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تحليل تطبيقي لمؤشرات التغير المناخي في مناطق الهضاب العليا الشرقية بالجزائر للفترة 1981 – 2020

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الملخّص

يهدف هذا البحث إلى تحليل تطبيقي لمؤشرات التغير المناخي في مناطق الهضاب الشرقية بالجزائر من خلال تحليل الاتجاهات العامة لدرجة الحرارة (الصغرى والعظمى)، وكميات الأمطار للفترة 1981-2020 في محطتي قسنطينة وسطيف اعتمادا على تحليل المعدلات الشهرية والفصلية والسنوية لدرجة الحرارة وكميات الأمطار باستخدام تحليل الانحدار الخطي Simple Linear Regression، واختبار تي (T-Test)، والفروقات المجمعة Cumulated Sums، وأظهرت النتائج وجود قيمًا موجبة للتغير(b) تَدل على زيادة المعدل السنوي لدرجة الحرارة العظمى في محطتي الدراسة عند مستوى دلالة إحصائية تراوحت بين 0.022 في محطة قسنطينة وأقل من 0.001 في محطة سطيف مع ظهور اتجاهات للزيادة للمعدل الفصلي لدرجة الحرارة العظمى في جميع الفصول، كما شهدت درجة الحرارة السنوية الصغرى اتجاها نحو تناقص معدلاتها لصالح الفترة من الثانية، وكان اتجاه نحو التناقص في أشهر الخريف والربيع والصيف دون دلالة إحصائية بفروق عن متوسط الفترة الأولى بلغت 0.105مْ و0.085مْ و0.175مْ على التوالي، في حين اظهر فصل الشتاء اتجاها للزيادة دون دلالة إحصائية وكان الفرق لصالح الفترة الثانية من الدراسة 2001 – 2020 بنحو 0.15مْ في محطة قسنطينة، وكانت الفروق نحو التناقص في المعدلات الفصلية لدرجة الحرارة الصغرى عند مستوى دلالة إحصائية أقل عن 0.05 في فصلي الخريف والشتاء في محطة سطيف وكانت الفروق نحو 0.77مْ في أظهرا فصلي الربيع والصيف اتجاها للتناقص دون دلالة إحصائية، وأخيرا أشارت نتائج تحليل الانحدار الخطي البسيط وجود قيمًا موجبة للتغير (b) تَدل على زيادة المعدل السنوي لكميات الأمطار في محطة قسنطينة بمناطق الهضاب الشرقية بالجزائر دون دلالة إحصائية، في حين شهدت محطة سطيف قيم سالبة للتغير (b) تدل على تناقص المعدل السنوي لكميات الأمطار خلال فترة الدراسة دون دلالة إحصائية، مع تباين اتجاهاتها الفصلية.

الكلمات المفتاحية:

تحليل الاتجاه، الانحدار الخطي البسيط، درجة الحرارة، الفروقات التراكمية، محطتي قسنطينة وسطيف، الجزائر.

An Applied Analysis of Climate Change Indicators in the Eastern High Plateau Regions of Algeria for the Period 1981-2020

Abstract

The research aims to conduct an applied analysis of climate change indicators in the Eastern Highlands regions of Algeria. This is achieved through the examination of general trends in minimum and maximum temperatures, as well as rainfall quantities for the period 1981-2020 at two stations, Constantine and Setif. The analysis involves studying monthly, seasonal, and annual temperature and rainfall patterns using Simple Linear Regression analysis, T-Test, and Cumulated Sums. The results reveal positive values for the change (b), indicating an increase in the annual average of maximum temperatures at both study stations, with statistical significance ranging between 0.022 in Constantine and less than 0.001 in Setif. Increasing trends are observed in the seasonal average of maximum temperatures across all seasons. In contrast, the annual minimum temperature shows a decreasing trend, particularly in the second period. Statistical significance is observed in the differences for fall, spring, and summer, while winter shows an increasing trend without statistical significance. The results show that a decrease in the seasonal average of minimum temperatures in fall and winter at Setif with statistical significance below 0.05. In spring and summer, the differences indicate a decreasing trend without statistical significance, with a decrease of 0.77°C in the spring and summer averages. Finally, the linear regression analysis indicates positive values for the change (b) in annual rainfall amounts at Constantine, suggesting an increase without statistical significance. In Setif, negative values for the change (b) suggest a decrease in annual rainfall during the study period without statistical significance, displaying varying seasonal trends.

Keywords

Trend Analysis, Simple Linear Regression, Temperature, Cumulated Sums, Constantine Station, Setif Station.

1. Introduction

Climate change, marked by rising temperatures and its far-reaching consequences, stands as a pressing global concern (David T. P et al. 2013). The collapse and melting of ice in Antarctica, Greenland, and Polar Regions emphasize the profound shifts occurring, documented through satellite imagery and studies. Notable examples include the erosion of ice masses on Mount Kilimanjaro, which has diminished by over half since the 1970s (Chakraborty, Set al. 2008).The destructive consequences of climate change have intensified over the past two decades, evidenced by unprecedented climatic events like volcanoes, floods, heavy rainfall, and hurricanes wreaking havoc on Earth (Raimi, M.et al.2021). The alarming collateral damage extends to thousands of plant and animal species, disrupting the delicate balance of the Earth's life cycle and biodiversity (Balasuriya, A. 2018). Studies issue a foreboding warning of a looming threat to plant species, with up to 80% facing potential extinction by 2080 if climate change persists (Gillen, G. H. 2023).The marine environment is profoundly affected, with tsunamis causing widespread destruction, and, and rising sea levels and temperature changes significantly impacting atmospheric and oceanic conditions (Khan, A. A.et al. 2024). Coral reefs, crucial for marine ecosystems, are particularly vulnerable, with 20% to 40% of global coral reefs under imminent threat due to climate change (Hoegh-G. O et al. 2017).One of the most evident and dangerous repercussions of climate change is the Earth's warming, with certain regions becoming uninhabitable due to increased temperatures in the coming decades (Gowdy, J. 2020). This warming is reflected in air pollution, erratic crop yields leading to food crises, demographic shifts, and recurrent health crises due to nature-induced displacements (Al-Jawaldeh, A. et al.2022). The Middle East and North Africa are experiencing a disproportionate rise in temperatures, with recent climate conferences, like the one held in Sharm El Sheikh, highlighting dire predictions of temperatures exceeding 40 degrees Celsius in some areas. (Audu, A. A.2020). Algeria, among the Mediterranean countries, faces significant climate change challenges, impacting agriculture and habitable areas, as studies underscore the vulnerability of ecosystems, economic sectors, and communities in regions experiencing extreme climatic events, such as droughts, floods, and storms (Mohammed, T., Al-Amin, A. Q.2018).The applied analysis of climate change indicators in the high plateau regions of Eastern Algeria is a crucial undertaking in light of the pressing environmental challenges these areas face (Warner, K. et al 2010). These high plateaus, characterized by their unique biodiversity and rich natural heritage, have become silent witnesses to rapid and often devastating climate transformations (Benmehaia, A. M.et al 2020). The region of the high plateaus in Eastern Algeria is subject to significant climate variations, with potential consequences for water resource availability, soil fertility, and the stability of local ecosystems (Benmahammed, A.et al 2010). Studying climate change indicators in this area provides valuable insights into regional climate dynamics, aiding the development of adaptation and mitigation strategies (Hakim, Bet al 2021). Indicators such as temperature variations, changes in precipitation, and meteorological patterns are essential tools for assessing climate impacts on local ecosystems and human communities (Rouabhi, A. 2017). This applied analysis will generate robust scientific data necessary for crafting public policies and action plans to mitigate the adverse effects of climate change (Bachir, H.et al 2016). Implementing such an analysis requires an interdisciplinary approach, bringing together experts in climatology, ecology, hydrology, and social sciences (Hani, M et al 2021). This collaboration will foster a holistic understanding of the complex interactions between climate, environment, and human activities in the high plateaus of Eastern Algeria (Hssaisoune, M et al 2020). Assessing climate change indicators is particularly important for local communities heavily reliant on the region's natural resources (Gourari, B et al 2023). Farmers, herders, and those dependent on natural resources will be directly affected by climate changes, necessitating strategic planning to ensure food security and sustainable livelihoods (Hacini, N et al 2022). The highlands of Eastern Algeria also face challenges related to desertification, soil degradation, and biodiversity loss, issues exacerbated by climate change (Merniz, N et al 2019). Analyzing climate indicators will provide crucial information for developing conservation and restoration measures to preserve the unique biological diversity of the region (Benmarce, K et al 2021). The growing awareness of environmental issues and the consequences of climate change underscores the significance of this analysis in the context of the high plateaus of Eastern Algeria (Slimani, N et al 2023). The research findings could also contribute to raising awareness among policymakers, civil society, and the general public about the urgency of concerted action against climate change (Maurer, G. 1992). In this regard, the use of advanced technologies such as remote sensing, regional climate models, and geographic information systems will be essential for gathering accurate data and establishing long-term climate trends (Drouiche, N et al 2012). Firstly, the focus is on uncovering trends in the annual and seasonal variations of minimum and maximum temperatures in the Eastern Highlands regions of Algeria from 1981 to 2020. Secondly, statistical analysis is employed to scrutinize time series data of seasonal and annual rainfall quantities in these regions, with an emphasis on understanding general trends during the same time frame (Elouissi, A et al 2016). The research problem revolves around several key questions. Firstly, is there a tangible trend of increase or decrease in the annual and seasonal temperatures (minimum, maximum, and dry) in the Eastern Highlands regions of Algeria from 1981 to 2020? Secondly, are there statistically significant differences in the changes of annual and seasonal rainfall averages in these regions during the same period? Finally, can climate change indicators be identified in the Eastern Highlands regions of Algeria from 1981 to 2020 using monthly averages of maximum and minimum temperatures and rainfall quantities?

2 Study Area and Climate Stations

The study area encompasses the provinces of Setif and Constantineis situated within the Republic of Algeria, The Eastern High Plateaus, with an average elevation of 800 meters, stretch between the Saharan and Tell Atlas mountains, extending eastward from the Aures Mountains. The region is characterized by its diverse topography and climate (see Figure 1). The analysis in this study relies on data from two weather stations in Algeria: Setif and Constantine both located in the Eastern Highlands region (Table 1). Constantine province is astronomically positioned between latitudes 36.5° and 36.38° North and longitudes 6.18° and 7.4° East. Similarly, Setif province is positioned between latitudes 35.38° and 36.36° North and longitudes 4.44° and 6.2° East (Fig. 1).

The chosen weather stations, CONSTANTINE and SETIF/AIN ARNAT in Algeria, offer a strategic vantage point for the climate study due to their unique geographical locations. CONSTANTINE, situated at latitude of 36.17N and longitude of 06.37E, stands at an altitude of 692 meters above sea level. On the other hand, SETIF/AIN ARNAT, positioned at 36.10N and 05.19E, is elevated at a higher altitude of 1015 meters above sea level (Tab.1). The diversity in altitude and geographical positioning of these stations within the Eastern Highlands of Algeria contributes to the richness of the climate data they provide. Such comprehensive data from these stations will be instrumental in unraveling the trends and patterns of temperature and rainfall in the region over the studied period.

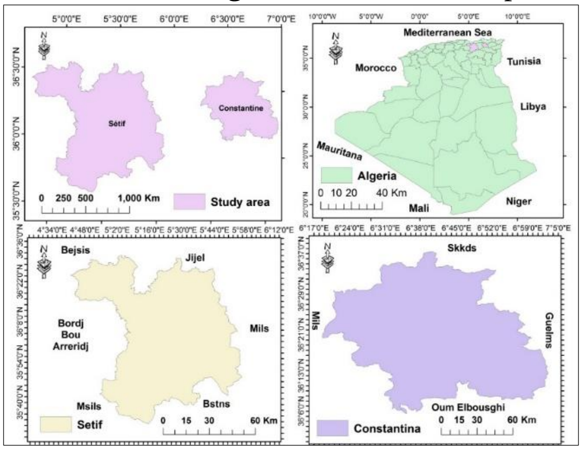


Fig.1. Geographic Location of the Study Area and Climate Stations. Source: By researchers using GIS

Station	Location	Altitude (masl)	Climate type
Constantine (Algeria)	36 17N, 06 37E	692	Semi-arid
Setif/Ain Arnat (Algeria)	36 10N, 05 19E	1015	Semi-arid

Source: Researchers depending on the **Constantine** and **Setif** meteorological stations, data, unpublished, 2023

Tab. 1. Geographical Significance of Constantine and Setif/Ain Arat Weather Stations

3. Dataset and methods

The researchers followed a quantitative methodology to analyze climate data and extract seasonal and annual averages at the SETIF and CONSTANTINE weather stations in Algeria. They utilized Microsoft Excel for data processing and statistical analysis and employed advanced statistical methods using the SPSS software package. The key climate data used in the study encompassed monthly, seasonal, and annual averages for maximum and minimum temperatures, as well as monthly, seasonal, and annual total rainfall for the period 1981-2020 in the Eastern Highlands of Algeria. The quantitative analysis aimed to unravel climate trends, variations, and patterns during the specified timeframe in the studied regions. To achieve the study's objectives, the researchers employed various statistical methods, including:

1. **Cumulated Sums (Cumulative Differences):** Cumulated Sums relies on plotting a curve

representing the cumulative sum of differences in values or seasonal and annual rates for minimum and maximum temperatures and rainfall. This is in relation to the seasonal or annual arithmetic mean in the SETIF and CONSTANTINE weather stations in the Eastern Highlands of Algeria. This method was used to study the changes that occur in the overall system of some climatic elements (Slim, 2016, p.29).

2. **Simple Linear Regression:** Simple Linear Regression analysis was employed to determine whether the general trend of seasonal temperature rates in the Eastern Highlands of Algeria for the period 1981-2020 has statistical significance. This is based on the assumption that annual and seasonal temperatures (minimum and maximum) and annual and seasonal rainfall are dependent variables, and years are independent variables at a significance level of 0.05, according to the following equation: Y = a + bx + e (Shehadeh, 2011, p.429). Here:
    - (Y) Represents the seasonal and annual rates for temperature and estimated rainfall.
    - (a) Represents the point of intersection of the regression line with the horizontal axis.
    - (b) Signifies the degree of change in the general trend.
    - (x) Represents the years or time.
    - (e) Denotes the change not attributed to the presence of a general trend.
3. **T-test:** The researchers divided the study period into two consecutive periods: the first period extending from 1981 to 2000 and the second period from 2001 to 2020. This was done to determine the average for each time period, increase or decrease in seasonal and annual temperatures (minimum and maximum), and rainfall amounts. The averages were then compared between the two periods to assess whether the differences in the calculated averages for temperature and rainfall had statistical significance at a 0.05 significance level using the T-test equation:

$$T(x1\text{-}x2) = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

Where:

(s)= Standard deviation

(N)=Number of data points

($\bar{X}$)=Average temperature and Average rainfall (Perkins, S. E et al 2007)

The research employed the statistical analysis software SPSS (Version 26) to analyze climatic data, utilizing simple linear regression to determine the correlation between seasonal and annual temperatures (minimum and maximum), as well as seasonal and annual rainfall. Additionally, the T-test analysis was utilized to assess the significance of differences between the arithmetic means of seasonal and annual temperatures and rainfall between the two study periods. The study also made use of Microsoft Excel to calculate the seasonal and annual averages for temperature and rainfall, as well as to compute cumulative differences from the seasonal and annual arithmetic means for temperature and rainfall.

4. Results

4.1. Characteristics of Monthly, Seasonal, and Annual Temperatures and Rainfall in study area Period 1981-2020:

Through the analysis of monthly, seasonal, and annual temperature and rainfall data, spatial and temporal variations in the Eastern Highlands of Algeria are evident, as outlined below:

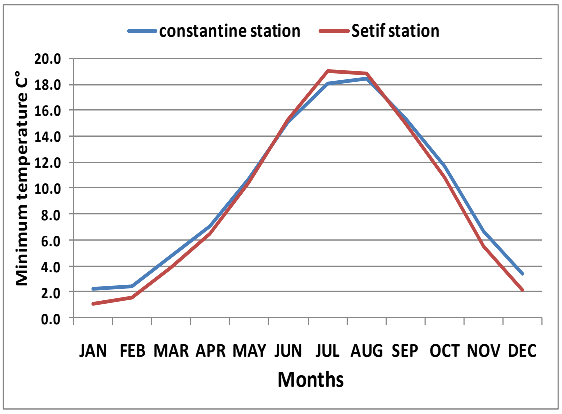
4.1.1 Characteristics of Minimum Temperatures: The annual average for minimum temperatures in the study area was approximately 8.6°C, ranging from 7.9°C in Constantine to around 9.2°C in Setif/Ain Arnat (Table 2). Minimum temperature represents the lowest recorded temperature in a day, usually occurring just before sunrise. In January, the coldest month, temperatures drop below freezing, reaching around -3.5°C in Setif/Ain Arnat in 2005 and about -2.6°C in Constantine. The monthly average minimum temperature was 1.1°C and 2.2°C in the study stations, respectively, for the period 1981-2020.

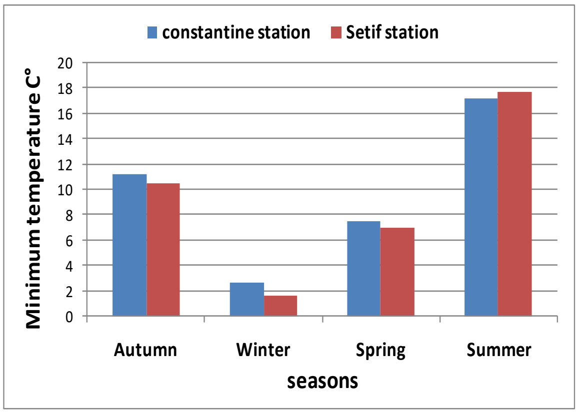
stations	Climate variable	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
Constantine	Minimum (T)	2.2	2.4	4.8	7.1	10.7	15.1	18.1	18.4	15.4	11.7	6.6	3.4	7.9
	Maximum (T)	12.2	13.5	16.7	19.8	25.2	31.0	34.7	34.4	29.2	24.3	17.5	13.2	22.6
	Rainfall	63.9	49.5	55.6	47.6	40.5	15.4	5.5	17.2	34.7	37.0	38.7	62.3	468
Setif	Minimum (T)	1.1	1.6	3.9	6.5	10.5	15.2	19.0	18.8	15.0	10.8	5.6	2.2	9.2
	Maximum (T)	9.9	11.3	14.4	17.9	23.3	29.7	33.9	33.2	27.2	21.8	15.0	10.6	20.7
	Rainfall	41.2	35.3	39.1	42.0	41.0	20.5	12.9	13.4	37.1	32.3	38.1	44.2	397.1

Source: Researchers depending on the **Constantine** and **Setif** meteorological stations, **temperature**, Rainfall data, unpublished, 2023

Table 2: Monthly Averages for Temperature (°C) in the Eastern Highlands of Algeria for the Period 1981-2020

The monthly average for minimum temperatures exhibits significant variation both temporally and spatially between the study stations. During the winter months, the lowest monthly average temperatures were recorded, ranging between 2.2°C in January and 3.4°C in December at the Constantine station. In Setif, due to the region's nature, movement of air masses, limited sunlight hours, and the impact of elevation, the lowest temperatures ranged between 1.1°C and 2.2°C. On the other hand, the summer months recorded the highest monthly average minimum temperatures in the eastern highlands, ranging between 15.1°C and 19°C at the study stations. This is attributed to clear skies and increased sunlight hours. The transitional seasons of autumn and spring, as depicted in Figure 2, show noticeable variation in minimum temperatures between months.





Source: Researchers depending on Table 2, 3

Figure 2: Monthly and Seasonal Averages for Minimum Temperatures (°C) at Constantine and Setif Stations in the Eastern Highlands of Algeria for the Period 1981 – 2010

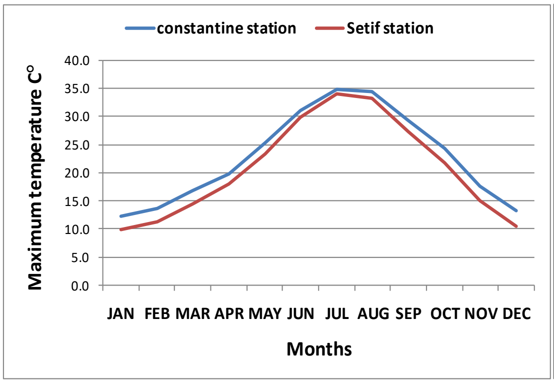
The seasonal averages for minimum temperatures in the study area exhibited both temporal and spatial variations. The winter season recorded the lowest seasonal averages for minimum temperatures, with values of approximately 2.7°C and 1.7°C at the study stations. The spring season followed with a seasonal average of 7.5°C, while the autumn season ranked third with a seasonal average of 11.2°C. Lastly, the summer season registered a seasonal average of around 17.2°C at Constantine. In contrast, Setif recorded seasonal averages of approximately 7°C, 10.5°C, and 17.7°C for spring, autumn, and summer, respectively, for the period 1981-2020 (Table 3, Figure 2).

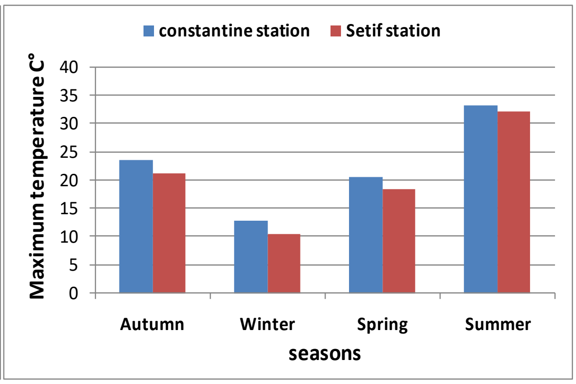
Stations	Climate variable	Autumn	Winter	Spring	Summer	Average
Constantine	Minimum temperature	11.2	2.7	7.5	17.2	9.7
	Maximum temperature	23.7	13	20.6	33.4	22.6
	Rainfall	110.4	175.8	143.7	38.1	468
Setif	Minimum temperature	10.5	1.7	7	17.7	9.2
	Maximum temperature	21.3	10.6	18.5	32.3	20.7
	Rainfall	107.5	120.7	122.1	46.8	397.1

Source: Researchers depending on the **Constantine** and **Setif** meteorological stations, **temperature**, Rainfall data, unpublished, 2023

Table 3: Seasonal and Annual Averages for Minimum Temperatures and Rainfall in the Eastern Highlands of Algeria for the Period 1981 – 2020

1.2 Monthly Characteristics of Maximum Temperature: The maximum temperature represents the highest daytime temperature recorded. The annual average of maximum temperatures in the eastern highlands of Algeria was around 21.7°C, reaching 22.6°C in Constantine and 20.7°C in Setif (Table 3). July recorded the peak of maximum temperatures, with monthly averages reaching about 34.7°C in Constantine and 33.9°C in Setif. Monthly temperature variations in the study area were influenced by factors such as sunlight hours, sky clarity, elevation, and others. August ranked second in terms of elevated maximum temperature averages, ranging from 34.4°C in Constantine to 33.2°C in Setif. A gradual decrease in temperature was observed towards the autumn and spring months (Figure 3). Maximum temperatures ranged between 17.5°C in November and 29.2°C in September in Constantine, and between approximately 15°C in November and 27.2°C in September in Setif. Moreover, the temperatures ranged from 14.4°C in March to around 23.3°C in May in Setif for the period 1981-2020 (Figure 3, Table 3). Seasonal averages for maximum temperatures varied between seasons in the eastern highlands of Algeria, with summer recording the highest averages of around 33.4°C in Constantine and 32.3°C in Setif. Autumn ranked second in the seasonal average of maximum temperatures, reaching around 23.7°C and 21.3°C, respectively (Figure 3, Table 3). Winter recorded the lowest seasonal averages for maximum temperatures, ranging from 13°C in Constantine to 10.6°C in Setif.



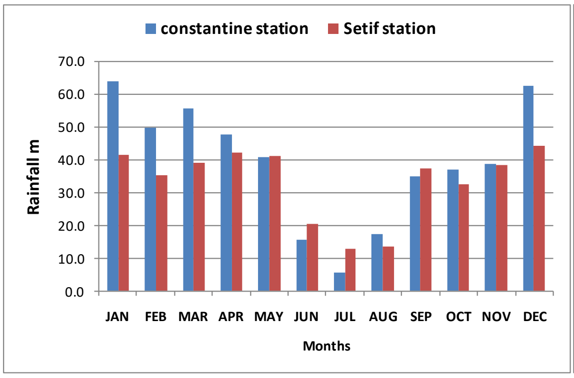


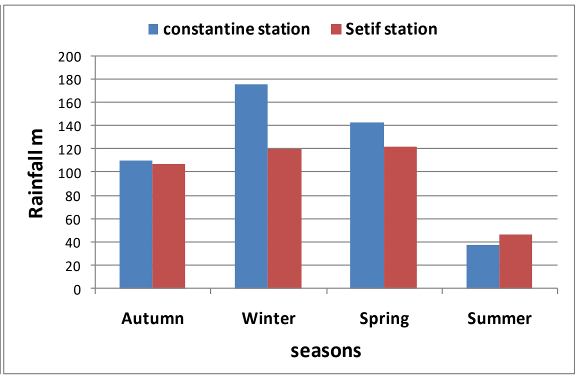
Source: Researchers depending on Table 2, 3

Figure 3: Monthly and Seasonal Averages of Maximum Temperature (°C) in the Eastern Highlands of Algeria for the Period 1981-2020

1.3 Monthly and Seasonal Characteristics of Rainfall Averages: Rainfall amounts vary monthly in the eastern highlands of Algeria between the two study stations due to differences in elevation above sea level, the passage of Mediterranean and surrounding air masses. Rainfall typically begins in September with varying amounts between the years, reaching an average of about 34.7 mm and rising to 37 mm in October and 38.7 mm in November in Constantine, while in Setif, it reaches around 37.1 mm, 32.3 mm, and

38.1 mm, respectively. Rainfall amounts increase during the winter months, peaking in January with a monthly average of 63.9 mm in Constantine, while December represents the peak rainfall in Setif with an average of about 44.2 mm (Table 3). Clear temporal fluctuations are evident during the study period. Subsequently, rainfall gradually decreases from March onwards until the summer months, which recorded amounts of 15.4 mm in June and 5.5 mm in July, and 17.2 mm in Constantine, and around 20.5 mm, 12.9 mm, and 13.4 mm, respectively, in Setif (Figure 4). Seasonal averages show clear temporal and spatial variations between the study stations. Winter in Constantine recorded the highest rainfall with a seasonal average of 175.8 mm, followed by spring with a seasonal average of 143.7 mm. Autumn came in third with a seasonal average of 110.4 mm, and finally, summer with an average of 38.1 mm, and an annual average of 468 mm. In Setif, spring represented the peak of rainfall with a seasonal average of 122.1 mm, followed by winter with a seasonal average of 120.7 mm. Autumn recorded the third position with approximately 107.5 mm, and finally, summer with an average of 46.8 mm for the period 1981-2020 (Figure 4 and Table 3), with an annual average of 397.1 mm.





Source: Researchers depending on Table 2, 3

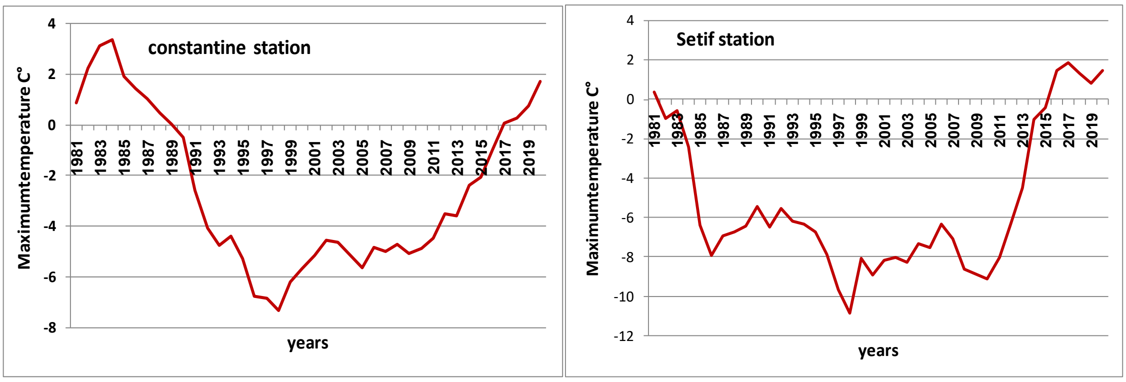
Figure 4: Monthly and Seasonal Averages of Rainfall (mm) in the Eastern Highlands Regions of Algeria for the Period 1980-2020.

2. Trends in Annual and Seasonal Temperature Averages in the Eastern Highlands Regions of Algeria for the Period 1981-2020

The results of statistical methods revealed diverse trends, including both increases and decreases, in the seasonal averages of minimum and maximum temperatures. These trends varied among the seasons at the study stations, and they are detailed as follows:

2.1 Trends in Annual and Seasonal Averages of Maximum Temperature:

2.1.1 **Cumulated Sums**: Cumulative sums curves demonstrated a clear upward trend in the annual and seasonal averages of maximum temperature at the study stations. The increase varied towards the end of the last decade of the previous century, continuing in a gradual rise until 2010. Subsequently, there was a noticeable increase by the end of 2020 (see Figure 5). This indicates a warming trend in the study area, especially at Constantine station. Periods of decreasing maximum temperature appeared at Setif station between 2006-2009, which then shifted towards a clear increasing trend by the end of the study period in 2010.

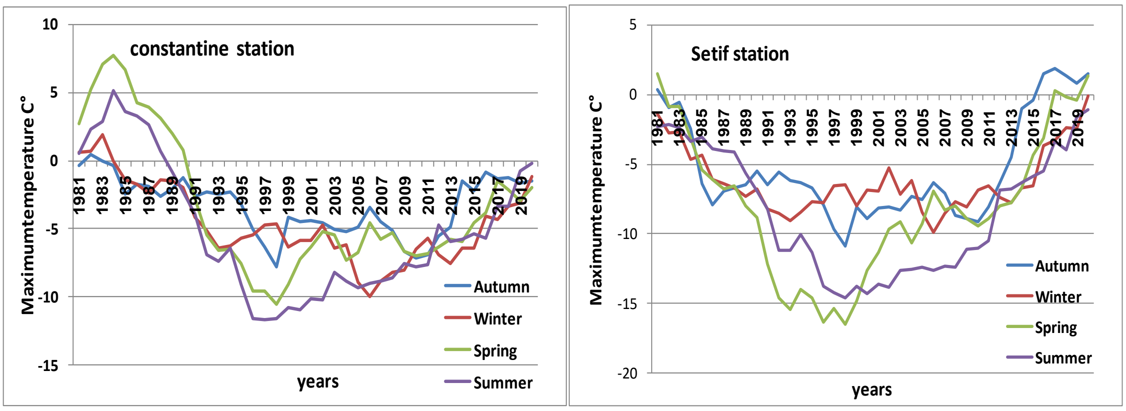


Source: Researchers depending on Cumulated Sums

Figure 5: Cumulative Differences for Annual Maximum Temperature (°C) in the Eastern Highlands Regions of Algeria for the Period 1981-2020.

Source: Researchers depending on Cumulated Sums

The cumulative differences curves showed clear trends of increase in the seasonal averages for maximum temperature at the study stations. The trend towards an increase has been observed since the end of the 1990s and continued consistently until 2020 in all seasons except for winter. Winter exhibited an increasing trend in maximum temperature since 2006, which continued to rise until the end of the study period in Constantine and Setif in the eastern highlands regions of Algeria (Figure 6).



Source: Researchers depending on Cumulated Sums

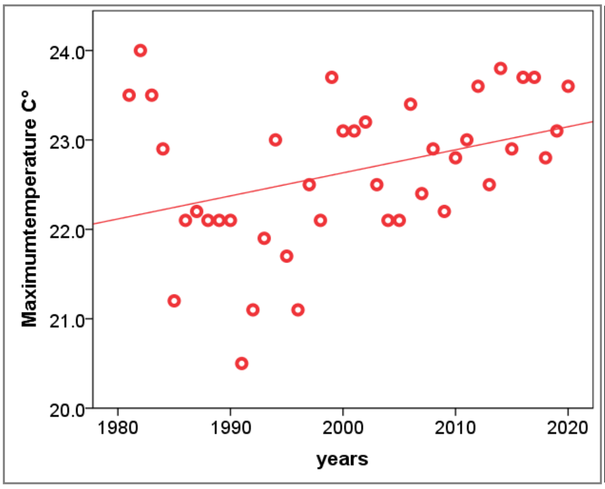
Figure 6: Cumulative Differences for Seasonal Maximum Temperature (°C) in the Eastern Highlands Regions of Algeria for the Period 1981-2020

2-1-2 **Simple Linear Regression**: The results of simple linear regression analysis (Table 4) and (Figure 7) revealed positive values for the coefficient of variation (b), indicating an increase in the annual average for maximum temperature in the study stations in the eastern highlands regions of Algeria. The statistical significance level ranged from 0.022 in Constantine station to less than 0.001 in Setif station. The explained variance ratio in the study stations was approximately 0.130 and 0.491, respectively.

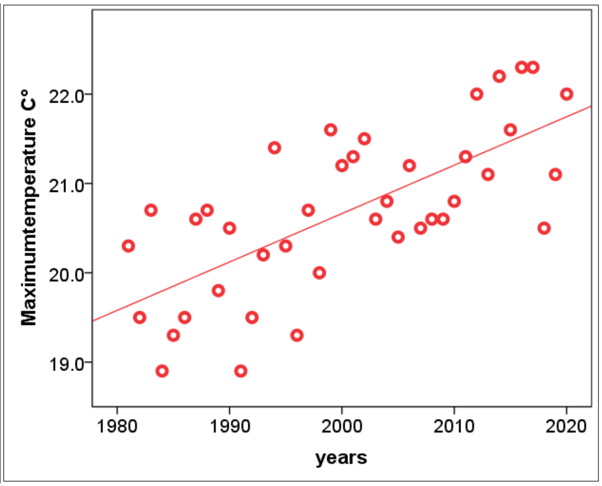
Stations	(b)	T	Sig	R2
Constantine	.026	2.380	.022	.130
Setif	.054	6.050	0.001	.491

Source: Researchers depending on SPSS

Table 4: Linear Regression for the Annual Average of Maximum Temperature (°C) in the Eastern Highlands Regions of Algeria for the Period 1981-2020.



Stations Constantine



Stations Setif

Source: Researchers depending on SPSS

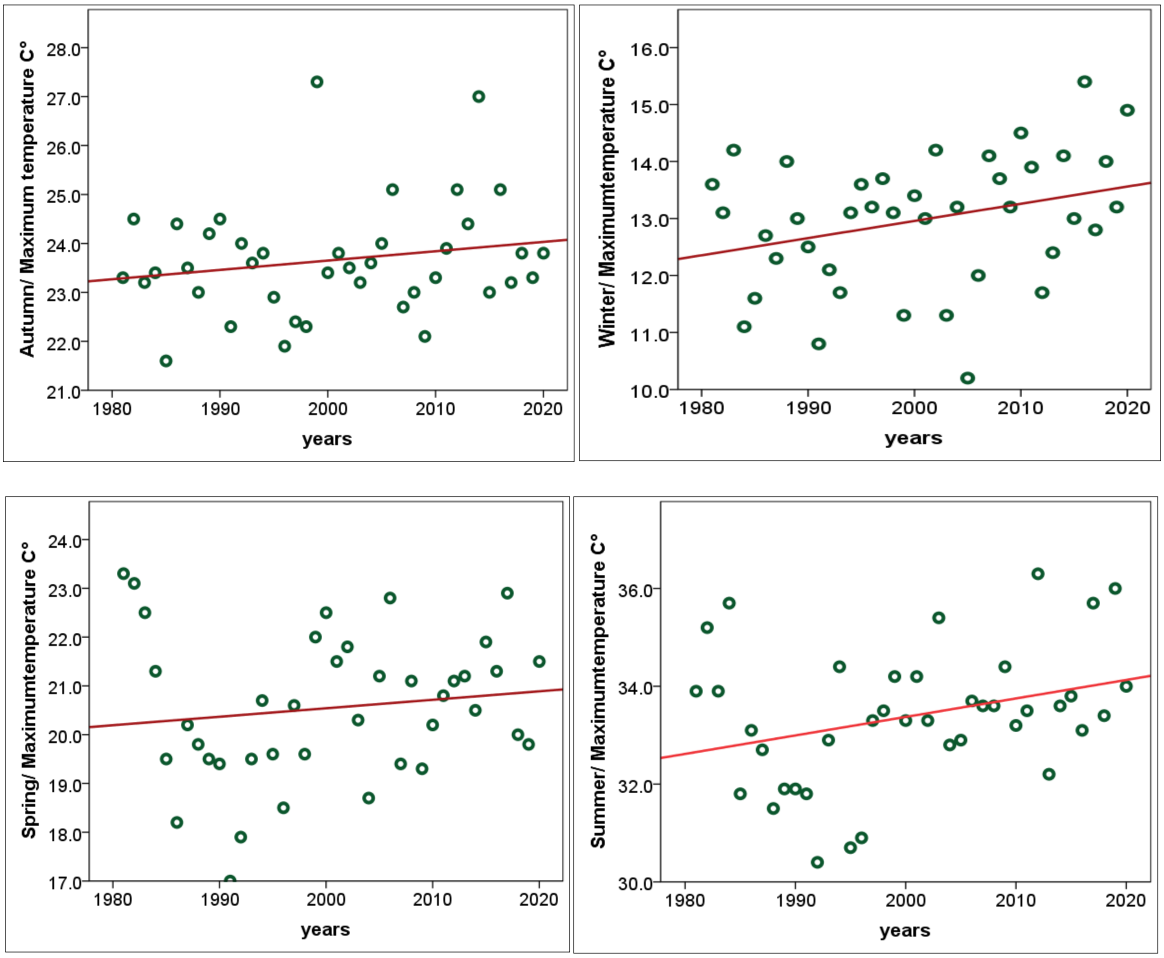
Figure 7: Linear Regression for the Annual Average of Maximum Temperature (°C) in the Eastern Highlands Regions of Algeria for the Period 1981-2020

The results of the regression analysis for the seasonal averages of maximum temperature at the study stations varied, with positive change values (Table 5 and Figure 8). The change values (b) ranged from 0.017 to 0.065, indicating trends of increase in the seasonal average of maximum temperature in the eastern highlands regions of Algeria for the period 1981-2020 in all seasons. The statistical significance levels ranged from less than 0.001 to 0.400. Two significant increasing trends were observed in the seasonal average of maximum temperature at Constantine station, the first being statistically significant at the 0.05 level in summer, while the second trend showed an increase without statistical significance. In the case of Setif station, the increasing trends in the seasonal average of maximum temperature were statistically significant, ranging from less than 0.001 in summer to 0.014 in autumn. The change values (b) ranged from 0.046 to 0.065. The explained variance ratios (R-squared) ranged from 0.019 in spring at Constantine station to 0.311 in summer at Setif station (Table 5 and Figure 9).

Stations	seasons	(b)	T	Sig	R^2
Constantine	Autumn	.019	1.203	.236	.037
	Winter	.030	1.971	.056	.093
	Spring	.017	.851	.400	.019
	Summer	.038	2.053	.047	.100
Setif	Autumn	.045	2.572	.014	.148
	Winter	.046	3.130	.003	.205
	Spring	.065	3.393	.002	.232
	Summer	.059	4.146	.001	.311

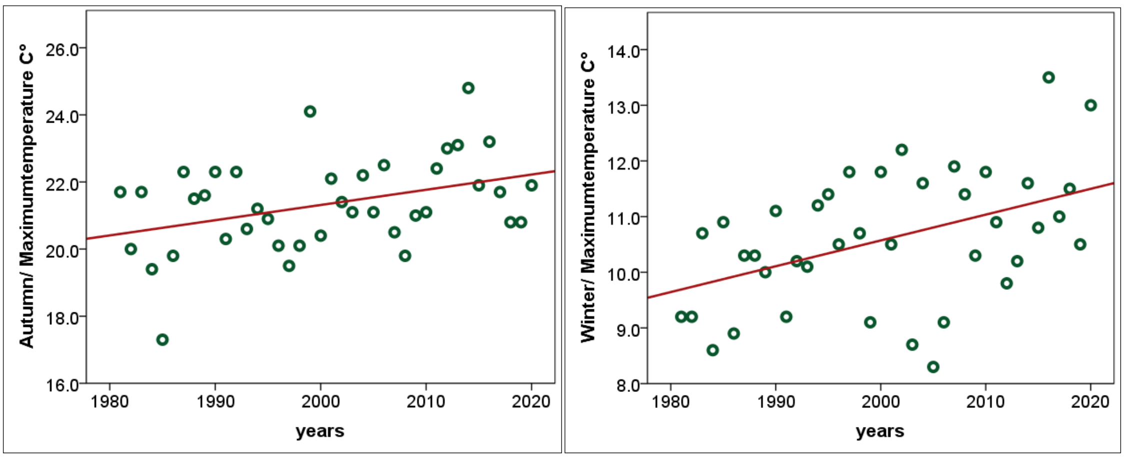
Source: Researchers depending on SPSS

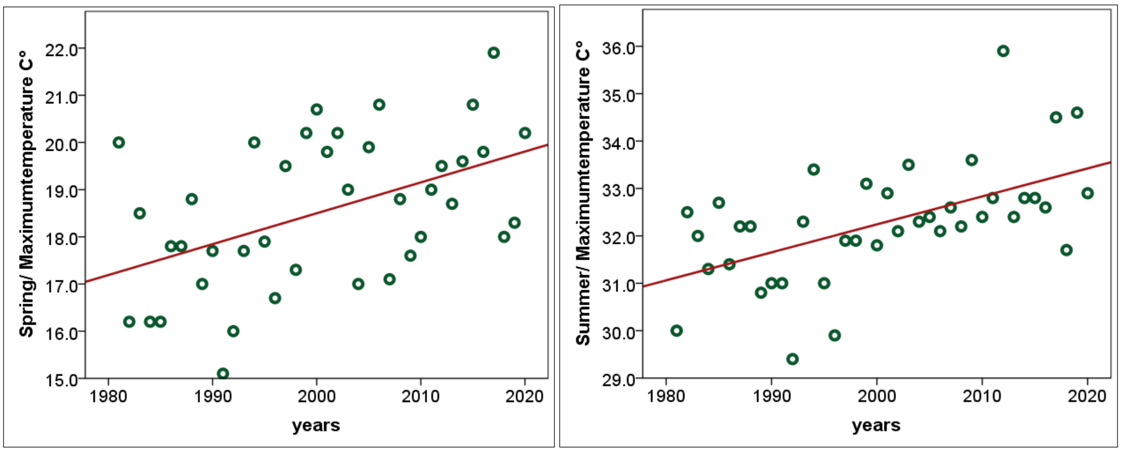
Table 5: Linear Regression for Seasonal Average Maximum Temperature (°C) in the Eastern Highlands Regions of Algeria for the Period 1981-2020



Source: Researchers depending on SPSS

Figure 8: General Trend for the Seasonal Average Maximum Temperature at Constantine Station for the Period 1981-2020





Source: Researchers depending on SPSS

Figure 9: General Trend for the Seasonal Average Maximum Temperature at Setif Station for the Period 1981-2020

2-1-3 **T-Test**: The study conducted a significant difference analysis for the annual average maximum temperature in the eastern highlands regions of Algeria between two study periods (1981-2000) and (2001-2020). The results indicated significant differences in the average annual maximum temperature between the two study periods in favor of the second period in the study area. Setif Station recorded a difference from the average of 1.09°C, and the differences were statistically significant at a level less than 0.001 (Table 6). Meanwhile, the difference from the first period at Constantine Station was about 0.65°C at a significance level less than 0.05 in favor of the second period of the study from 2001-2020. The results demonstrate a clear warming trend in the average annual maximum temperature in the study area.

Stations	Study group	Mean	T	df	sig	Average difference
Constantine	1	22.320	2.638	38	.012	0.65
	2	22.970	2.638	30.386	.013	
Setif	1	20.145	4.749	38	.000	1.09
	2	21.235	4.749	36.510	.000	

Source: Researchers depending on SPSS

Table 6: Differences between the Means of Annual Maximum Temperatures for the Study Periods (1981-2000) and (2001-2020)

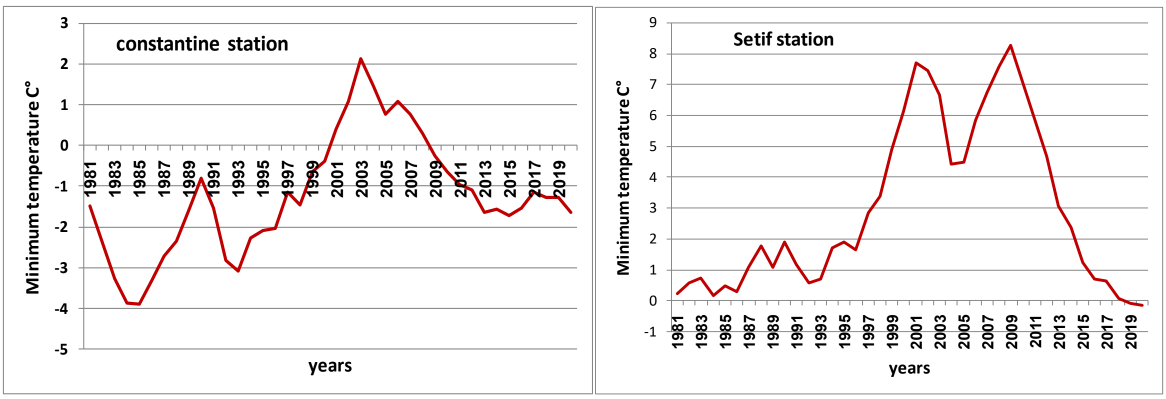
The results of the analysis of the differences in the mean values of the seasonal maximum temperatures in the eastern highlands of Algeria between the study periods (1981-2000) and (2001-2020) showed variations in the average seasonal maximum temperature between the two study periods in favor of the second period in the study area. This variation was evident across the seasons (Table 7), with an increasing trend in the fall, winter, and spring without statistical significance, with differences from the mean of the first period reaching 0.37°C, 0.54°C, and 0.63°C, respectively, and statistical significance greater than 0.05. In contrast, the summer season showed a statistically significant increasing trend at a significance level of 0.012, with differences in favor of the second period of the study (2001-2020) by approximately 1.1°C in Constantine. The differences were statistically significant at a level less than 0.05 in all seasons in Setif, except for the winter season, which showed a non-significant increasing trend. The differences ranged from 0.67°C to 1.4°C (Table 7), highlighting a consistent thermal trend of increase in both the annual and seasonal average of the maximum temperature in the study area.

Stations	seasons	Study group	Mean	T	Df	Sig	Average difference
Constantine	Autumn	1	23.475	1.005	38	.321	0. 37
		2	23.845	1.005	37.370	.321	
	Winter	1	12.705	1.485	38	.146	0.54
		2	13.240	1.485	35.944	.146	
	Spring	1	20.235	1.356	38	.183	0.63
		2	20.865	1.356	31.977	.185	
	Summer	1	32.850	2.632	38	.012	1.1
		2	33.935	2.632	35.274	.012	
Setif	Autumn	1	20.855	2.340	38	.025	0.97
		2	21.820	2.340	36.228	.025	
	Winter	1	10.260	1.822	38	.076	0.67
		2	10.930	1.822	34.804	.077	
	Spring	1	17.865	2.903	38	.006	1.3
		2	19.200	2.903	36.440	.006	
	Summer	1	31.590	4.155	38	.000	1.4
		2	32.955	4.155	37.951	.000	

Source: Researchers depending on SPSS

Table 7: Differences between the Means of Annual Minimum Temperatures for the Study Periods (1981-2000) and (2001-2020)

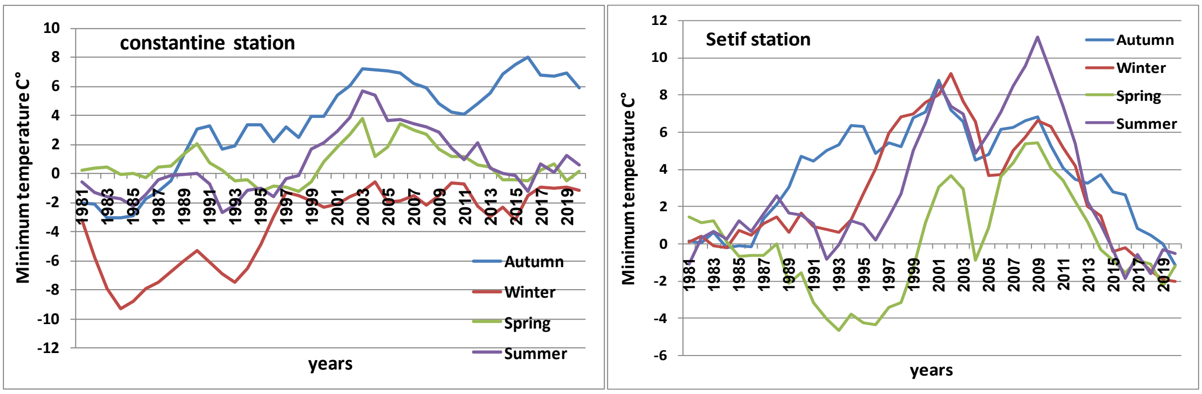
2.2. Trends in Annual and Seasonal Changes in Minimum Temperature: 2.2.1. Cumulated Sums: The cumulative sum curves indicated a decreasing trend in annual and seasonal minimum temperature rates at the study stations, especially during the last decade. The decrease began in 2002 and continued until 2020 (Figure 10), with intermittent periods of increase observed between 1993-2002 at Constantine station. Meanwhile, Setif station exhibited a clear decreasing trend during the last decade of the study period (2010-2020) after showing an increasing trend in minimum temperature for the period 1981-2010 (Figure 10).



Source: Researchers depending on Cumulated Sums

Figure 10: Cumulative Differences for Annual Minimum Temperature in the Eastern Highlands of Algeria for the Period 1981-2020

The cumulative seasonal differences for the minimum temperature in the study stations showed varying trends across seasons. Starting from 2005 to 2020, there was a decreasing trend in both spring and summer seasons at the Constantine station, with a notable increase in autumn. Meanwhile, the winter season maintained its overall trend with some fluctuations observed at the Constantine station (Figure 11). Clear decreasing trends were observed in the Setif station from 2010 to 2020, following a period of seasonal increases in all seasons from 1981 to 2002 (Figure 11).



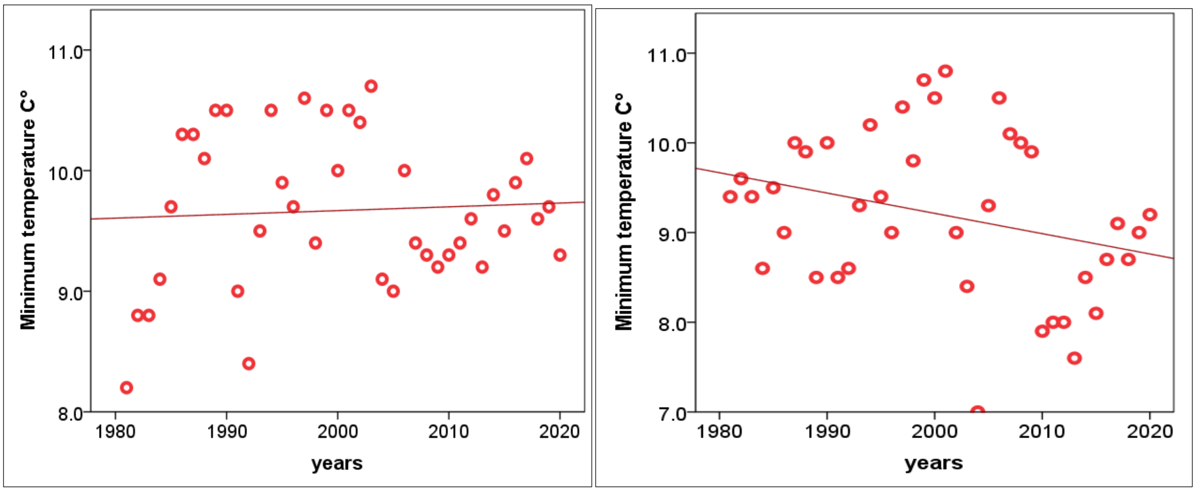
Source: Researchers depending on Cumulated Sums

Figure 11: Cumulative Seasonal Differences for Minimum Temperature in the Eastern Highlands Regions of Algeria for the Period 1981-2020

2-2-2- Simple Linear Regression: The results of the simple linear regression analysis (Table 8) and (Figure 12) revealed negative values for the coefficient of change (b), indicating a decrease in the annual average minimum temperature in the study stations in the eastern highlands regions of Algeria. These changes were statistically non-significant, with variation values ranging from 0.003 in Constantine station to 0.023 in Setif station. The explained variance ratio in the study stations was approximately 0.003 in Constantine and 0.086 in Setif.

Stations	(b)	T	Sig	R^2
Constantine	-.003	0.195	.721	.003
Setif	-.023	2.275	.066	.086

Table 8: Linear Regression for the Annual Average Minimum Temperature in the Eastern Highlands Regions of Algeria for the Period 1981-2020.



Source: Researchers depending on SPSS

Figure 12: Linear Regression for the Annual Average Minimum Temperature in the Eastern Highlands Regions of Algeria for the Period 1981-2020

The results of the regression analysis for the seasonal averages of the minimum temperature in the study stations indicated negative values for the change coefficient (b) (Table 9 and Figure 13), suggesting a decrease in the seasonal average of minimum temperature. These values ranged between -0.002 in summer and -0.005 in spring, with no statistical significance in the Constantine station. There was also an indication of an increasing trend in the seasonal average of minimum temperature in winter, although statistically non-significant, in the eastern highlands regions of Algeria for the period 1981–2020. On the other hand, the decreasing trends in the seasonal average of minimum temperature in Setif station were statistically significant at a significance level less than 0.05 in both autumn and winter, with change coefficient values (b) ranging between -0.026 and -0.033. The explained variance ratio values in all seasons in the study stations ranged from 0.001 in summer at Constantine station to 0.135 in autumn at Setif station (Figure 14). The consistency of the decreasing trend in the seasons at the study stations is evidence of the reliability of this trend even without statistical significance.

Stations	**Seasons**	(b)	T	Sig	R^2
Constantine	Autumn	-.004	.334	.740	.003
	Winter	.021	1.387	.174	.084
	Spring	-.005	.425	.673	.005
	Summer	-.002	.162	.872	.001
Setif	Autumn	-.033	2.619	.013	.135
	Winter	-.026	2.176	.036	.111
	Spring	-.004	.210	.835	.001
	Summer	-.024	1.293	.204	.042

Source: Researchers depending on SPSS

Table 9: Linear Regression for the Seasonal Average Maximum Temperature in the Eastern Highlands Regions of Algeria for the Period 1981-2020.

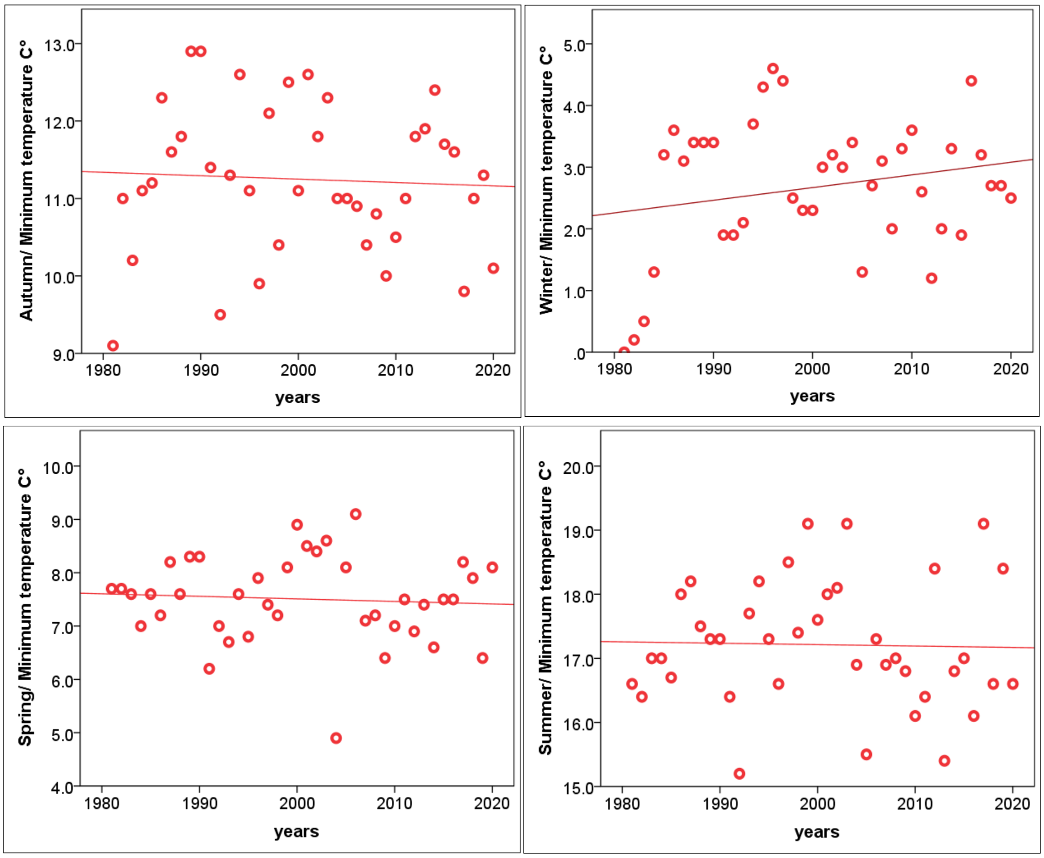


Figure 13: General Trend of Seasonal Average Minimum Temperature in Constantine Station for the Period 1981-2020

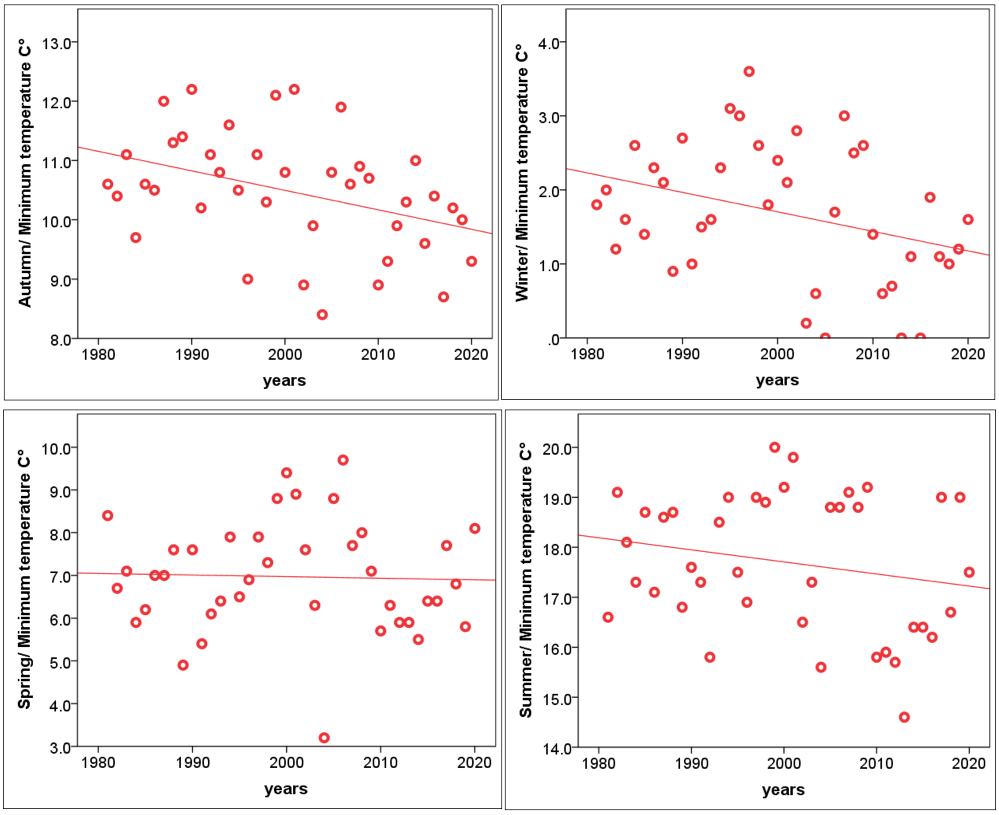


Figure 14: General Trend of Seasonal Average Minimum Temperature in Setif Station for the Period 1981-2020

2.2.3. The T-test: results indicated significant differences in the mean annual averages of minimum temperatures in the eastern highland regions of Algeria between the study periods (1981-2000) and (2001-2020). There were differences in the average minimum temperature favoring the second period in the study area. Station Setif recorded a difference from the average of 0.625 meters, and the differences were statistically significant at a level less than 0.05 (Table 10). Meanwhile, the difference from the first period in Constantine Station was around 0.04 meters without statistical significance. The decrease favored the second period of the study from 2001 to 2020, indicating a trend of decreasing annual average minimum temperature in the study area.

Stations	Study group	Mean	T	Df	Sig	Average difference
Constantine	1	9.690	0.199	38	.843	0.04
	2	9.650	0.199	32.282	.844	
Setif	1	9.515	2.308	38	.027	0.625
	2	8.890	2.308	33.281	.027	

Source: Researchers depending on SPSS

Table 10: Differences Between the Averages of Minimum Annual Temperatures for the Study Periods (1981-2000) and (2001-2020)

When analysing the results of the t-test for the significance of differences in the mean values of seasonal minimum temperatures between the study periods (1981-2000) and (2001-2020), differences were observed in the average seasonal minimum temperature between the study periods in favor of the second period in the study area, varying across seasons (Table 11). The trend was towards a decrease in the months of autumn, spring, and summer without statistical significance, with differences from the average of the first period reaching 0.105m, 0.085m, and 0.175m, respectively, and the statistical significance was greater than 0.05. Meanwhile, the winter season showed a trend towards an increase without statistical significance, and the difference favored the second study period (2001-2020) by about 0.15m in Constantine station.

Stations	seasons	Study group	Mean	T	Df	sig	Average difference
Constantine	Autumn	1	11.300	0.346	38	.731	0.105
		2	11.195	0.346	35.048	.731	
	Winter	1	2.605	0.429	38	.670	0.15
		2	2.755	0.429	30.347	.671	
	Spring	1	7.550	0.327	38	.745	0.085
		2	7.465	0.327	33.013	.745	
	Summer	1	17.300	2.308	38	.576	0.175
		2	17.125	2.308	36.546	.576	
Setif	Autumn	1	10.865	2.666	38	.011	0.77
		2	10.095	2.666	35.891	.011	
	Winter	1	2.075	2.667	38	.007	0.77
		2	1.305	2.667	35.514	.007	
	Spring	1	7.050	0.386	38	.701	0.16
		2	6.890	0.386	35.373	.701	
	Summer	1	18.035	1.595	38	.119	0.68
		2	17.355	1.595	33.997	.120	

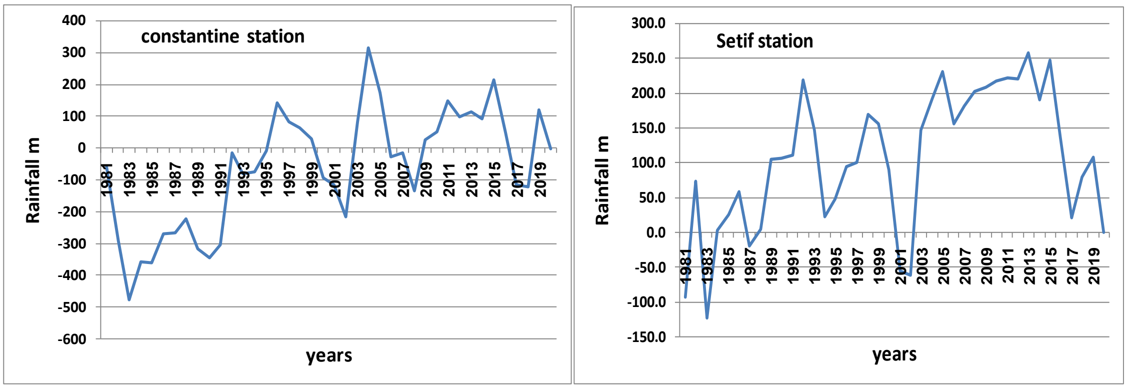
Source: Researchers depending on SPSS

Table 11: Differences Between Averages of Annual Minimum Temperature for the Study Periods (1981 - 2000) and (2001 - 2020)

The differences indicated a decrease in the seasonal minimum temperature values at a statistical significance level less than 0.05 in the autumn and winter seasons in Setif station. The differences were around 0.77m, showing a decreasing trend without statistical significance in the spring and summer seasons, with differences ranging from 0.16 to 0.68m (Table 11). The results reveal a thermal trend towards a decrease in the annual and seasonal averages of minimum temperatures in the study area.

3.3 Changes in Annual and Seasonal Rainfall Patterns:

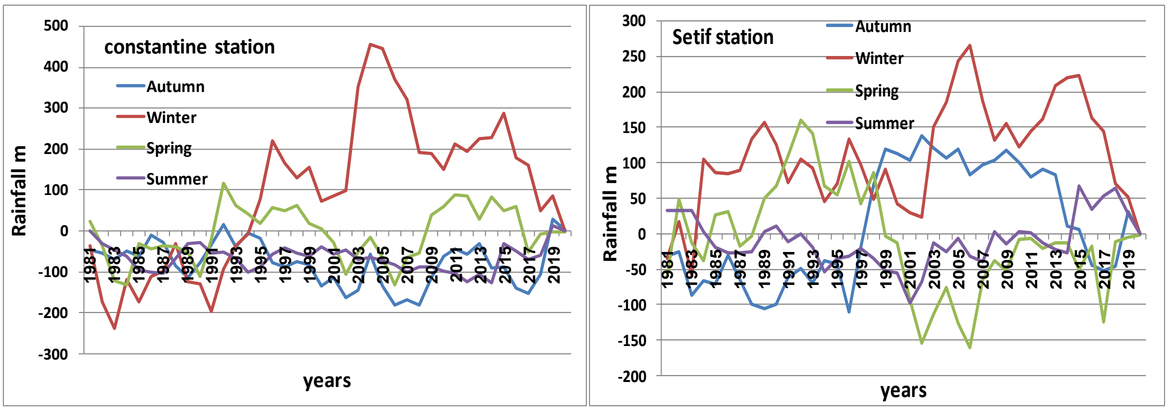
3.3.1 Cumulated Sums: Cumulative sum curves indicate varying trends of increase and decrease in annual rainfall quantities at the study stations, especially in the recent years of the study. The last five years witnessed a decrease in precipitation in the station of Setif (Figure 15), with intermittent periods of increase and decrease. Meanwhile, the station of Constantine exhibited a clear upward trend throughout the study period, interspersed with periods of fluctuating decrease (Figure 15).



Source: Researchers depending on Cumulated Sums

Figure 15: Cumulative Differences for Annual Rainfall Quantities in the Eastern Highlands of Algeria for the Period 1981-2020

The cumulative differences curves for rainfall quantities at the study stations revealed diverse trends across seasons. The trends indicated a decrease starting from the year 2004 until 2020 in the winter season at Constantine station, with fluctuations in rainfall values around their average in the other seasons. Periods of both decrease and increase were observed in the spring curve at Constantine station (Figure 16). Clear and varied trends towards decrease were evident in Setif station during the period from 2002 to 2017 in the autumn season, and from 2005 to 2020 in the winter season. The spring season experienced a decrease starting from 1992 to 2006, while the summer season maintained its overall average and exhibited fluctuations around it (Figure 16).



Source: Researchers depending on Cumulated Sums

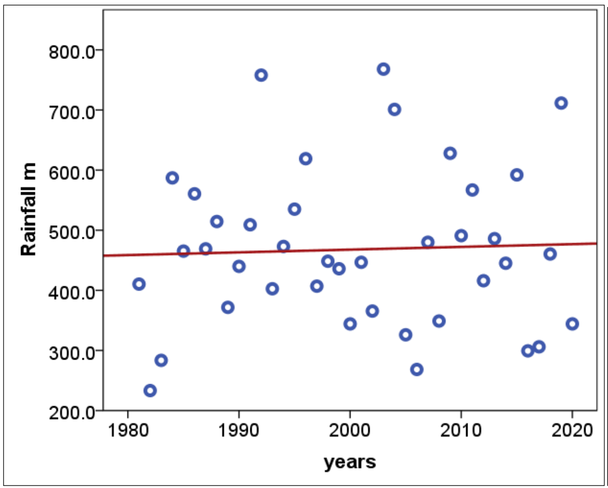
Figure 16: Cumulative Differences for Seasonal Rainfall Quantities in the Eastern Highlands of Algeria for the Period 1981-2020.

3-3-2 **Simple Linear Regression**: The results of the simple linear regression analysis (Table 12), and (Figure 17), revealed positive values for the coefficient (b), indicating an increase in the annual rainfall quantities in Constantine station in the eastern highland regions of Algeria without statistical significance, as it was greater than 0.05. Meanwhile, Setif station witnessed negative values for the coefficient (b), suggesting a decrease in the annual rainfall rates during the study period without statistical significance. The explained variance ratio in the study stations was approximately 0.002 in Constantine station and 0.012 in Setif station.

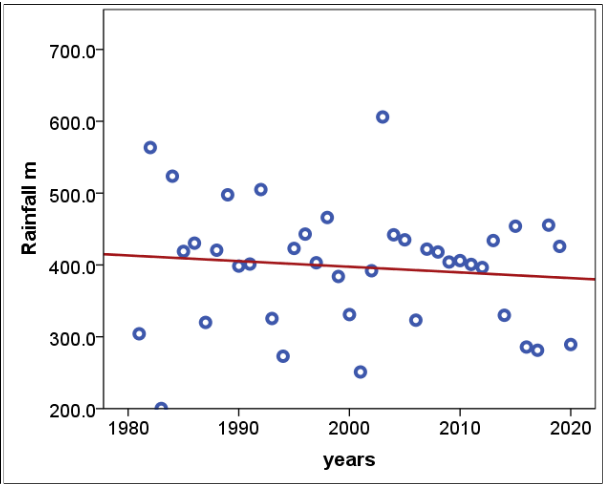
Stations	(b)	T	Sig	R^2
Constantine	.455	0.249	.805	.002
Setif	-.788	0.675	.504	.012

Source: Researchers depending on SPSS

Table 12: Linear Regression for the Annual Mean of Maximum Temperature in the Eastern Highland Regions of Algeria for the Period 1981-2020



Stations Constantine



Stations Setif

Source: Researchers depending on SPSS

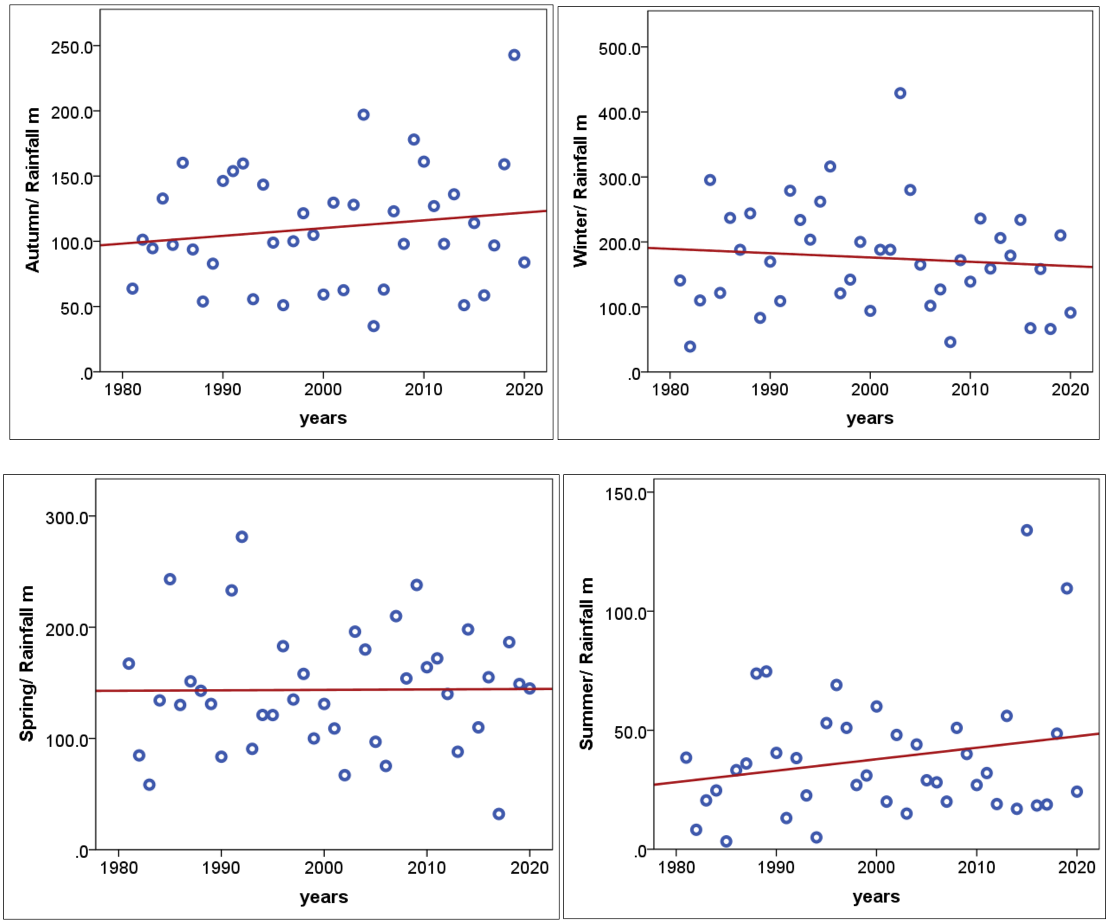
Figure 17: Linear Regression for the Annual Mean of Rainfall Quantities in the Eastern Highland Regions of Algeria for the Period 1981-2020

The results of the regression analysis for the seasonal rates of rainfall in the study stations revealed contrasting trends. The change coefficients (b) were positive for the autumn, spring, and summer months, as shown in Table 13 and Figure 18, indicating increasing trends in the seasonal rainfall rates at the Constantine station for the period 1981–2020 without statistical significance. In contrast, the winter season exhibited a trend towards a decrease, although statistically insignificant. For the seasonal rainfall variations at the Setif station, the trends were not statistically significant, with a significance level greater than 0.05. The trends pointed towards a decrease in the autumn and winter months, while the change coefficients (b) were positive in the spring and summer seasons, suggesting an increase in the seasonal rainfall rates without statistical significance at the Setif station (Figure 19).

Stations	seasons	(b)	T	Sig	R^2
Constantine	Autumn	.594	.957	.345	.037
	Winter	-.661	.588	.560	.009
	Spring	.039	.053	.958	.000
	Summer	.482	1.338	.189	.045
Setif	Autumn	-.084	.161	.873	.001
	Winter	-.828	1.160	.253	.034
	Spring	.049	.066	.948	.000
	Summer	.075	.197	.845	.001

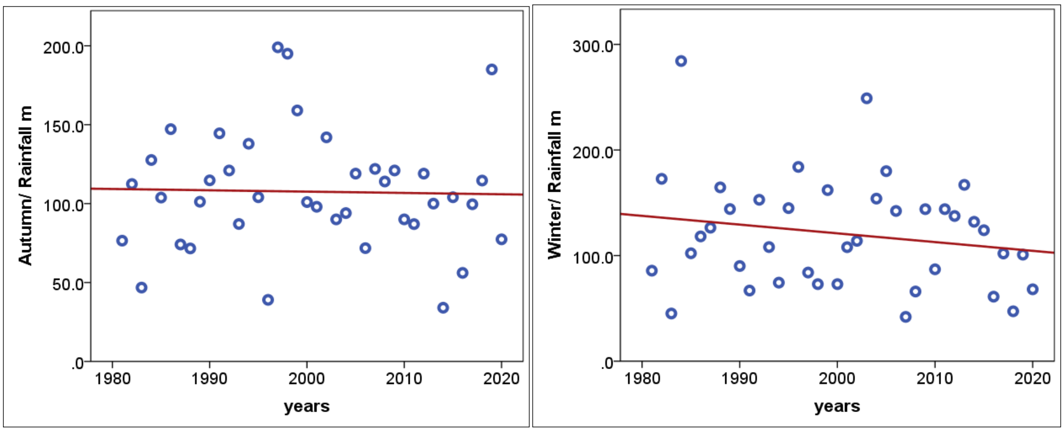
Source: Researchers depending on SPSS

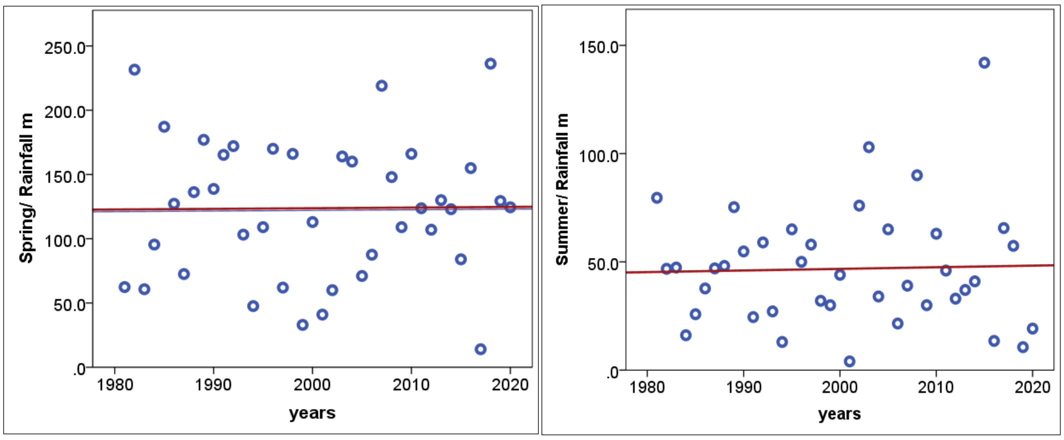
Table 13: Linear Regression for the Seasonal Mean of Rainfall Quantities in the Eastern Highland Regions of Algeria for the Period 1981-2020.



Source: Researchers depending on SPSS

Figure 18: General trend of quarterly rainfall amounts at Constantine station for the period 1981-2020





Source: Researchers depending on SPSS

Figure 19: General trend of quarterly rainfall amounts at Setif station for the period 1981-2020

3.3.3 T-Test:

A study and analysis demonstrated the statistical significance of differences in the annual mean temperatures in the Eastern Highlands regions of Algeria between two study periods (1981-2000) and (2001-2020). Differences were observed in the annual average rainfall between the two study periods, favoring the second period in the study area. The study stations recorded differences from the mean of 1.19 mm in Constantine, indicating an increasing trend. Meanwhile, the trend in annual averages showed a decrease, with a difference from the first period mean of 9 mm in Setif. However, the differences in the study area were not statistically significant (Table 14)

Stations	Study group	Mean	T	Df	Sig	Average difference
Constantine	1	463.36	.218	38	.829	9.19
	2	472.55	.218	36.260	.829	
Setif	1	401.59	.332	38	.742	9
	2	392.59	.332	37.630	.742	

Source: Researchers depending on SPSS

Table 14: Differences between means of annual temperatures for rainfall amounts for the study periods (1981-2000) and (2001-2020)

When analyzing the statistical significance of differences in the mean quarterly rainfall amounts in the Eastern Highlands regions of Algeria between the two study periods (1981-2000) and (2001-2020), variations in the mean quarterly rainfall amounts emerged favoring the second period in the study area, with differences observed across seasons (Table 15). The trend indicated an increase in rainfall amounts during the autumn and summer months without statistical significance, with differences from the mean of the first period being 13.4 mm and 3.82 mm, respectively. Meanwhile, the trend showed a decrease in rainfall amounts during the winter and spring seasons without statistical significance, with differences of 6.95 mm and 0.75 mm, respectively, in Constantine. Similarly, during the second study period, there were non-statistically significant differences indicating a decrease in rainfall amounts during the autumn and winter seasons in Setif, with differences of 11.24 mm and 4.33 mm, respectively (Table 15). Additionally, there were trends toward an increase in rainfall amounts favoring the second study period (2001-2020) during the spring and summer months, with differences of 1.1 mm and 5.48 mm, respectively, in the study area's Setif station.

Stations	seasons	Study group	Mean	T	Df	Sig	Average difference
Constantine	Autumn	1	103.71	.933	38	.357	13.4
		2	117.11	.933	33.744	.357	
	Winter	1	179.43	.279	38	.782	6.95
		2	172.16	.279	37.626	.782	
	Spring	1	144.05	.043	38	.966	0.75
		2	143.30	.043	37.905	.966	
	Summer	1	36.17	.449	38	.656	3.82
		2	39.99	.449	34.192	.656	
Setif	Autumn	1	113.17	.945	38	.351	11.24
		2	101.93	.945	34.967	.351	
	Winter	1	122.84	.259	38	.797	4.33
		2	118.51	.259	37.639	.797	
	Spring	1	121.52	.064	38	.949	1.1
		2	122.62	.064	37.999	.949	
	Summer	1	44.06	.630	38	.532	5.48
		2	49.54	.630	39.095	.534	

Source: Researchers depending on SPSS

Table 15: Differences between the means of annual rainfall amounts for the study periods (1981-2000) and (2001-2020)

Results and Recommendations:

The study of climate change is one of the internationally significant topics that require in-depth research to understand its scientific foundations, identify its causes in the Arab world, and assess its impact on various human activities, especially natural, agricultural, and water resources. The study also explores strategies, plans, and early warning systems to adapt to and live with the local and global effects of climate change. The study has yielded a set of the following results:

1. The results of simple linear regression analysis confirmed cumulative difference curves, indicating positive values for change (b). This suggests an increase in the annual maximum temperature in the study stations, with statistical significance ranging from 0.022 in Constantine station to less than 0.001 in Setif station.
2. Regression analysis results revealed increasing trends in the seasonal average maximum temperature in the eastern highlands of Algeria for the period 1981–2020 across all seasons. The significance levels ranged from less than 0.001 to 0.400. The first trend was statistically significant at the 0.05 level in summer, while the second trend towards an increase was not statistically significant in Constantine station. The latter trend was significant at various levels, ranging from less than 0.001 in summer to 0.014 in autumn, with change values (b) ranging from 0.065 to 0.46.
3. Cumulative difference curves for annual and seasonal minimum temperature in the study stations, especially during the last decade, showed a decreasing trend. The decline began in 2002 and continued until 2020, with periods of increase between 1993 and 2002 in Constantine station. Conversely, Setif station exhibited a clear decreasing trend in the last decade of the study period, from 2010 to 2020, after showing an increasing trend in minimum temperature for the period 1981–2010.
4. Analysis of the statistical differences in the average annual minimum temperature between the study periods (1981–2000) and (2001–2020) in the eastern highlands of Algeria showed a decreasing trend in annual rates. The differences in the average annual minimum temperature were statistically significant below 0.05, with a decrease of about 0.625°C in Setif, while the difference in Constantine was around 0.04°C, without statistical significance.
5. The t-test analysis of the statistical significance of differences in the seasonal average minimum temperature showed a decreasing trend in autumn, spring, and summer without statistical significance, with differences from the first period averaging 0.105°C, 0.085°C, and 0.175°C, respectively. Winter, however, showed an increasing trend without statistical significance, with a difference in favor of the second period of 0.15°C in Constantine. Statistically significant differences in the seasonal minimum temperature were less than 0.05 in autumn and winter in Setif. The differences were towards a decrease, ranging from 0.16 to 0.68°C in spring and summer, with differences between 0.77°C and 0.16–0.68°C, respectively.

6. Cumulative difference curves for rainfall quantities in the study stations showed varied trends between seasons. Trends towards a decrease were observed from 2004 to 2020 in winter in Constantine, with fluctuation in rainfall values around their average in other seasons. The spring trend in Constantine showed periods of both decrease and increase. In Setif, clear and varied trends towards a decrease were observed from 2002 to 2017 in autumn and from 2005 to 2020 in winter. The spring season showed a decrease from 1992 to 2006, while the summer season maintained its averages with fluctuations around the overall average.
7. Simple linear regression analysis showed positive change values (b) indicating an increase in the annual rainfall amounts in Constantine station in the eastern highlands of Algeria without statistical significance. In Setif station, negative change values (b) indicated a decrease in annual rainfall during the study period without statistical significance.
8. Analysis of the statistical differences in the average seasonal rainfall quantities revealed differences between the study periods (1981–2000) and (2001–2020) in the study area. The trends varied between seasons, with an increasing trend in autumn and summer without statistical significance, with differences of 13.4 mm and 3.82 mm, respectively. The trend was towards a decrease in rainfall quantities in winter and summer without statistical significance, with differences of 6.95 mm and 0.75 mm, respectively, in Constantine. In Setif, the differences indicated a decrease without statistical significance in autumn and winter during the second period of the study, with differences of 11.24 mm and 4.33 mm, respectively. Conversely, the differences favored the second period of the study (2001–2020) in spring and summer, with differences of 1.1 mm and 5.48 mm, respectively.

Recommendations:

1. Focus on collaborative scientific research in the Mediterranean regions on observed and potential climate changes, their causes, impacts, and the development of strategies for adaptation and mitigation.

2. Increase attention to recent scientific studies on climate change in Algeria and its effects on water resources, forestry, agricultural production, and pastoralism.

3. Open avenues for the exchange of scientific expertise in climate studies and the development of local capacities in scenario planning for future climate change.

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