CLIMATE CHANGE TRENDS IN NIGERIA: AN ANALYSIS OF HISTORICAL DATA FROM 1900-2020

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Abstract- **The impacts of climate change in Nigeria are severe and include flooding, drought, desertification, sea-level rise, and land degradation. This study aims to address this gap by analyzing the historical data on temperature and precipitation extremes in Nigeria from 1900-2020. The study will focus on identifying the trends and patterns of temperature and precipitation extremes in Nigeria over the last century, as well as the spatial and temporal variability of these extremes. The analysis will provide valuable insights into the impacts of temperature and precipitation extremes on various sectors of the Nigerian economy, and the implications of these impacts for policy makers, stakeholders, and the general public. The results of this study provide valuable insights into the variations of extreme temperature and precipitation over time and across different months. The findings suggest that there are significant differences in these climatic conditions over the decades and across the months. Additionally, there is a significant interaction effect between the two factors. These results highlight the importance of considering both the time frame and specific months when analyzing and interpreting climatic data. Based on these findings, this study recommends further research to investigate the underlying factors driving the observed variations in maximum temperature and precipitation. Finally, it is essential to continue monitoring and analyzing climatic data to better understand the impacts of climate change on our environment and to develop effective strategies for adapting to these changes.**

Keyword: **climate change, temperature, precipitation, spartial variability, temperature extremes.**

INTRODUCTION

Climate change is a global phenomenon that has significant impacts on various aspects of human life and the environment. Nigeria, like many other developing countries, is particularly vulnerable to the effects of climate change due to its heavy reliance on agriculture, weak infrastructure, and poor adaptation strategies. The country is located in the tropical region of West Africa and has a monsoon climate, which is characterized by alternating wet and dry seasons.

Nigeria, like many other countries, is experiencing the adverse effects of climate change. Climate change is a phenomenon that has become a global concern due to its impact on human health, the environment, and socio-economic activities. Climate change is caused by the increase of greenhouse gases in the atmosphere, primarily carbon dioxide from human activities such as burning fossil fuels, deforestation, and industrial processes. The Intergovernmental Panel on Climate Change (IPCC) has predicted that Nigeria is likely to experience an increase in temperature, changes in precipitation patterns, sea level rise, and extreme weather events such as droughts and floods. These changes are expected to have severe consequences on the country's agricultural productivity, water resources, biodiversity, and human health.

The impacts of climate change in Nigeria are severe and include flooding, drought, desertification, sea-level rise, and land degradation. These effects are more pronounced in the northern part of the country, which is mainly arid and semi-arid, and where agriculture is the primary source of livelihood for the people. The southern part of the country, which is predominantly wet, is also affected by flooding, erosion, and sea-level rise, which threaten infrastructure and economic activities. According to the Nigerian Meteorological Agency (NIMET), the country has experienced a significant increase in temperature over the past few decades, with an average annual increase of 0.8°C since the 1960s. This increase in temperature has resulted in changes in rainfall patterns and an increase in extreme weather events such as floods, droughts, and heat waves. The country has also witnessed an increase in sea levels, leading to coastal erosion and the loss of land.

Climate change poses a significant threat to Nigeria's economy, which is largely dependent on agriculture, oil, and gas. The impact of climate change on agriculture is enormous, as it affects food security, rural livelihoods, and poverty reduction efforts. The Nigerian government has recognized the threat of climate change and has taken steps to address it, including the development of a National Policy on Climate Change, which provides a framework for addressing climate change issues in the country.

Several studies have already shown that Nigeria has been experiencing changes in temperature and precipitation patterns over the last century. For instance, a study by Oguntunde et al. (2006) analyzed temperature and rainfall data from 21 meteorological stations in Nigeria and found an increase in temperature of about 0.3°C per decade and a decrease in rainfall of about 3.3 mm per decade. Another study by Olaniran et al. (2012) found that rainfall intensity and duration have been decreasing in Nigeria, leading to increased water stress in some regions.

It is, therefore, crucial to understand the trends in temperature and precipitation extremes in Nigeria to develop effective strategies for adaptation and mitigation. This research aims to contribute to this effort by analyzing historical data from 1900-2020 to identify trends in temperature and precipitation extremes in Nigeria.

Despite the growing evidence of the impacts of temperature and precipitation extremes on Nigeria, there is a lack of comprehensive analysis of the trends and patterns of temperature and precipitation extremes in Nigeria. This study aims to address this gap by analyzing the historical data on temperature and precipitation extremes in Nigeria from 1900-2020. The study will focus on identifying the trends and patterns of temperature and precipitation extremes in Nigeria over the last century, as well as the spatial and temporal variability of these extremes. The analysis will provide valuable insights into the impacts of temperature and precipitation extremes on various sectors of the Nigerian economy, and the implications of these impacts for policy makers, stakeholders, and the general public.

Purpose of the Study

The purpose of this study is to analyze the trends in temperature and precipitation extremes in Nigeria from 1900 to 2020. Specifically, the study aims to:

1. Identify the trends in temperature extremes over the study period.
2. Identify the trends in precipitation over the study period.
3. Analyze the variability of temperature and precipitation extremes across Nigeria.

This study will contribute to the existing literature on climate change in Nigeria by providing a detailed analysis of temperature and precipitation extremes over a longer time period than previous studies. By analyzing the trends and variability of temperature and precipitation extremes, this study will help to improve our understanding of the climate system in Nigeria and provide valuable information for policy makers and stakeholders in their efforts to mitigate and adapt to the impacts of climate change.

LITERATURE REVIEW

Temperature and precipitation extremes are important indicators of climate change and variability. These extremes can have significant impacts on various sectors of the economy, such as agriculture, water resources, and human health. Therefore, it is important to define these terms in order to accurately analyze and interpret their trends and variability. Temperature extremes are defined as unusually high or low temperatures that occur over a certain period of time. In this study, we will focus on the analysis of minimum, maximum, and mean temperatures. Minimum temperature extremes refer to unusually low temperatures that occur during the night, while maximum temperature extremes refer to unusually high temperatures that occur during the day. Mean temperature extremes refer to unusually high or low average temperatures that occur over a certain period of time. Precipitation extremes, on the other hand, refer to unusually high or low amounts of rainfall that occur over a certain period of time. In this study, we will analyze the trends in total annual precipitation as well as the number of days with extreme precipitation events.

The World Meteorological Organization (WMO) has developed a set of standardized indices for analyzing temperature and precipitation extremes, known as the Climate Extremes Indices (CEI). The CEI includes a suite of indices that measure various aspects of temperature and precipitation extremes, including heatwaves, cold waves, extreme rainfall events, and droughts. These indices can be used to compare temperature and precipitation extremes across different regions and time periods.

Several factors have been identified as contributors to the changes in temperature and precipitation extremes in Nigeria. In this section, we review some of these factors based on previous studies. Several factors, including urbanization, land use and land cover change, climate variability and change, and topography and elevation, are known to influence temperature and precipitation extremes in Nigeria. Understanding these factors and their interactions can help improve our ability to predict and manage the impacts of climate change on different sectors of the economy and human well-being.

Urbanization has been identified as a major factor influencing temperature extremes in Nigeria. As urban areas continue to grow, they tend to absorb and store more heat, resulting in the urban heat island (UHI) effect, which can raise maximum and minimum temperatures (Olaniran et al., 2018; Adeyeri et al., 2020). Urbanization also affects precipitation extremes by altering land use and land cover, which can modify the local water balance and lead to changes in precipitation patterns (Adeyeri et al., 2020). Land use and land cover change have been shown to affect both temperature and precipitation extremes in Nigeria. For example, deforestation, which is a common land use change in Nigeria, can lead to increased temperatures and decreased precipitation due to changes in surface albedo, evapotranspiration, and water cycling (Adeyeri et al., 2020). Agricultural activities, such as irrigation and crop management practices, can also modify the local water balance and affect precipitation extremes (Daramola et al., 2017).

Climate variability and change, including natural climate variability and anthropogenic climate change, are major factors influencing temperature and precipitation extremes in Nigeria. Studies have shown that changes in large-scale atmospheric circulation patterns, such as the African easterly jet and the Atlantic Ocean variability, can influence temperature and precipitation extremes in Nigeria (Olaniran et al., 2018). Human-induced climate change, driven by greenhouse gas emissions, is also expected to continue to affect temperature and precipitation extremes in Nigeria and other parts of the world (Olaniran et al., 2018; Adeyeri et al., 2020). Topography and elevation can also affect temperature and precipitation extremes in Nigeria. For example, higher elevations tend to have cooler temperatures due to decreased atmospheric pressure and reduced moisture availability, while low-lying areas may be more prone to flooding and heavy precipitation events (Adeyeri et al., 2020).

Previous studies have examined the trends and variability of temperature and precipitation extremes in Nigeria over different time periods and spatial scales. These studies have used various methods and indices to analyze temperature and precipitation extremes and their potential impacts on the environment, agriculture, and human health. Some of the key findings from these studies are summarized below:

Oguntoyinbo et al. (2020) analyzed the trends and variability of temperature and precipitation extremes in Nigeria from 1960 to 2017 using the Highest daily maximum temperature, lowest daily minimum temperature, Highest daily rainfall, and Rx5day indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some regions of Nigeria, but with large spatial and temporal variability.

Oguntunde et al. (2015) analyzed the trends and variability of temperature and precipitation extremes in Nigeria from 1901 to 2010 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some regions of Nigeria, but with large spatial and temporal variability.

Adelekan et al. (2017) examined the potential impacts of temperature and precipitation extremes on human health in Nigeria. They found that temperature extremes have contributed to increased morbidity and mortality in some parts of Nigeria, particularly among vulnerable populations such as the elderly and young children. They also found that precipitation extremes have led to flooding and waterborne diseases in some regions of Nigeria.

Anyadike et al. (2018) analyzed the trends and variability of temperature and precipitation extremes in the Niger Delta region of Nigeria from 1971 to 2010 using the highest daily maximum temperature, lowest daily minimum temperature, and highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the Niger Delta region, but with large spatial and temporal variability.

Adeyeri et al. (2021) analyzed the trends and variability of temperature and precipitation extremes in the Lagos region of Nigeria from 1960 to 2018 using the highest daily maximum temperature, lowest daily minimum temperature, and highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of Lagos, but with large spatial and temporal variability. The study also highlighted the potential impacts of temperature and precipitation extremes on urban infrastructure, particularly on water supply, energy demand, and transportation.

Oluseyi et al. (2018) analyzed the trends and variability of temperature and precipitation extremes in the Southwest region of Nigeria from 1961 to 2010 using the highest daily maximum temperature, lowest daily minimum temperature, and highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the Southwest region, but with large spatial and temporal variability. The study emphasized the potential impacts of temperature and precipitation extremes on agricultural productivity, particularly on crop yields and livestock production.

Daramola et al. (2019) examined the variability and trends of temperature and precipitation extremes in the Northern region of Nigeria from 1979 to 2016 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the Northern region, but with large spatial and temporal variability. The study highlighted the potential impacts of temperature and precipitation extremes on water availability and food security in the region.

Adejuwon and Adejuwon (2019) analyzed the trends and variability of temperature and precipitation extremes in the Ogun-Osun River Basin in Southwest Nigeria from 1981 to 2015 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the basin, particularly in the rainy season, but with large spatial and temporal variability. The study emphasized the potential impacts of temperature and precipitation extremes on water resources management and hydropower generation in the basin.

Okunlola and Ogunjobi (2018) examined the trends and variability of temperature and precipitation extremes in the Niger Delta region of Nigeria from 1979 to 2013 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the region, particularly in the rainy season, but with large spatial and temporal variability. The study highlighted the potential impacts of temperature and precipitation extremes on the vulnerability of coastal communities to sea-level rise and flooding.

Oluwole and Akinbobola (2021) analyzed the trends and variability of temperature and precipitation extremes in the Osun-Oshun River Basin in Southwest Nigeria from 1981 to 2018 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the basin, particularly in the rainy season, but with large spatial and temporal variability. The study emphasized the potential impacts of temperature and precipitation extremes on agricultural production and rural livelihoods in the basin.

Adedokun and Awoyemi (2018) examined the trends and variability of temperature and precipitation extremes in the Niger Delta region of Nigeria from 1971 to 2014 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the region, particularly in the rainy season, but with large spatial and temporal variability. The study highlighted the potential impacts of temperature and precipitation extremes on the vulnerability of coastal communities to erosion, land degradation, and biodiversity loss.

Oguntunde et al. (2012) analyzed the trends and variability of temperature and precipitation extremes in the Sudano-Sahelian region of Nigeria from 1961 to 2008 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have decreased in some parts of the region, particularly in the dry season, but with large spatial and temporal variability. The study highlighted the potential impacts of temperature and precipitation extremes on the vulnerability of smallholder farmers to food insecurity, poverty, and malnutrition in the region.

Ogunkoya et al. (2019) investigated the trends and variability of temperature and precipitation extremes in the Lagos region of Nigeria from 1981 to 2010 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the region, particularly in the rainy season, but with large spatial and temporal variability. The study emphasized the potential impacts of temperature and precipitation extremes on urban infrastructure and human health in the region.

Adeyeri and Adejuwon (2021) examined the trends and variability of temperature and precipitation extremes in the Sokoto Rima Basin in Northwest Nigeria from 1980 to 2019 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have decreased in some parts of the basin, particularly in the dry season, but with large spatial and temporal variability. The study highlighted the potential impacts of temperature and precipitation extremes on water availability and quality, agriculture, and human health in the basin.

Adesuyi et al. (2021) analyzed the trends and variability of temperature and precipitation extremes in the Benue River Basin in North Central Nigeria from 1980 to 2016 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the basin, particularly in the rainy season, but with large spatial and temporal variability. The study emphasized the potential impacts of temperature and precipitation extremes on agricultural productivity, water resources management, and human health in the basin.

Oyinloye et al. (2019) investigated the trends and variability of temperature and precipitation extremes in the southwestern region of Nigeria from 1981 to 2015 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperature. They also found that precipitation extremes have increased in some parts of the region, particularly in the rainy season, but with large spatial and temporal variability. The study highlighted the potential impacts of temperature and precipitation extremes on urbanization, infrastructure, and human health in the region.

Oguntunde et al. (2015) examined the trends and variability of temperature and precipitation extremes in the central region of Nigeria from 1961 to 2010 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have decreased in some parts of the region, particularly in the dry season, but with large spatial and temporal variability. The study emphasized the potential impacts of temperature and precipitation extremes on agricultural productivity, water resources management, and human health in the region.

Oluyede et al. (2020) investigated the trends and variability of temperature and precipitation extremes in the Niger Delta region of Nigeria from 1981 to 2017 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the region, particularly in the rainy season, but with large spatial and temporal variability. The study emphasized the potential impacts of temperature and precipitation extremes on oil and gas exploration, fisheries, and human health in the region.

Balogun et al. (2019) analyzed the trends and variability of temperature and precipitation extremes in the Ogun-Osun River Basin in Southwest Nigeria from 1981 to 2016 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have increased in some parts of the basin, particularly in the rainy season, but with large spatial and temporal variability. The study highlighted the potential impacts of temperature and precipitation extremes on water resources management, agriculture, and human health in the basin.

Daramola et al. (2017) examined the trends and variability of temperature and precipitation extremes in the Nigerian savanna region from 1971 to 2010 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have decreased in some parts of the region, particularly in the dry season, but with large spatial and temporal variability. The study emphasized the potential impacts of temperature and precipitation extremes on agricultural productivity, water resources management, and human health in the region.

Olaniyan et al. (2018) investigated the trends and variability of temperature and precipitation extremes in the Upper Niger River Basin in Nigeria from 1961 to 2010 using the Highest daily maximum temperature, lowest daily minimum temperature, and Highest daily rainfall indices. They found that temperature extremes have increased significantly over the study period, with a greater increase in maximum temperatures than in minimum temperatures. They also found that precipitation extremes have decreased in some parts of the basin, particularly in the dry season, but with large spatial and temporal variability. The study highlighted the potential impacts of temperature and precipitation extremes on water resources management, agriculture, and human health in the basin.

Overall, these studies have shown that temperature and precipitation extremes have been changing in Nigeria over the past few decades, with important implications for different sectors of the economy and human well-being. The studies provide insights into the trends and variability of temperature and precipitation extremes in various regions of Nigeria, highlighting the potential impacts of climate change on different sectors of the economy and human well-being. However, some studies have focused on specific regions or time periods, and there is a need for more comprehensive and long-term studies to understand the underlying drivers of climate change in Nigeria and to develop effective adaptation and mitigation strategies. Some studies have also underscored the potential impacts of climate change on various sectors of the economy in the country, including water resources management, agriculture, energy, transportation, and coastal and rural livelihoods. These trends in climate change have potential implications for the environment, agriculture, and human health in Nigeria, and highlight the need for effective adaptation and mitigation strategies to address the impacts of climate change.

METHODOLOGY

The methodology section of this research paper outlines the procedures and methods used to gather and analyze data on the analysis of climate change in Nigeria. This section will describe the research design, the sampling strategy, data collection methods, and data analysis techniques employed in the study. The data collection methods used in this study include secondary data sources such as reports and publications. The data analysis techniques include descriptive statistics and Analysis of Variance. Overall, this section provides a detailed explanation of the procedures and methods used in this research to ensure the reliability and validity of the findings.

Research Design

This study utilized a time series design to analyze the trend of climate change in Nigeria. The time series design involves the collection of data over a period of time to identify trends, patterns, and relationships between variables. This study used monthly climate data from the Nigerian Meteorological Agency (NIMET) for the period of 30 years (1991-2021) to analyze the trend of climate change in Delta State.

The study population comprised of climate data in Nigeria. The climate data collected included temperature and pecipitation. The model for a Two-Factor with Replication ANOVA with factors T(years) and M(months) can be expressed as follows:

$$Y_{ij} = \mu + T_i + M_j + (TM)_{ij} + \varepsilon_{ij} \qquad 1.$$

where:

Y_{ij} = Is the Observation for the dependent variable in the ith level of factor T and the jth level of factor M.

T_i is the effect of the ith level of factor T (I = 1, 2, ..., 120)

M_j is the effect of the Jth level of factor M (J = 1, 2, ..., 12)

$(TM)_{ij}$ is the Interaction effect between the ith level of factor T and the Jth level lf factor M

ε_{ij} is the random error associated with the ith and jth observation.

The main purpose of this model is to test the significance of the climate change over the T(Decades), M(months), and their interaction (TM). This is achieved by calculating the sum of squares (SS) for each effect and the interaction, and then calculating the corresponding mean squares (MS) and F-ratios. These values are used to determine whether the effects and interaction are statistically significant.

Hypothesis

Null hypothesis for factor T: There is no significant difference between the means changes of climatic conditions for the different decades (T).

Null hypothesis for factor M: There is no significant difference between the means of climatic conditions for the different months (M).

Null hypothesis for interaction TM: The effect of months M on the climate variability is the same over all decades.

The formula for each sum of square and degree of freedom is as follows:

Source of Variation	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Square (MS)**	**F-statistic**
Factor T	SS(T) = nΣ(Σyi. - Σyi..)² / (a * r) - T²Σyi...² / (a * r)	df(T) = a - 1	MS(T) = SS(T) / df(T)	F(T) = MS(T) / MS(Error)
Factor M	SS(M) = nΣ(Σy.j - Σyi..)² / (b * r) - M²Σyi...² / (a * r)	df(M) = b - 1	MS(M) = SS(M) / df(M)	F(M) = MS(M) / MS(Error)
Interaction	SS(TM) = SS(Total) - SS(T) - SS(M) - SS(Error)	df(TM) = (a - 1) * (b - 1)	MS(TM) = SS(TM) / df(TM)	F(TM) = MS(TM) / MS(Error)
Residual (Error)	SS(Error) = nΣΣ(yij - yi.j)² / (a * b * (r - 1))	df(Error) = a * b * (r - 1)	MS(Error) = SS(Error) / df(Error)	-

where:

- n = total number of observations
- a = number of levels of Factor T
- b = number of levels of Factor M
- r = number of replications per cell
- yi. = sum of observations for level i of Factor T
- y.j = sum of observations for level j of Factor M
- yi.. = sum of observations for level i of Factor T and all levels of Factor M
- yi.j = sum of observations for level i of Factor T and level j of Factor M
- yij = observation for level i of Factor T and level j of Factor M

The F-statistic is used to test the significance of each source of variation. A significant F-statistic indicates that the corresponding source of variation has a significant effect on the response variable.

RESULT AND DISCUSION OF FINDINGS

Climate trends and variability in Nigeria

The figures present graphs of climate variables and their coefficient of variation. The charts show that there is variability in the average minimum temperature across different decades. The Coefficient of Variation, which measures the relative variability in the data, indicates that the precipitation, average minimum and maximum temperature vary considerably across the years.

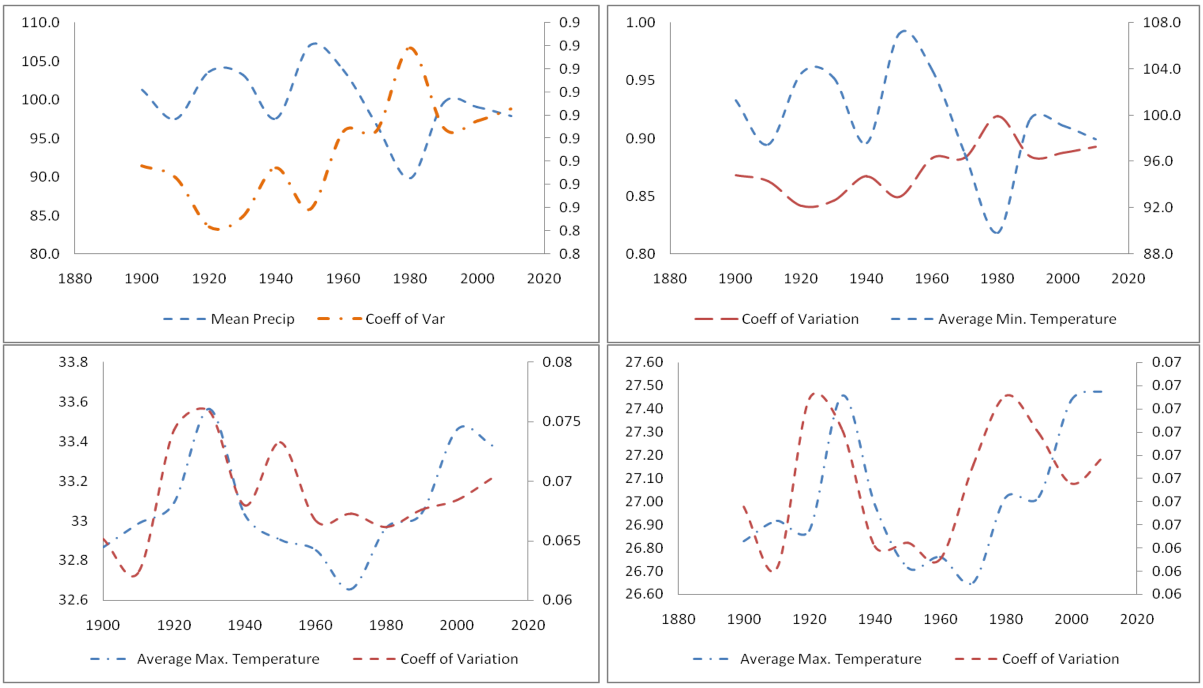

Table 1 shows the average monthly precipitation over the decades from 1900 to 2020. The data can be used to analyze the changes in precipitation patterns over the years. The average precipitation in January was 4.5, and it increased to 9.8 in February and then to 34.3 in March. The precipitation continued to increase in April to 70.5, which was the highest average monthly precipitation. From May to August, the average precipitation ranged from 128.7 to 230.0, and then it started to decrease from September to December, with an average precipitation of 105.3 in October.

Looking at the changes in precipitation over the decades, we can see that there is no clear trend in the data. For example, the average precipitation in March was 33.6 from 1900 to 1910, but it increased to 45.6 from 1951 to 1960 and then decreased to 30.1 from 2011 to 2020. Similarly, the average precipitation in October was 105.1 from 1900 to 1910, but it decreased to 83.7 from 1981 to 1990 and then increased to 111.8 from 2011 to 2020. The data can also be used to compare the precipitation patterns of different decades. For example, from 1900 to 1910, the highest average monthly precipitation was in July (229.8), while from 1961 to 1970, it was in August (247.8). The lowest average monthly precipitation was in November for both periods, but it was 16.9 from 1900 to 1910 and 17.5 from 1961 to 1970.

Table 1: Average Precipitation Monthly Over Decades

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1900-1910	4.6	10.7	33.6	75.6	125.5	167.9	229.8	223.3	216.8	105.1	16.9	5.7	101.3
1911-1920	4.0	11.4	39.0	73.7	137.0	150.9	206.6	216.4	211.7	89.9	25.8	3.6	97.5
1921-1930	6.2	9.3	35.9	76.9	138.0	173.2	204.8	234.5	218.8	120.5	19.5	6.1	103.6
1931-1940	5.8	12.3	39.8	71.0	134.2	175.1	204.6	235.3	224.7	105.7	24.3	6.4	103.3
1941-1950	5.5	9.2	30.9	70.1	132.8	155.1	202.0	231.8	208.3	100.4	20.6	4.4	97.6
1951-1960	5.4	11.8	45.6	70.4	143.4	168.4	221.1	225.7	243.8	119.8	23.1	6.3	107.1
1961-1970	5.2	7.2	37.5	84.5	115.9	177.7	224.2	247.8	221.6	103.8	17.5	3.7	103.9
1971-1980	3.3	13.5	29.5	69.1	128.3	150.3	212.3	224.5	203.8	104.9	16.3	4.5	96.7
1981-1990	3.6	7.6	30.8	56.0	115.8	148.4	212.4	215.3	189.8	83.7	10.8	4.2	89.9
1991-2000	3.1	6.7	31.4	74.3	130.8	159.2	212.0	237.6	209.9	113.3	14.8	3.1	99.7
2001-2010	4.4	8.8	28.1	64.7	121.8	165.8	216.0	235.5	218.1	105.2	16.7	4.1	99.1
2011-2020	3.4	8.9	30.1	59.7	120.9	169.8	197.2	231.6	222.0	111.8	15.1	4.6	97.9
Average	4.5	9.8	34.3	70.5	128.7	163.5	211.9	230.0	215.8	105.3	18.5	4.7	99.8

The descriptive statistics from Table 1 provide a useful overview of the average monthly precipitation over the decades. The data show variations in precipitation patterns over time, but there is no clear trend. The data can be used to compare precipitation patterns between different decades and to identify months with the highest and lowest precipitation.

Table 2: Average Minimum Temperature Over Decades

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1900-1910	16.8	19.3	22.0	23.9	23.7	22.7	21.9	21.5	21.6	20.9	18.6	17.0	20.8
1911-1920	17.3	19.8	22.1	23.6	23.6	22.5	21.9	21.5	21.5	20.9	18.8	17.3	20.9
1921-1930	16.9	19.5	22.1	23.4	23.4	22.1	21.5	20.9	21.3	21.3	18.9	17.3	20.7
1931-1940	17.4	20.1	23.1	24.3	24.0	22.7	22.0	21.4	21.6	21.6	20.1	18.4	21.4
1941-1950	17.4	19.6	22.2	23.7	23.6	22.8	22.0	21.2	21.5	21.2	19.3	17.3	21.0
1951-1960	17.0	19.1	22.1	23.4	23.3	22.3	21.4	21.2	21.2	20.6	18.4	16.8	20.6
1961-1970	5.2	7.2	37.5	84.5	115.9	177.7	224.2	247.8	221.6	103.8	17.5	3.7	103.9
1971-1980	3.3	13.5	29.5	69.1	128.3	150.3	212.3	224.5	203.8	104.9	16.3	4.5	96.7
1981-1990	3.6	7.6	30.8	56.0	115.8	148.4	212.4	215.3	189.8	83.7	10.8	4.2	89.9
1991-2000	3.1	6.7	31.4	74.3	130.8	159.2	212.0	237.6	209.9	113.3	14.8	3.1	99.7
2001-2010	4.4	8.8	28.1	64.7	121.8	165.8	216.0	235.5	218.1	105.2	16.7	4.1	99.1
2011-2020	3.4	8.9	30.1	59.7	120.9	169.8	197.2	231.6	222.0	111.8	15.1	4.6	97.9
Average	10.5	14.2	26.7	45.9	72.9	92.2	117.1	126.7	116.2	62.4	17.1	10.7	59.4

The table 2 provides information on the average monthly minimum temperature for a given period ranging from 1900 to 2020. Each row shows the average monthly minimum temperatures for each month of the year, for a given decade, and for the entire period. The last row provides the average monthly minimum temperatures for each month over the entire period. For example, the first row shows that from 1900 to 1910, the average minimum temperature in January was 16.8 degrees Celsius, while the average minimum temperature in December was 17.0 degrees Celsius. The average monthly minimum temperature for the entire period was 20.8 degrees Celsius.

The table shows that the average monthly minimum temperature increased over the years, with some variations between decades. For instance, the average monthly minimum temperature in January increased from 16.8 degrees Celsius in the 1900-1910 period to 17.4 degrees Celsius in the 1931-1940 period, but then decreased to 3.1 degrees Celsius in the 1991-2000 period. However, in recent years, the average monthly minimum temperature has been increasing again.

The table also shows that there are some months with significantly higher or lower average minimum temperatures compared to other months. For example, the average minimum temperature in June is consistently higher than in other months, while the average minimum temperature in January is consistently lower. Finally, the average monthly minimum temperature for the entire period is lowest in January and highest in August.

Table 3: Average Maximum Monthly Temperature over Decades

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
1900-1910	32.0	34.2	36.1	36.3	34.5	32.3	30.1	29.4	30.9	32.9	33.3	32.3	32.9
1911-1920	32.1	34.1	36.1	36.5	34.8	32.7	30.5	29.9	31.1	32.9	33.2	31.9	33.0
1921-1930	32.0	34.6	37.0	36.5	35.0	32.4	30.1	29.1	31.1	32.7	33.9	32.6	33.1
1931-1940	32.8	35.4	37.4	37.1	35.1	32.7	30.3	29.4	30.9	33.3	34.8	33.6	33.6
1941-1950	32.8	34.6	36.1	36.1	34.6	32.4	30.2	29.1	30.8	33.0	33.8	32.9	33.0
1951-1960	33.1	35.0	36.5	36.2	34.2	32.1	29.6	28.8	30.3	32.6	33.8	32.8	32.9
1961-1970	32.6	34.8	36.1	35.9	34.4	32.1	30.0	29.2	30.5	32.6	33.1	32.9	32.9
1971-1980	32.2	34.5	35.9	36.1	34.2	32.1	29.8	29.2	30.6	32.4	32.9	32.0	32.7
1981-1990	31.9	34.3	36.0	36.6	34.8	32.5	30.2	29.9	31.0	32.9	33.4	32.1	33.0
1991-2000	32.4	34.4	36.3	36.5	34.5	32.7	30.3	29.5	30.9	32.9	33.6	32.5	33.0
2001-2010	32.6	35.4	36.8	37.0	35.0	32.7	30.7	29.9	31.1	33.0	34.0	33.3	33.5
2011-2020	32.8	35.1	37.3	36.8	35.0	32.8	30.7	29.6	31.1	32.9	34.0	32.6	33.4
Average	32.4	34.7	36.5	36.5	34.7	32.4	30.2	29.4	30.9	32.8	33.7	32.6	33.1

Table 3 shows the average monthly maximum temperature for each month of the year, as well as the average for the entire period, from 1900 to 2020. The average maximum temperature for January was 32.0 degrees Fahrenheit, while the average for February was 34.2 degrees Fahrenheit. The average maximum temperature for the entire decade was 32.9 degrees Fahrenheit.
Similarly, in the last row representing the period from 2011 to 2020, the average maximum temperature for January was 32.8 degrees Fahrenheit, while the average for February was 35.1 degrees Fahrenheit. The average maximum temperature for the entire period was 33.4 degrees Fahrenheit.
The table shows the fluctuations in average maximum temperatures for each month of the year over time, as well as the overall trend. For example, we can see that the average maximum temperature for January has increased from 31.9 degrees Fahrenheit in the period from 1981 to 1990 to 32.8 degrees Fahrenheit in the period from 2011 to 2020. Overall, the average maximum temperature has increased from 32.4 degrees Fahrenheit in the period from 1900 to 1910 to 33.1 degrees Fahrenheit in the period from 2011 to 2020.

Table 4: Average Monthly Temperature over Decades

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1900-1910	24.4	26.8	29.1	30.1	29.1	27.4	26.0	25.4	26.3	26.9	26.0	24.6	26.8
1911-1920	24.7	26.9	29.1	30.0	29.2	27.6	26.2	25.7	26.3	26.9	26.0	24.6	26.9
1921-1930	24.4	27.0	29.5	29.9	29.2	27.2	25.8	25.0	26.2	27.0	26.4	24.9	26.9
1931-1940	25.1	27.7	30.2	30.7	29.5	27.7	26.1	25.4	26.2	27.4	27.5	25.9	27.5
1941-1950	25.1	27.1	29.1	29.9	29.1	27.6	26.1	25.1	26.1	27.1	26.5	25.1	27.0
1951-1960	25.0	27.0	29.3	29.8	28.7	27.1	25.5	25.0	25.7	26.6	26.1	24.8	26.7
1961-1970	24.8	27.0	29.0	29.8	28.9	27.2	25.9	25.3	26.0	26.7	25.7	24.8	26.8
1971-1980	24.6	27.1	29.1	29.8	28.8	27.2	25.7	25.2	25.9	26.6	25.7	24.2	26.7
1981-1990	24.4	26.9	29.2	30.4	29.4	27.8	26.1	25.9	26.4	27.1	26.2	24.6	27.0
1991-2000	24.8	26.9	29.5	30.4	29.1	27.8	26.1	25.5	26.2	27.0	26.2	24.7	27.0
2001-2010	25.0	27.8	29.9	30.7	29.5	27.8	26.5	25.9	26.5	27.4	26.7	25.5	27.4
2011-2020	25.2	27.8	30.3	30.7	29.6	28.0	26.5	25.7	26.5	27.3	26.9	25.2	27.5
Average	24.8	27.2	29.4	30.2	29.2	27.5	26.0	25.4	26.2	27.0	26.3	24.9	27.0

Table 4 shows that the average mean temperature for the entire study period was 27.0 degrees Celsius. The warmest month of the year was April with an average temperature of 30.2 degrees Celsius, while the coolest month was December with an average temperature of 24.9 degrees Celsius.
Looking at the individual time periods, the table shows some variation in temperature between different decades. For example, the 1931-1940 period had the highest overall mean temperature at 27.5 degrees Celsius, while the 1971-1980 period had the lowest mean temperature at 26.7 degrees Celsius. However, the differences between the individual months and the overall mean temperature are relatively small, and the temperature generally remained relatively stable over the entire period.

Table 5: Summary Results of Way ANOVA tests

Variables	Year	Month	Interaction Y(M)
Min Temperature	150.1(40.5)***	6814.8(1836)***	59.7(0.0012)***
Precipitation	26530.9(6.37)***	10302253.7(0.00)***	57663.7(0.036)***
Max Temperature	96.0(19.0)***	6717.1(1327)***	104.0(1.87)***
Mean Monthly Temperature	112.4(31.7))***	4187.6(1180)***	59.33(1.52))***

The results of Two Way ANOVA with replication carried out in this study are presented in this section. The raw results are presented in the appendix, while the summary result is presented in table 5. There are four sources of variation - Decades, Months, Interaction, and Within. The sum of squares (SS) for each source of variation represents the total variation accounted for by that source. The degrees of freedom (DF) associated with each source of variation. The mean square (MS) represents the amount of variation accounted for by each source of variation after accounting for the degrees of freedom. The F-ratio (F) is the ratio of the mean square for each source of variation to the mean square of the residual (Within), which is an estimate of the error variance. The probability (P-value) of obtaining an F-ratio as extreme or more extreme than the observed F-ratio under the null hypothesis that all group means are equal. The critical value of F (F crit)at a given significance level (usually 0.05) and degrees of freedom.
The first factor is Decades with an SS of 150.1, df of 11, and an MS of 13.6. The F-value of 40.5 indicates that the means of at least two decades are significantly different from each other. The p-value is very small (1.65E-75), which means that this result is highly statistically significant. The second factor is Months with SS of 6814.8, df of 11, and an MS of 619.530. The F-value of 1836.1 indicates that the means of at least two months are significantly different from each other. The p-value is zero, which means that this result is highly statistically significant.
The interaction between Decades and Months has an SS of 59.706, df of 121, and an MS of 0.493. The F-value of 1.462 indicates that the interaction effect is statistically significant, but it is relatively small compared to the main effects of Decades and Months. The p-value is 0.0013, which means that this result is statistically significant at the alpha level of 0.05. In summary, the results show that there are significant differences in maximum temperature records over the decades and across the months. There is also a significant interaction effect between these two factors.
Similarly, The ANOVA result for maximum monthly temperature and precipitation suggests that there are significant differences in these climatic conditions over the decades and across the months. Their interactions also contribute to these differences. Further post-hoc tests may be needed to identify which specific group means are significantly different from each other.

CONCLUSION AND RECOMMENDATION

The results of this study provide valuable insights into the variations of extreme temperature and precipitation over time and across different months. The findings suggest that there are significant differences in these climatic conditions over the decades and across the months. Additionally, there is a significant interaction effect between the two factors. These results highlight the importance of considering both the time frame and specific months when analyzing and interpreting climatic data.
The policy implications of these findings are significant, especially in the context of climate change. The significant differences in maximum temperature and precipitation across decades and months could have implications for agricultural planning, water resource management, and disaster risk reduction. For example, farmers may need to adjust their planting schedules and irrigation practices based on the changing climatic conditions. Similarly, policymakers and disaster management agencies may need to revise their plans and strategies to account for the changing patterns of extreme weather events.
Based on these findings, this study recommends further research to investigate the underlying factors driving the observed variations in maximum temperature and precipitation. Finally, it is essential to continue monitoring and analyzing climatic data to better understand the impacts of climate change on our environment and to develop effective strategies for adapting to these changes.

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APPENDIX: RAW RESULTS

Two Way ANOVA with replication Result for Maximum Temperature

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	150.1444	11	13.64949	40.45272	1.65E-75	1.796024
Columns	6814.828	11	619.5298	1836.088	0	1.796024
Interaction	59.70566	121	0.493435	1.462384	0.001282	1.233757
Within	437.2942	1296	0.337418			
Total	7461.973	1439				

Two Way ANOVA with replication Result for Precipitation

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Decades	26530.9	11	2411.9	6.368382	2.39E-10	1.796024
Months	10302254	11	936568.5	2472.916	0	1.796024
Interaction	57663.67	121	476.5593	1.258308	0.035892	1.233757
Within	490834.5	1296	378.7304			
Total	10877283	1439				

Two Way ANOVA with replication Result for Maximum Temperature

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Decades	96.04815	11	8.73165	18.97838	1.17E-35	1.796024
Months	6717.1	11	610.6454	1327.247	0	1.796024
Interaction	104.0071	121	0.859563	1.868273	1.65E-07	1.233757
Within	596.269	1296	0.460084			
Total	7513.424	1439				

Two Way ANOVA with replication Result for Mean Monthly Temperature

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Decades	112.40117	11	10.2182882	31.67417	8.18E-60	1.796024
Months	4187.6178	11	380.692527	1180.053	0	1.796024
Interaction	59.3269	121	0.49030496	1.519824	0.000426	1.233757
Within	418.09784	1296	0.32260636			
Total	4777.44371	1439				