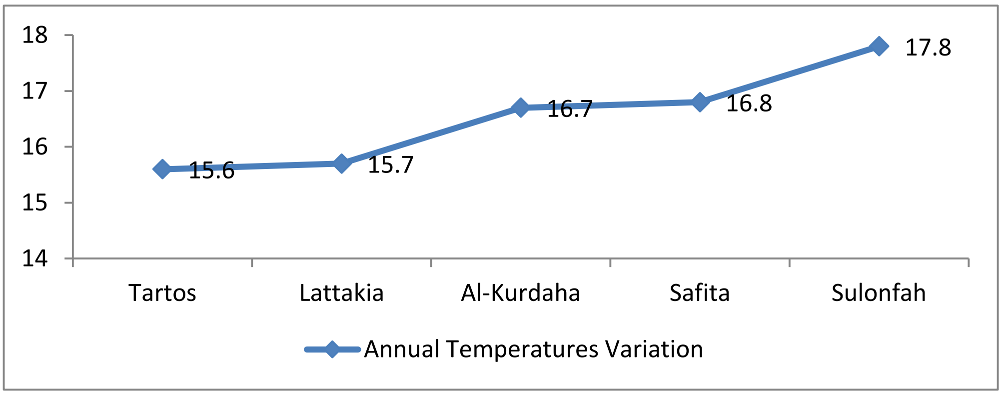


Figure 5. Annual Temperature Variation during the period (1980-to 2020) at stations representing the study area.

1.2Rainfall:

Rain is regarded as one of the most important climatic factors in the Climatic or Hydrological Water Balance for estimating water deficits through evaporation and the extent of the need for water, especially if we know that rain is gaining greater importance in the Eastern Mediterranean region. This is due to the relative poverty of running surface water resulting from the decline in annual precipitation. The results of the One-Sample Kolmogorov-Smirnov Test for normal distribution of Annual Rainfall Rates at stations in the study area showed that the "Sig" value is >0.05, which means the randomness of data distribution related to the Annual Average in the period between (1980-to 2020) ,see Table 2.

Table 2. Results of the One-Sample Kolmogorov-Smirnov Test (1980-to 2020) for normal distribution and randomness of data used through the significance of the test value for the stations.

	Al-Kurdaha	**Sulonfah**	**Lattakia**	**Tartos**	**Safita**
Mean	1058.5	1164.5	767.6	792.6	1109.5
Kolmogorov-Smirnov Z	.606	.826	.633	.975	.462
Asymp. Sig. (2-tailed)	.857	.503	.818	.298	.983

The results of the analysis of annual, seasonal and monthly precipitation rates for stations in the study area during the same period revealed the following:

- A variation in annual precipitation rates between regions of the studied region, as Annual Precipitation Rates increase inward in the study area; The Average Annual Precipitation for the study period at stations in the region was as follows: in Latakia (767.6 mm), Tartos (792.6 mm), Al-Kurdaha (1058.5 mm), Safita (1109.5 mm) and Slunfah (1164.5 mm) see Table2.

- The highest average amount of rainfall was recorded in the Syrian Coastal Region in the winter months. In January 248.4 mm, followed by February 203.3 mm then December 193.8mm, in Slunfah station See Tables 4.
- The fall months ranked second in terms Average amount of Seasonal Precipitation Rates in the Syrian Coastal Region. It was recorded in in the Autumn months, November 100.2 mm and October 74.3 mm. In the spring, the highest average amount of precipitation during the study period was recorded in March 116.3 mm and then April 67.7 mm, See Tables 3.
- Seasonal variation in Precipitation Rates at all stations in the study area; While the winter(DJF) Precipitation Rates reached 215.1 mm, followed by Spring (MAM) 101.2 mm, then Autumn(SON) 67.3mm respectively. see Table 5.

Table 3. Average amount of precipitation/mm in the fall and spring months at the study stations between the years (1980-to 2020).

Station	Nov	Oct	Sep	May	Apr	Mar
Lattakia	92.9	65.4	10.1	20.5	47.4	86.8
Tartos	96.6	69.2	8.6	33.8	53.6	91.7
Al-Kurdaha	102.4	88.1	12.6	40.6	83.8	124.2
Slunfah	109.1	74.7	18.3	54.6	86.2	162.8
Average	100.2	74.3	12.4	37.3	67.7	116.3

Table 4. Average amount of precipitation/mm during the summer and winter seasons at the study stations and the annual total between the years (1980-to 2020).

Station	DJF			JJA		
	Feb	Jan	Dec	Aug	Jun	Jul
Lattakia	100.2	148.4	145.8	4.2	1.0	5.5
Tartos	130.9	155.9	155.6	3.5	1.3	11.4
Al-Kurdaha	151.9	184.8	178.1	5.1	2.0	20.7
Slunfah	203.3	248.4	193.8	1.95	10.6	1.35

Table 5. Average seasonal amount of precipitation/mm in the study region between the years (1980-to 2020).

Station	SON/mm	MAM/mm	DJF/mm
Lattakia	56.1	51.4	131.5
Tartos	58.1	59.5	147.5
Al-Kurdaha	67.7	82.9	171.6
Slunfah	67.3	101.2	215.1

1.3Relative Humidity:

The Mediterranean Sea is the primary source of humidity in the study region. The Relative Humidity in the region generally decreases from the coast to the inland, due to the factor of distance from the sea. It also increases with height above sea level due to the decrease in temperature with height and the increase in the amount of rainfall. Relative Humidity is one of the most important elements of the Climatic Water Balance. The analysis of Relative Humidity data in the study area during the period between 1980-2020 revealed the following:

- Latakia station recorded the highest percentage of Relative Humidity Annual Average in the study area (71.9%), and in Tartos it recorded about 67.5%. Also, the Relative Humidity Annual Average in Slunfah rose to (69.8%). This is due to its elevation above sea level and then the low temperature. The rate of evaporation is low and the amount of precipitation increases during the winter which increases the Relative Humidity in Safita (66.2%) and Al-Kurdaha (62.7%), See Table 6.

Table 6. Relative Humidity Seasonal Average % at most stations in the study region during the period (1980-to 2020).

Station	DJF	MAM	JJA	SON	Average
Al-Kurdaha	63.69	62.85	65.61	59	62.7
Safita	66.66	64.9	69.2	64.05	66.2
Tartos	66.37	67.95	72.25	63.69	67.5
Slunfah	77.7	65.34	65.11	71.22	69.8
Lattakia	72.43	71.29	74.24	69.92	71.9

- The results of the analysis of the Relative Humidity Seasonal Average in the Syrian Coastal Region showed that Relative Humidity recorded its highest levels during the summer (JJA) in the coastal and plateau regions of the study region, in Latakia (74.2%), Tartos (72.2%), Al-Kurdaha (65.6%) and Safita (69.2%). This is due to its proximity to the sea and its low altitude, as the combination of humidity and high temperature leads to an increase in the heat capacity of the air, which means it can absorb more humidity.
- A significant increase in Relative Humidity levels during the winter was recorded in the mountainous areas of the Syrian Coastal Region, where it was recorded in Slunfah (77.7%). This is due to the altitude being above sea level, the lower temperature, the lower rate of evaporation and the increased amount of precipitation during the winter. In the coastal areas of Tartos (66.3%), Latakia (72.4%) and Safita (66.6%) it is noted that Relative Humidity increases during the winter in areas of altitudes above sea level. In fact, it became clear that the strongest factor affecting the distribution of Relative Humidity in the studied region during the summer is the factor of proximity and distance from the Mediterranean Sea. During the winter, however, the strongest affecting factor is the humid air masses that come to the region with air depressions. The frontal area that crosses the region from West to East (Al Mousa, 2007).
- Variation in the Average Relative Humidity in the spring between (62-71%) (Al-Kurdaha 62.8%, Safita 64.9%, Slunfah 65.3%, Tartos 67.9%). In the fall, a variation in Relative Humidity was recorded between the study areas as follows: Latakia 69.9%, Al-Kurdaha 59 %, Slunfah 71.2%.(see Table 6)

1.4 Solar Irradiance:

The number of hours of luminosity depends on the length of the day depending on the seasons. The longer the period during which the sun shines, the greater the amount of luminosity that a place on the surface receives. The length of the day in the study area reaches its maximum in the month of June when the amounts of solar luminosity do not decrease. reaching areas of the region exceeds 26 megajoules/m2/during the day (GORS, 2007). This quantity varies between stations in the region, ranging between (26-28) megajoules/m2/during the day, which is reflected in the variation in temperatures between parts of the region. The region also increases the length of the day in the summer to record the highest temperatures. The importance of analyzing the duration of Solar Luminosity lies in its connection to the process of evapotranspiration, which is directly proportional to the duration of Solar Luminosity and thus plays an important role in determining the Water Balance of the region. Analyzing the data available at the Latakia station during the period (1980-to 2020), it was found that the annual duration of Solar Luminosity is about 2900 hours on average. The average monthly duration of Solar Luminosity Variations between 151.7 hours (January) and 330.3 hours (July).

1.5 Wind in the study area:

The wind component has a major impact on the phenomenon of drought because of its role in the evapotranspiration process. By replacing and renewing the air mass, the wind changes the temperature and air humidity (Allen et al, 1998). In the winter, the Siberian high air pressure that dominates the region coincides with cold and dry Northerly and Northeasterly Winds. The margins of the Azorean high pressure also shift, expanding its area from its center towards the Northeast to include the Northwestern parts of the African Continent of which the Northwestern Highs are formed. Atmospheric air pushes air and this air reaches the eastern basin of the Mediterranean Sea and Syria (Abdel Salam et al, 2004), while the subtropical high pressure is a source of Southern and Southwesterly winds (Mousa, 1990). In the summer, when the region is under the control of the warm Indian Monsoon low pressure, and since Syria is located on the Northwestern outskirts of this low, it attracts air from the north and west. Therefore, Westerly gusty winds prevail in the region in the Coastal Strip. The passage of these winds over the Mediterranean Sea leads to an increase in humidity, which increases the temperatures in the coastal areas of the region. Also, an increase in the speed of summer winds is noted when the direction of the prevailing winds corresponds with the direction of the local winds, with the summer winds being non-continuous and of low frequency is low. The center of Azorean high pressure that dominates the Western part of the Mediterranean sends its air toward the region in the form of Westerly winds. It is clear from the results of the wind speed data analysis for the period (1980-2020) with the Latakia, Safita and Tartos stations used as a model that the annual averages reached 2.9 m/s at the Tartos station, 3.8 m/s in Latakia, 3.9 m/s in Safita, and 2.8 m/s in Al-Kurdaha and 4.3 m/s in Slunfah. As for the monthly level, it is clear from the monthly averages of wind speed analysis that the lowest wind speeds recorded in September at the Tartos and Safita stations were 2.1 m/s and 2.5 m/s, respectively. In October, it reached 2.8 m/s for the Latakia station. As for the highest wind speed, it was recorded in February for the Latakia and Tartos stations, and it was 4.5 m/s and 4 m/s, respectively. In the months of December and January in Safita, it reached 5.6 m/s.

2. Analysis of temporal changes in temperature and precipitation in the studied region during the period (1980-to 2020).

According to the report issued by the Intergovernmental Panel on Climate Change, average annual global emissions of greenhouse gases are increasing, reaching their highest levels in human history during the period (2010-2019) (IPCC, 2020).

2.1Temporal changes in the temperature element during the period (1980-to 2020) ;

The general trend of the temperature path in its spatial units is a reflection of the total forces of atmospheric greenhouse elements in the Earth's atmosphere, and the radiative reflection forces of solid suspended particulates in the atmosphere. Long-term changes in average air temperature near the Earth's surface will cause various impacts on the ecosystem, especially on plants, soil water balance, agriculture and human health (Hohman and Frei, 2003).

2.1.1Deviation of the average annual temperature during the period (1980-to 2020) from the average for the standard period (1960-1990):

The study and analysis of temperature average value deviations during the period (1980-to 2020) from the average temperature for the standard period (1960-to 1990) revealed the following, (see Figure 6 and Table 8):

- An increasing and significant deviation in the values of average annual temperatures during the studied period from the values of average annual temperatures for the standard period (1960-to 1990). This increase became clear after 1990,see Figure 6

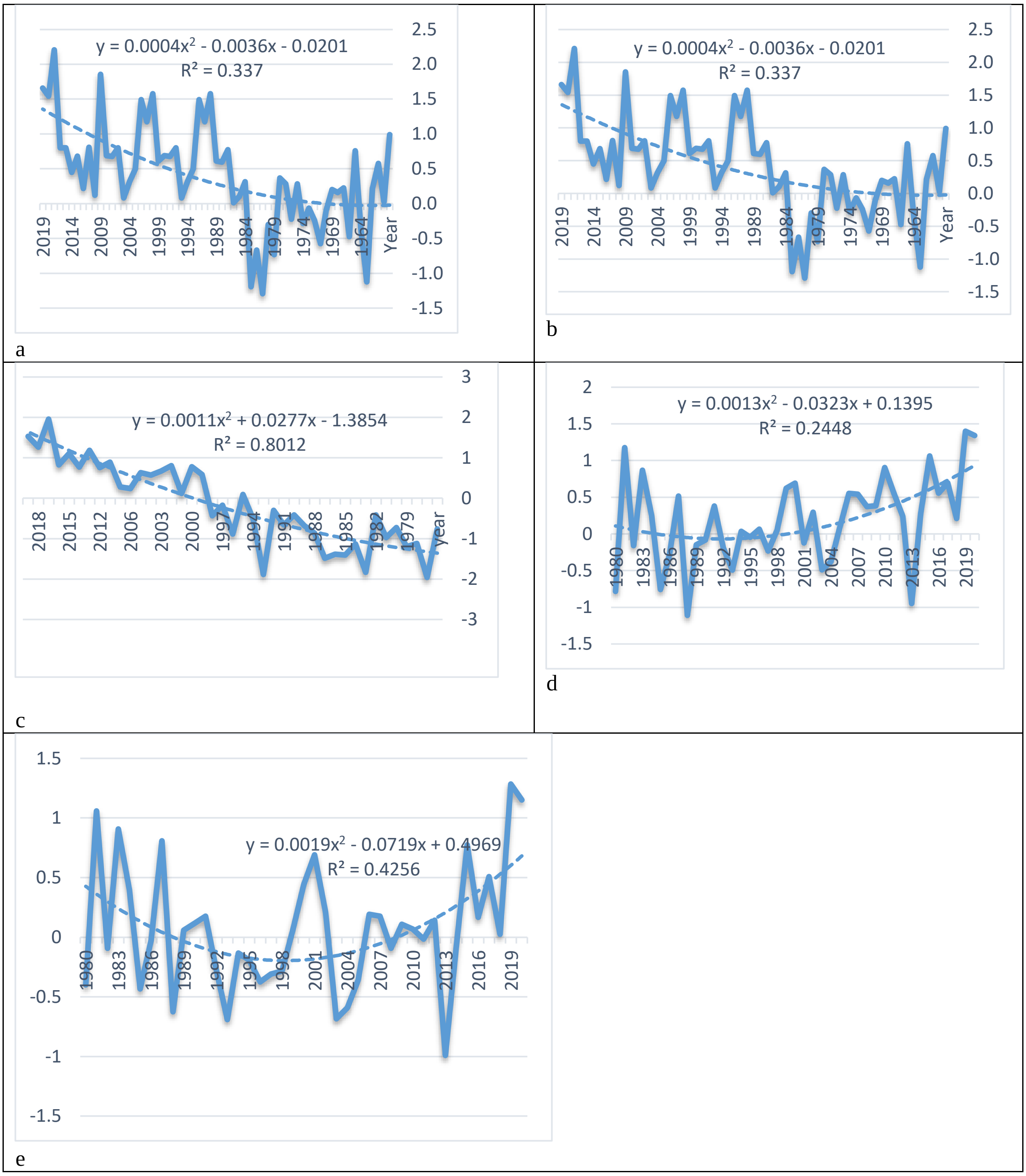


Figure 6. The deviation of the annual temperature during the period (1980-to 2020) from the average for the standard period (1960-to 1990), where a: Latakia, b: Al-Kurdaha, c: Slunfah, d: Safita, e: Tartos.

- A positive deviation in the temperature average values for all five stations with significant statistical significance P ≥0.90 from the average for the standard period, where the level of significant significance varied between: P=0.99 (28 values), P=0.95 (2 values) and P= 90 (10 values). This indicates that the average annual temperature tends towards a positive increase in general in the study area.
- There has been an increase in the frequency of positive deviation from the standard period average since the mid-eighties of the last century. The highest value of deviation in the positive rate was recorded at 2.2°C, which was indicated

by the high significance of the increase to P=0.99, (see Table 7).

- The results of the Independent Samples Test include an increase in the value of the calculated level of significance (Sig.= 0.706), over the specified level of significance of 0.05. Thus, we accept the null hypothesis that there is homogeneity and reject the alternative hypothesis to fulfill the conditions of the test. It is also clear from the results of the t-test that the value of the calculated level of significance (Sig. = 0.559) is greater than 0.05. Therefore, there are statistically significant deviations of the final averages from the average of the standard period, and it was also shown that there are confidence limits for the difference between the averages of the two samples, (see Table 8).

Table 7. Value and significance of the deviation of the seasonal and annual average temperature from the average for the standard period 1960-1990 in the Syrian Coastal Region during the period (1960 – 2020).

Station	Years	Sig	ANN	Sig	SON	Sig	JJA	Sig	MAM	Sig	DJF
lattakia	40	***	0.5	***	3.1	***	1.4	***	2.6	*	0.71
Sulunfah	40	**	0.6	**	3.4		1.3	***	2.5		0.52
Al-Kurdaha	40	**	0.7	**	2.9	*	1.1	*	2.2		0.61
Tartos	40	***	0.6	***	3.2	***	1.5	***	2.5	*	0.69
Safita	40	**	0.8	**	2.8	*	0.95	*	2.3		0.63

Table 8. Independent Samples Test results. (*p=90, **p=95, ***p=99)

	Levene's Test for Equality of Variances		t-test for Equality of Means					
	F	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Equal variances assumed	.273	.706	-.593	.558	-.1379	.33509	-.654	.365
Equal variances not assumed			-.643	.530	-.138	.2341	-.643	.476

1.2. Studying the temporal changes in rainfall rates in the Syrian Coastal Region between the years (1980- to 2020) using the Mann-Kendall (MK) test:

The study area is characterized by a rain regime consisting of two distinct seasons: First, a dry season in which precipitation is low or almost non-existent. Second: a rainy season characterized by varying amounts of rainfall and irregular temporal and spatial distribution.

It is clear from the climate data analysis (monthly and annual rainfall) and the rain coefficient during the period (1980- to 2020) at the selected stations that the rainy season begins in September, and the rain reaches its peak in January and then gradually decreases until June. Rainfall during the humid period (October to April) plays an important role regarding the annual water balance because during this period water reservoirs in the region are replenished. The rain coefficients (the percentage between the average rainfall for the month in question and the average annual rainfall) show the importance of rain for each month of the year. The largest percentage of rain falls in the winter, and the month of January is considered the rainiest month of the year with 20% of the annual total rainfall. Next in importance is the month of December. The results of using the Mann–Kendall (MK) test to evaluate trends in rainfall and clarify temporal changes in rainfall rates have been shown during the analysis of the time series of annual rainfall amount for 40 years without interruption at stations (Latakia - Slunfah - Al-Kurdaha - Tartos - Safita) between the years 1980-to 2020 The following results:

- The general trends of seasonal rainfall during the period (1980-to 2020) showed a clear decrease in spring rainfall amounts in the five stations, with deviation rates ranging between -1.5 mm in Latakia, - 1.9 mm in Tartos, - 2.2 mm in Safita, - 2.3 mm in Al-Kurdaha and - 0.9 mm in Slunfah. The amounts of autumn rain showed an increasing trend in each of the Latakia, Safita, Slunfah and Al-Kurdaha stations, with deviation rates of: 0.62 mm, 1 mm, 1.5 mm, and 1.7 mm, respectively, as they tended to decrease at a very slight rate in Tartos (- 0.09 mm). As for the winter, we notice an increasing linear trend in rainfall amounts at the stations of Tartos, Safita, Al-Kurdaha and Slunfah, with deviation rates reaching 1.4 mm, 2.5 mm, 2.6 mm and 2.7 mm, respectively. The deviation recorded a negative value at the Lattakia station (- 1.9 mm).

- The P results in the Mann–Kendall's test recorded relatively few high values in the Al-Kurdaha, Safita, and Slunfah stations, and slightly lower than the average in the Lattakia and Tartos stations, where the Sen's Slope values Variationd between being low negative and low positive.
- The slope of the general trend of annual rainfall at Latakia station did not record a significant value, and the results of the Mann–Kendall test during the studied period indicated that there were no significant annual changes in rainfall.
- No significant decline in annual precipitation was recorded at Tartos station, and the results of the Mann–Kendall's test during the studied period indicated that there were no significant annual changes in rainfall.
- The annual precipitation at Al-Kurdaha station did not decline in the general direction, but rather fluctuations were recorded in the amount of precipitation around the general average with a confidence level of 95%. According to the Mann–Kendall's test, it was found that the value of P = 0.224 is greater than "Sig". Therefore, this regression has no significant value.

2.3Referencial Evapotranspiration (ET0):

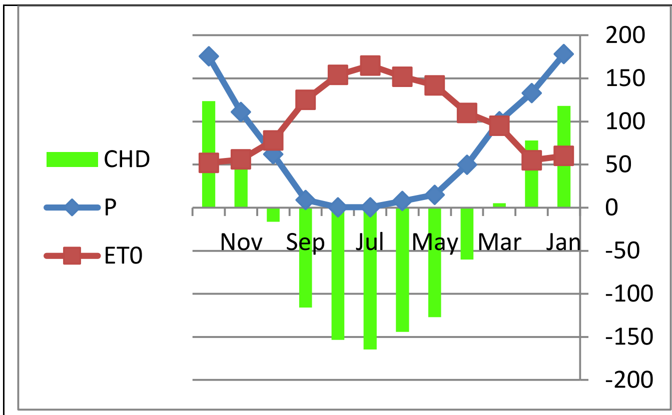
It is clear from analyzing the results of the Referential Evapotranspiration calculation based on the Ivanov equation in the stations studied during the period (1980-to 2020), that the annual average of Evapotranspiration reached 1448.7 mm in Latakia, 1355.9 mm in Tartos, 1459.4 mm in Safita, 1478 mm in Al-Kurdaha and 1227 mm in Slunfah. It was found that the monthly average values in the stations studied reached their lowest values in January, recording 73.4 mm in Latakia, 68.2 mm in Tartos, 66.9 mm in Safita, 66.2 mm in Kurdaha and 60.1 mm in Slunfah. The maximum values were recorded during the dry period of the year, and reached a peak in July, recording 173.4 mm in Latakia, 172.4 mm in Safita 164.6 mm in Tartos, 173.5 mm in Kurdaha and 161.7 mm in Slunfah. Data analysis of the Referential Evapotranspiration at the seasonal level during the period (1980-2020) showed that the largest amount of it was recorded in the summer, followed by the spring and then the fall. The lowest quantities were recorded in winter, See Table 9. We also noticed that the quantities of water lost during the Referencial Evapotranspiration process at the Safita station exceeded those lost in Latakia during the spring and fall seasons, as well as a lower amount of water lost through the Referencial Evapotranspiration in Tartos than in the Latakia and Safita stations. The highest Evapotranspiration percentage was recorded in the Al-Kurdaha area, while the lowest percentage was recorded in the Slunfah area.

Table 9. Seasonal averages of Referencial Evapotranspiration /mm:

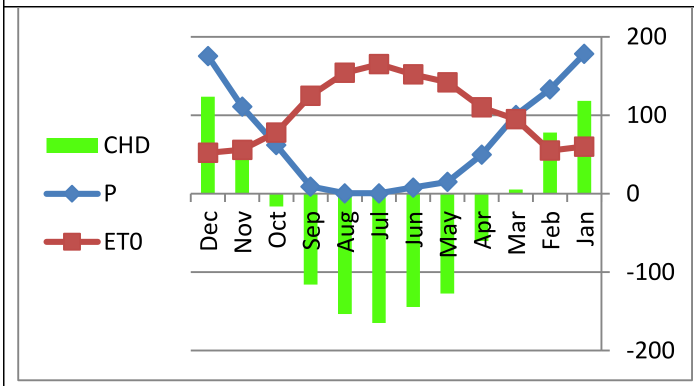
	JJA	MAM	DJF	SON
Lattakia	502.8	359.7	228.9	358.3
Tartos	475.9	341.9	210.9	327.7
Safita	502.7	371.7	213,7	369.2
Al-Kurdaha	530.1	381.2	225.5	372.6
Sulonfa	415.1	342.7	195.8	317.2

2. Study of the water deficit in the Syrian Coastal Region during the period (1980-to 2020):

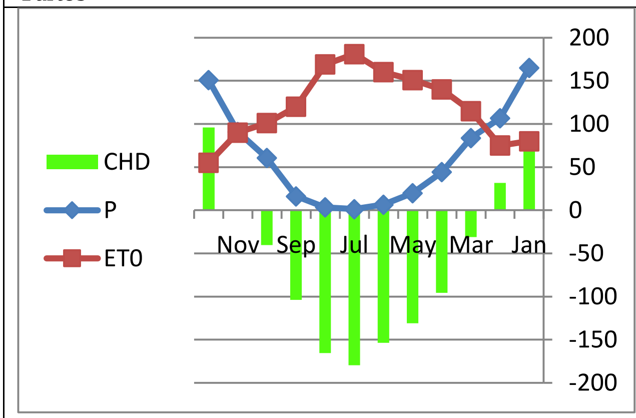
The results of applying the Climatic Water Deficit equation during the period (1980-to 2020) for the five stations revealed that the general water balance for these sites is negative, but it was positive in some years as is the situation in Safita in the years 1979-to 1980 and 2002-to 2003, during which the amount of rainfall amounted to 1493.9 mm and 1724.8 mm, respectively. The amounts of Referential Evapotranspiration for the same two years were 1407.4 mm and 1497.4 mm, respectively. It was also shown from the analysis of the Referential Evapotranspiration data and the Climatic Water Deficit (mm) in the five stations during the studied period, that the changes in the water deficit are proportional to changes in the Referential Evapotranspiration, as the Climatic Water Deficit appears to start in March in the Latakia station and continues until November. Therefore, this means that the rainfall only partially meets the need for water. In the Tartos and Safita stations, it was observed that it begins in April and continues until October. At the seasonal level, the region witnesses a clear water deficit during the spring and fall seasons, except for some years that witnessed an abundance of seasonal rainfall, especially in Safita where the amount of spring rainfall reached 491.2 mm in 1981, recording a 200% increase over the general average for this season (244.9 mm). As for the Latakia station, it did not witness an abundance of water during the study period except in the year 1983, when the amount of spring precipitation reached 323.5 mm, thus achieving an increase of 210% over the general average for this season (154.3 mm). As for the Tartos station, it showed an absolute water deficit in the spring during the years of the study, (see Figure 7).



Safita



Tartos



Lattakia

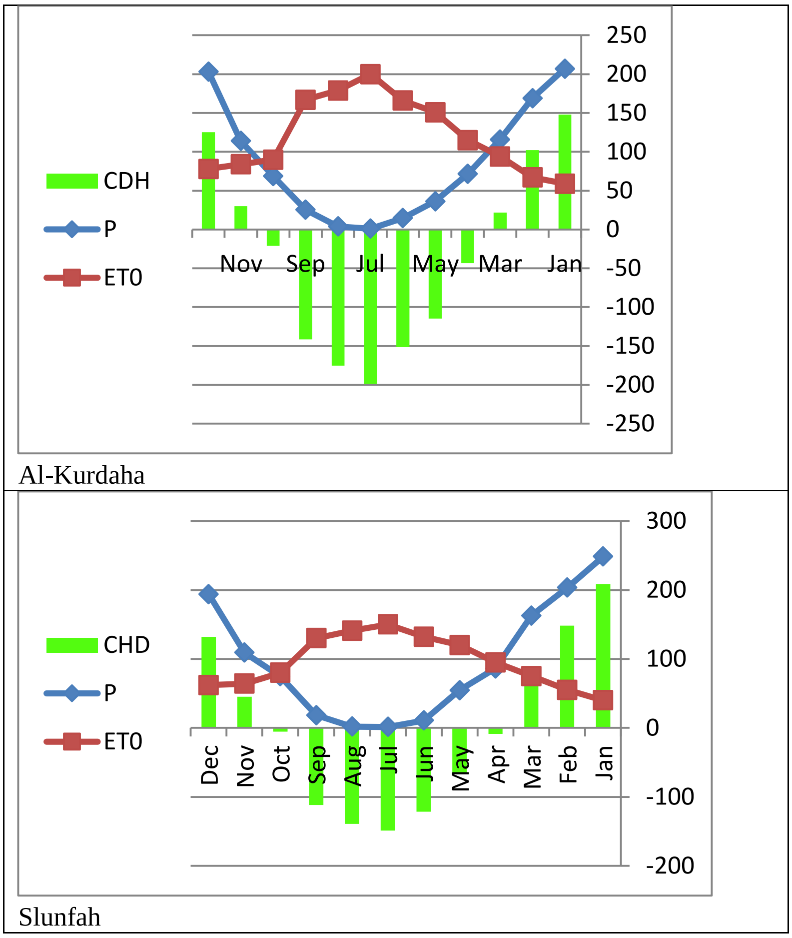


Figure 7: Referential Evapotranspiration and seasonal Climatic Water Deficit (mm) at the studied stations during the period (1980-to 2020).

The fall did not differ much from the spring season in terms of water abundance as the water deficit dominated the entire region in general. This season did not witness a water surplus except during a few years, as the Safita station recorded a surplus of rain (524.7 mm) during this season. This was in 1986, achieving an increase of 218% compared to the general average for this season of 240.6 mm, followed by the Tartos station (CHD=131.9) and then the Latakia station (CHD=91.9) in the years 1979-to 1980.

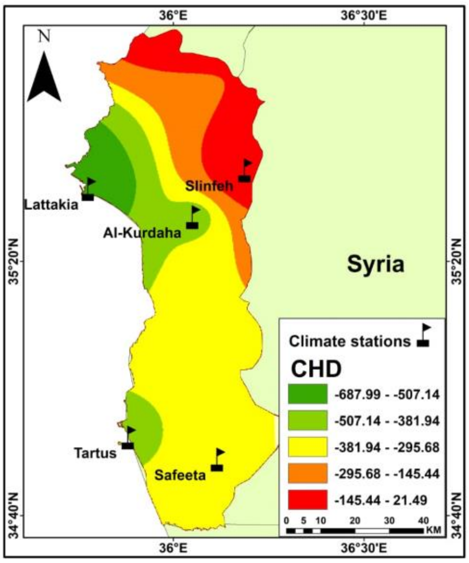


Figure8: Climatic Water Deficit (CHD) /mm at the studied stations during the period (1980-to 2020)

In winter, the region did not witness a water deficit during the study period in the five stations. As for the annual water deficit, it is clear that there is a water deficit in the Latakia, Al-Kurdaha, Tartos and Safita stations respectively in terms of percentage. Slunfah did not witness a water deficit during the studied period, see Figure 8,9.

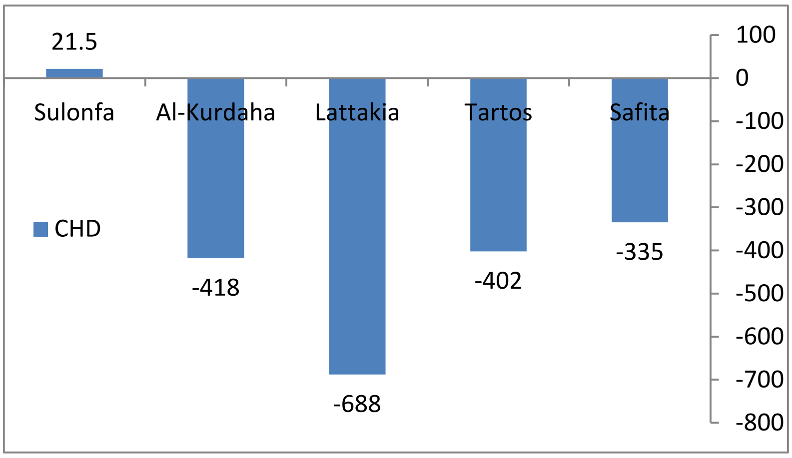


Figure 9: Referential Evapotranspiration and annual Climatic Water Deficit /mm at the studied stations during the period (1980-to 2020).

3. Frequency of drought in the Syrian Coast Region during the period (1980-to 2020):

To evaluate the temporal distribution of rainfall and estimate the probability of the occurrence of dry and wet periods in the study sites. The technique for decile estimation depends on dividing the distribution of monthly record precipitation into 10 parts (Gibbs and Maher 1967). method was applied, where the rainfall data for 40 years were arranged in ascending order and then divided into five rows as shown in Table 10, which shows the non-exceeding frequency annual rainfall amounts/mm, where lower rainfall values below the median indicate dry periods and those above it indicate humid periods, see Figure 10.

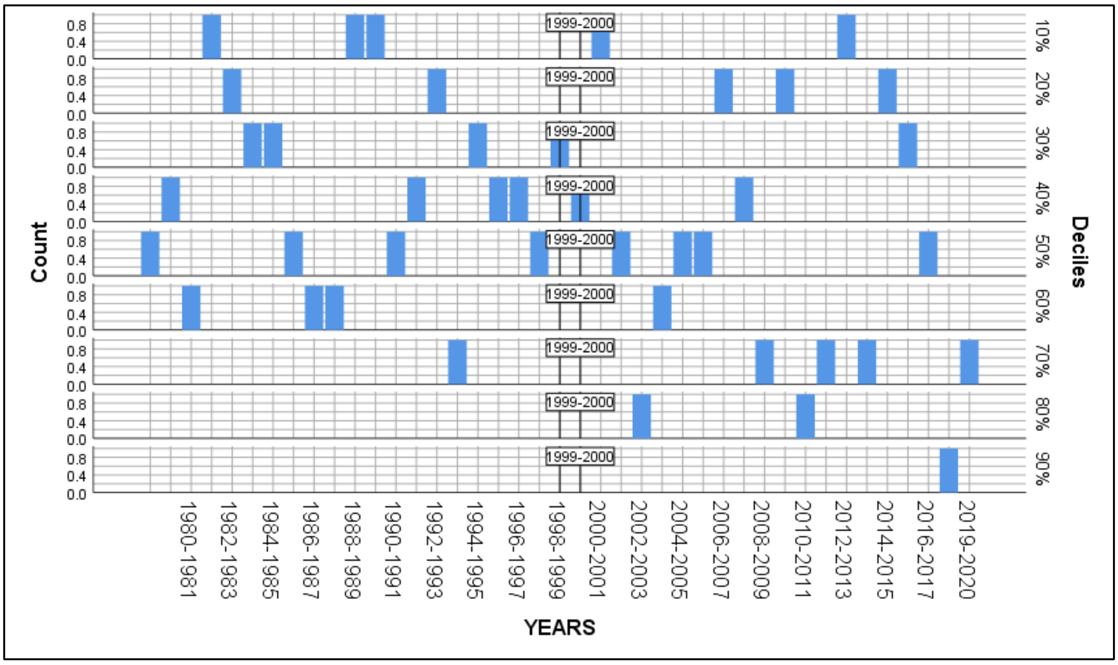


Figure 10: Identification of drought and non-drought years using deciles

Table 10. Classification of years of drought and water surplus in the study stations based on the deciles during the period (1980-to 2020).

Deciles	Al-Kurdaha	Slunfah	Safita	Tartos	Latakia
1	7	7	12	7	5
2	5	5	2	3	5
3	4	5	3	2	6
4	5	4	2	4	2
5	4	4	5	6	4
6	7	3	2	4	5
7	3	4	5	2	2
8	2	3	8	3	2
9	3	3	1	4	5
10	1	3	1	6	5

To assess the drought year deciles drought index is estimated for the years1980–2020, Figure 10 shows the drought and non-drought years for the study area using deciles.

From Figure 10, it is observed that years 1981-1982, 1982-1983, 1988-1989, 1989-1990, 1992-1993, 2000-2001, 2006-2007, 2009-2010, 2012-2013, 2014-2015are much below normal that is 20% lower and years1979-1980, 1983-1984, 1984-1985, 1991-1992, 1994-1995, 1995-1996, 1996-1997, 1998-1999, 1999-2000, 2007-2008, 2015-2016, fall in below normal that is 20% following and years 1980-1981, 1985-1986, 1986-1987, 1987-1988, 1987-1988, 1990-1991, 1997-1998, 2001-2002, 2001-2002, 2003-2004, 2004-2005, 2005-2006, 2016-2017comes under near normal i.e. 20% medium and years 1993-1994, 2002-2003, 2008-2009, 2010-2011, 2011-2012, 2013-2014, 2019-2020 and 2017-2018fall in above normal that is 20%

Following and year 2018 fall under much above normal category that is 20% more high.

The agricultural drought years recorded in the deciles during the period (1980-2010) in the study area as a whole accounted for 48.8% of the total number of years. It has been revealed that there is a variation between stations in the Syrian coastal areas in terms of drought years and extreme precipitation based on deciles, due to differences in site nature, orientation, and natural factors. However, data analysis has shown that the number of years below the average and significantly below the average ranged from 16 to 21 years out of the study period, see Table 10.

The irregular frequency of wet and dry years in the five stations was revealed by counting the number of dry years - which turned out to be similar in the five locations - as 6 years recorded much less than the average and were dry and 9 were less than the average. Thus, the number of years in which precipitation was reported to be less than the average during the studied period was 15 years, (see Figure 11).

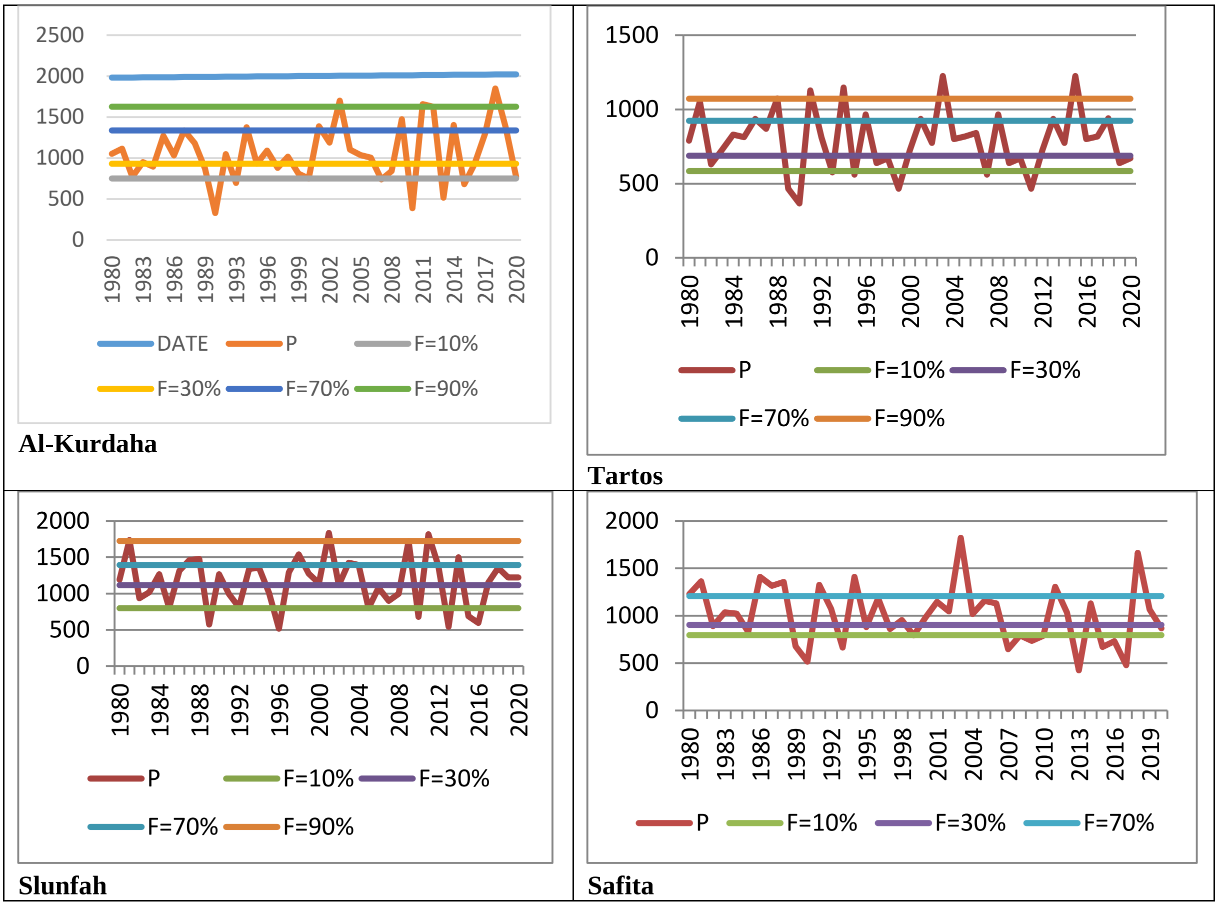


Figure 11: Rainfall amounts at different non-exceeding probability levels/mm.

Conclusion*:*

In conclusion, the study presented an analytical investigation into the impacts of climate change on the dynamics of the water balance in the region. The general trend of rainfall in the Syrian coast was analyzed, along with the study of agricultural drought years and periods of water surplus based on decadal categories. Additionally, the study evaluated the climatic water balance during the period (1980-2020), shedding light on the variations and challenges faced due to natural factors and site characteristics. The results emphasize the importance of understanding and monitoring the effects of climate change on water resources to develop effective water management strategies in the Syrian coastal region. Further research and continuous monitoring are necessary to adapt to changing climatic conditions and ensure sustainable water resource management in the future.

Results:

In light of the methodology used to study the impact of climate change on the Climatic Water Balance in the Syrian Coast Region (Syria) during the period extending between (1980-2020), the study resulted in the following results:

- The analysis utilized the Mann–Kendall (MK) test to assess trends in rainfall and elucidate temporal variations in rainfall patterns over a continuous 40-year period at stations (Latakia, Slunfah, Al-Kurdaha, Tartos, Safita) spanning the years 1980-2020.
- Examination of the quarterly variations in precipitation trends across all study stations from 1980 to 2020 revealed general patterns in rainfall amounts.
- The slope of the overall trend in annual rainfall at Latakia and Tartous stations did not exhibit a significant value. The results of the Mann–Kendall test over the study period indicated no significant annual changes in rainfall at these stations

- There was a significant increase in the rates of possible evapotranspiration (ET0) in the Syrian Coastal Region during the period (1980-to 2020). The values of (ET0) showed a noticeable increase in the summer, reaching its peak in July and then gradually decreasing as it reached its minimum value in the winter, specifically in January. The latter was considered the least value in terms of water loss in the studied area.
- The Climatic Water Deficit equation from 1980 to 2020 for the five stations indicate a general negative water balance, with occasional positive balances in certain years, The analysis of Referential Evapotranspiration and Climatic Water Deficit data across the five stations during the study period revealed that changes in water deficit were proportional to changes in Referential Evapotranspiration. the region experienced a clear water deficit during the spring and fall seasons, except in years with abundant seasonal rainfall
- The Syrian coastal areas experienced varying levels of drought severity and precipitation patterns during the period from 1980 to 2020. The decile analysis revealed that certain years were significantly below normal precipitation levels, with 10 years experiencing a 20% lower than normal precipitation. On the other hand,11 years fell slightly below normal precipitation levels by 20%. Additionally, 11 years were classified as near normal, while 7 others were above normal or much above normal (2017-2018) in terms of precipitation.
- Agricultural drought years accounted for approximately 48.8% of the total years between 1980 and 2010 in the study area. Variations in drought occurrences and extreme precipitation were observed among different stations in the Syrian coastal areas, attributed to differences in site characteristics and natural factors. The analysis indicated that a significant number of years experienced below-average and significantly below-average precipitation levels, ranging from 16 to 21 years throughout the study period.

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