SPATIOTEMPORAL FLUCTUATION OF RAINFALL IN THE STATIONS OF DUHOK GOVERNORATE BETWEEN (2000-2020)

2022
MASTER THESIS
DEPARTMENT OF GEOGRAPHY

Jiwan Mohammed ABDULLAH

Supervised by
Prof. Dr. Mücahit COŞKUN

SPATIOTEMPORAL FLUCTUATION OF RAINFALL IN THE STATIONS OF DUHOK GOVERNORATE BETWEEN (2000-2020)

Jiwan Mohammed ABDULLAH

Prof. Dr. Mücahit COŞKUN

T.C.
Karabuk University
Institute of Graduate Programs
Department of Geography

Prepared as
Master Thesis

KARABUK
August, 2022

TABLE OF CONTENTS

THESIS APPROVAL PAGE

I certify that in my opinion the thesis submitted by Jiwan Mohammed ABDULLAH titled "SPATIOTEMPORAL FLUCTUATION OF RAINFALL IN THE STATIONS OF DUHOK GOVERNORATE BETWEEN (2000-2020)" is fully adequate in scope and quality as a thesis for the degree of Master of Science.

Prof. Dr. Mücahit COŞKUN ....

Thesis Advisor, Department of Geography

This thesis is accepted by the examining committee with a unanimous vote in the Department of Mechanical Engineering as a Master of Science thesis. 15.08.2022

Examining Committee Members (Institutions) Signature

Chairman : Prof. Dr. Mücahit COŞKUN (KBU) ....

Member : Assist. Prof. Dr. Cemil İRDEM (KBU) ....

Member : Assist. Prof. Dr. Dilek AYKIR (ARU) ....

The degree of Master of Science by the thesis submitted is approved by the Administrative Board of the Institute of Graduate Programs, Karabuk University.

Assoc. Prof. Dr. Müslüm KUZU ....

Director of the Institute of Graduate Programs

DECLARATION

I hereby declare that this thesis is the result of my own work and all information included has been obtained and expounded in accordance with the academic rules and ethical policy specified by the institute. Besides, I declare that all the statements, results, materials, not original to this thesis have been cited and referenced literally.

Without being bound by a particular time, I accept all moral and legal consequences of any detection contrary to the aforementioned statement.

Name Surname:

Signature :

ACKNOWLDGEMENTS

First, I thank God Almighty for making this study available to me. I would like to thank my dear Professor Dr. Mücahit COŞKUN for his support, encouragement and guidance, as he guides me on the right path, to get the best knowledge. God bless him. I would like to thank the staff of the Department of Geography at Karabuk University and all the teachers and students who helped me.

I would also thank my parents who helped me and encouraged me all my life. May God protect them.

Also, I would thank my friend and husband Akram, who gave me a lot of patience and hope throughout the study period. God bless you dear. I don't forget to thank my dear friend Chinar Muhsin and everyone who supported me in my study, may God reward you with all the best.

ABSTRACT

The study aims to analyze the temporal and local scale changes and fluctuations of rainfall in Duhok province between 2000-2020.

This study used multiple statistical methods to analyze and interpret the results, graphs, and maps. The study aims to identify the spatiotemporal fluctuations between rainfall stations and find the effect of natural factors on rainfall precipitation as well as determine the nature of annual rainfall changes. In addition, it determines the general trend of rainfall and the possibility of predicting future rainfall changes in the study area.

To achieve its objectives, the study relied on different descriptive, regional, and statistical approaches, including various programs, such as Arc Gis.10.4, SPSS 23 and Minitab.

The study has come up with the results; the most important of them is the existence of a difference in time and place in the amount of rainfall in the study area. This disparity was affected by the climatic and topographical variations, which explains the high amount of rainfall in the mountainous stations in the study area, while the lower plains stations do not receive the same amount of rain. In the lowlands represented by stations (Zakho, Bateel, Semel, Duhok, Sheikhan, Qasrok, Bardarash), their height is between (365-510 m) above sea level, and the annual total rainfall is between (458.1-602.6 mm). The amount of precipitation increases as we head towards the higher areas in the north and north-east of the study area represented by the stations (Akre, Dinarta, Zawita, Mangesh, Chamanke, Sarsank, Amedi, Swaratoka, Bamarne, Batofa, Kani Mas, Deraluk, Darkar), with height about (636-1670 m) above sea level, the total annual rainfall is between (584.1-1051.8 mm). The study area fell within the influences of many low pressure and air masses responsible for the prevalence of unstable weather conditions, temporary weather changes and rainfall in the area. It is clear by studying the fluctuated averages that the direction of the rainfall regression line tends to rise in general. It has been found through the study that the study area's topography clearly impacts the amount of rainfall at the monthly and seasonal levels in the study area.

There is a robust direct correlation between the altitude variable and the rainfall variable, where the value of the correlation coefficient is (0.573**), which is statistically significant. Therefore, the altitude variable is considered one of the most positively related variables at the seasonal and monthly levels. The study area witnessed an apparent temporal fluctuation of the annual average of rainfall, where the fluctuation in the rainfall average recorded a large rate for some years and a small rate for others, which negatively affects the various life activities, where the annual average of rainfall in Dohuk governorate is about (739.8) mm. However, the severe decreases in the amount of precipitation over years negatively affect many sectors. It has been determined that there is a correlation between total precipitation and average temperatures. However, it is not statistically significant due to the distance from the water sources. While there was no statistical significance between temperature and precipitation, the significance value was found at the level of (0.790**) between moisture source and precipitation (0.01). There is a weak direct correlation between the rainfall variable and the atmospheric pressure variable, as it reached (0.403) due to the terrain factor, in which the atmospheric pressure decreases the higher we rise. The application of the statistical Mankendal equation on the rainfall data in all stations of the governorate for the period (2000-2020) shows a fluctuation value in most stations that tend to rise, the future prediction of rainfall data in the stations of Duhok governorate was deduced employing the seasonal Holt Winters and based on the multiplication seasonal model for years (2022-2030).

The study recommends providing advanced tools to continuously and correctly read all climatic elements and build a climatic database that includes all stations in the governorate.

Keywords: Rainfall; Stations; Fluctuation; Climate; Duhok; Terrain; Depressions

ÖZET

Çalışmanın amacı, Duhok vilayetinin 2000-2020 yılları arasındaki yağışların zamansal ve yerel ölçekte değişimleri ve dalgalanmalarını analiz etmektir.

Çalışmada, verileri analiz etmek ve yorumlamak için çeşitli istatistiksel yöntemler kullanılmıştır, elde edilen sonuçları anlamlı kılmak içinde farklı grafikler ve haritalar hazırlandı. Bu çalışma kapsamında, istasyonlar arasında yağışların zamansal ve mekansal dalgalanmalarının tespit edilmesi çalışmanın temel amacını oluşturmaktadır. Alt amaçlar ise, bu değişim ve dalgalanmalara neden olan doğal unsurların belirlenmesi, yağmurların genel eğiliminin tespit edilmesi ve vilayet genelinde yağış değişikliklerinin gelecekteki seyrinin ortaya konulması için tahminlerin yapılması çalışmanın alt amaçlarını oluşturmaktadır.

Çalışmanın amaçlarına ulaşmada, GIS programı, SPSS programı ve Minitab programı dahil olmak üzere çeşitli programlar kullanılarak nitel, nicel, bölgesel ve istatistiksel yöntem kullanılarak karma araştırma modeli tercih edilmiştir.

Yapılan analizler sonucunda alana düşen yağışın eşit miktarda dağılmadığı tespit edilmiştir. Düşen yağışlardaki eşitsizliklerinin en önemli nedeni zaman ile mekandan kaynaklı olduğu belirlenmiştir. Dağlık istasyonlara düşen yağış miktarının yüksek olurken, ova istasyonlarında aynı miktarda yağış almamaktadır. Yükseklikleri deniz seviyesine yakın olan istasyonlarda (365-510 m) (Zakho, Bateel, Semel, Duhok, Shekhan, Qasrok, Bardarash) yıllık toplam yağışın (458.1- 602.6 mm) arasında olduğu tespit edilmiştir. Çalışma alanı olan Duhok vilayetinde kuzey ve kuzeydoğuya doğru gidildikçe yükseltinin artmasına bağlı olarak yağış miktarı artmaktadır. Akre, Dinarta, Zawita, Mangesh, Chamanke, Sarsank, Amedi, Swaratoka, Bamarne, Batofa, Kani Mas, Deraluk, Darkar istasyonları deniz seviyesinden 636-1670m arasında olup, yıllık toplam 584.1-1051.8 mm, yağış almaktadır. Çalışma alanının güney - güneybatısından kuzey ve kuzeydoğusuna doğru gidildikçe yükseltinin artmasına bağlı olarak yağış miktarındaki değişimi açıklamaktadır. Çalışma alanı, bölgedeki istikrarsız hava koşullarının, geçici hava değişikliklerinin ve yağışların yaygınlığından büyük ölçüde sorumlu olan bir dizi depresyon ve hava kütlesinin etkisine girmiştir. Hareketli

ortalamaları inceleyerek, yağmur regresyon çizgisinin yönünün genel olarak yükselme eğiliminde olduğu açıktır. Çalışma alanındaki topografya şartlarının, yıllık, aylık ve mevsimlik düzeylerde alana düşen yağış miktarı üzerinde net bir etkiye sahip olduğu çalışma ile ortaya konulmuştur Burada korelasyon katsayısının değeri 0,573** olurken, istatistiki açıdan anlamlılık göstermektedir. Bu nedenle, çalışma alanındaki yağışların artmasında yükseklik değişkeninin önemi, mevsimsel ve aylık düzeylerde en olumlu ilişkili değişkenlerden biri olarak kabul edilmektedir. Çalışma alanı, genel ortalama çevresinde artış ve düşüş dönemleri yıldan yıla yağmur miktarının açık bir zamansal dalgalanmasına tanık olmaktadır. Burada yağmur ortalamasındaki zaman dalgalanması bazı yıllar için büyük bir oranda olurken diğer yıllar için ise küçük bir oran kaydettiği gözlenmiştir.. Çalışma alanın uzun yıllar toplam yağış değerinin 739,8 mm olduğu tespit edilmiştir. Fakat yıllar arası yağış miktarındaki ciddi azalışlar birçok sektörü olumsuz etkilemektedir. Toplam yağış ile ortalama sıcaklıklar arasında bir ilişkinin (korelasyonun) olduğu saptanmıştır. Fakat su kaynaklarının uzak olmasından dolayı istatistiki açıdan anlamlılık göstermemektedir. Sıcaklık ve yağış arasında istatistiki açıdan anlamlılık görülmezken, nem kaynağı ile yağışlar arasında 0,790** düzeyinde, anlamlılık değeri 0,01 olacak şekilde güçlü bir ilişki söz konusudur. İstatistiki işlemler 0,403 değerine ulaştığından, doğrudan doğruya zayıf bir korelasyon vardır. İstatistiksel Mann-kendal denkleminin valiliğe bağlı tüm istasyonlarda (2000-2020) yükselme eğilimi gösteren çoğu istasyonda dalgalanma değeri gösteren yağış verilerine uygulanması, Duhok vilayetinin istasyonlarındaki yağış verilerinin gelecek tahmini, mevsimsel Holt Winters aracılığıyla ve çarpma mevsimsel modeline olan güven yıllar için 2022-2030.

Çalışma sonunda tüm iklim unsurlarını sürekli ve doğru bir şekilde okumak için gelişmiş ölçüm araçları sağlamayı ve valilik yönetimindeki tüm iklim istasyonlarında veritabanı oluşturma öne çıkan öneridir.

Anahtar Kelimeler : Yağış; İstasyonlar; Dalgalanma; İklim; Duhok; Arazi; Depresyon

ARCHIVE RECORD INFORMATION

Name of Thesis	Spatiotemporal Fluctuation of Rainfall in the stations of Duhok governorate between (2000-2020)
Author of Thesis	Jiwan Mohammed ABDULLAH
Advisor of Thesis	Prof. Dr. Mücahit COŞKUN
Degree of Thesis	Master Degree
Date of Thesis	15.08.2022
Field of Thesis	Geography
Place of Thesis	KBU/LEE
Number of Pages	213
Keywords	Rainfall; Stations; Fluctuation; Climate; Duhok; Terrain; Depressions

ARŞİV KAYIT BİLGİERİ

Tez Adı	Duhok Valiliği İstasyonlarında Yağışların Mekansal Zamansal Dalgalanması (2000-2020)
Yazar	Jiwan Mohammed ABDULLAH
Tezin Danışmanı	Prof. Dr. Mücahit COŞKUN
Tezin Derecesi	Yüksek Lisans Tezi
Tezin Tarihi	15.08.2022
Tezin Alanı	Coğrafya
Tezin Yeri	KBÜ/LEE
Tezin Sayfa Sayısı	213
Anahtar Kelimeler	Yağış; İstasyonlar; Dalgalanma; İklim; Duhok; Arazi; Depresyon

LIST OF ABBREVIATIONS

AD **:** Calendar year

Apr **:** April

Av **:** Average

Cm **:** Centimeter

Dec **:** December

E **:** East

Feb **:** February

GIS **:** Geography Information System

Jan **:** January

Jl **:** July

Jn **:** June

km **:** Kilometer

Km^2 **:** Square kilometers

m **:** Meter

Ma **:** May

Mar **:** March

Max **:** Maximum

Mb **:** Mill bars

Min **:** Minimum

mm **:** Millimeter

N **:** Number

Nov **:** November

Oct **:** October

Sep **:** September

SPSS **:** Statistical Package for the Social Sciences

URL **:** Uniform Resource Loader

WMO **:** World Meteorological Organization

Y **:** Year

Z **:** Result of Mann Kendall & Spearman test

° **:** Degree

°**C** **:** Celsius Temperature

% **:** Perce

INTRODUCTION

PRELIMINARY REMARKS

Rainfall analysis is important in different domains such as: agricultural planning, water resources plannings, runoff prediction, climatological studies, environmental studies, stream flow estimation and human life activitiesRainfall analysis is important in different domains such as: agricultural planning, water resources plannings, runoff prediction, climatological studies, environmental studies, stream flow estimation and human life activitiesRainfall analysis is important in different domains such as: agricultural planning, water resources plannings, runoff prediction, climatological studies, environmental studies, stream flow estimation and human life activities Rainfall analysis is essential for different domains such as agricultural planning, water resources, climatological studies, environmental studies, stream flow estimation and human activities. Variations of rainfall in regard to space and time are studied in this research. Thus, the study of climate change is considered an essential subfield of physical geography that deals with the scientific study of earth's climate. (Sharif, 1998).

Rainfall is one of the essential climatic elements. It is a water source for arid and semi-arid areas of the world. Rainfall is the most vital component of the climate. The amount of rainfall varies from year to year in all regions of the world, especially in semi-arid climate regions. These regions show wide-range fluctuations, which is significant to the future of the vital environment and human activities.

In general, the rainfall season begins in the study area at the beginning of October with the arrival of the air depressions and ends at the end of May, the end of the rainfall season. However, it extends to the mountainous regions until the end of June. The beginning of the rainfall season is linked to the beginning of the emergence of the activity of the depressions. The weather starts from October until May approximately.

IMPORTANCE OF THE STUDY

This study provides information on descriptive rainfall statistic and spatio-temporal variability; trend significance, and distribution of rainfall on different time and places. Climatic studies are seen as important in scientific and academic research. The climate of the study area of this research is a part of the Mediterranean climate, which covers all parts of Duhok Governorate, where rainfall occurs in winter. At the same time, summer is characterized by a dry and hot climate. Moreover, this study is expected to be of importance as, to the best of researcher's knowledge, there is no study that has worked in such phenomenon before. The fluctuations of rain emerge due to the impact of climatic factors such as low pressures, air masses, winds, atmospheric pressure, temperatures and humidity. The value of this study is reflected in determining the years of heavy and light amounts of rainfall throughout the specified period.

OBJECTIVES OF THE STUDY

The study aims to achieve a set of objectives as follows:

1. The general objective of this study is the spatial and temporal analysis of rainfall trends in Duhok governorate.

2. Evaluating the spatial and temporal variation of rainfall at different time scales

3. Exploring station-based trend analysis at different time scales.

4. Studying the factors that affect rainfall and its spatial distribution.

5. Predict future rainfall scenarios and assess their implication.

STATEMENT OF THE PROBLEM

The impacts of rainfall fluctuations are increasingly becoming a challenge for people in tackling water problems. Such issues are more evident and well-known due to changes in rainfall magnitude and intensities in different geographic locations. Changes in annual and seasonal rainfall affect water resources for agriculture production and overall economic growth. The main problem of this study is to figure out the amounts of rainfall fluctuation at the level of seasons and years in all stations of the study area, Duhok governorate.

HYPOTHESIS OF THE STUDY

This research hypothesizes the following:

H_o: There is a strong direct relationship between the variable of location and distance from the sea with the variable of rain in the study area.

H_a: There is no strong direct relationship between the variable of location and distance from the sea with the variable of rain in the study area.

H_o: The topography of the study area has a clear effect on the amount of rainfall on the monthly and seasonal levels.

H_a: The topography of the study area does not have a clear effect on the amount of rainfall on the monthly and seasonal levels.

H_0: There is a relationship between the rain variable and other climatic elements (temperature, humidity and atmospheric pressure).

H_a: There is no relationship between the rain variable and other climatic elements (temperature, humidity and atmospheric pressure)

H_0: There is a clear temporal fluctuation of the amount of rain from year to year between high and low.

H_a: There is no clear temporal fluctuation of the amount of rain from year to year between high and low.

H_0: The triple and five moving averages have periods of increasing and decreasing amounts of rain, and they are regular periods.

H_a: The triple and five moving averages have periods of increasing and decreasing amounts of rain, which are irregular periods.

H_0: The stations located in the mountainous region witness a noticeable rise in the monthly averages of the amount of rain, respectively.

H_a: The stations located in the mountainous region do not witness a noticeable rise in the monthly averages of the amount of rain, respectively.

H_0: The stations located in the plain region witness a noticeable decrease in the monthly averages of the amount of rain.

H_a: The stations located in the plain region do not witness a noticeable decrease in the monthly averages of rainfall.

LIMITS OF THE STUDY AREA

1. **Temporal Limits:** The study is limited to the period of 2000-2020AD due to the availability of the data of this period only.

2. **Spatial Limits:** The study was done in Duhok governorate, located in the far north and northwest of Iraq.

REASONS FOR CHOOSING THE STUDY

The motives for choosing this topic are:

1. The importance of climate change, especially rainfall changes and water resources.

2. The availability of rainfall data for a time series extending over twenty-one (21) consecutive years, which were regularly recorded on twenty (20) climatic stations to measure rainfall in different places within the limits of the study area.

3. Lack of applied climatic research specialized in temporal and spatial analysis in the study area using statistical programs.

4. Develop a future vision for the amounts of rainfall in the study area according to a model for analyzing rainfall forecasts during the coming years until 2030 AD.

STUDY METHODOLOGY

To achieve the objectives of the study, twenty climatic stations distributed over the study area were selected. The stations were Zakho, Darkar, Batofa, Bateel, Semel, Duhok, Zawita, Mangesh, Swaratoka, Sarsink, Bamarne, Chamanke, Amedi, KaniMasi, Deralok, Shekhan, Qasrok, Bardarash, Dinarta and Akre. The reason for choosing these stations is because these stations record the climate elements and data for the monitoring period (2000-2020). As a result of the security conditions in the region, the recordings of all stations were not completed before the year (2000), so the data through these (21) years were relied upon in the study and analysis in the thesis chapters. Therefore, the study has utilized the following approaches:

1. **The Descriptive Approach:** It depends on studying the geographic and climatic characteristics of the study area, especially rainfall, to show its density and distribution.

2. **The Regional Approach:** It deals with the study of rainfall amounts in a local framework, which is (Duhok Governorate).

3. **The Statistical Approach:** it is represented by studying the interrelationships between the spatial variables of rainfall, analyzing them by statistical methods, and determining the general trends of temporal and spatial variation in rainfall by following some statistical programs such as SPSS, GIS, Minitab and Excel. The following hypotheses were considered for testing the homogeneity of the mean:

The directions were determined by Mann-Kendall test.

The Mann-Kendall test is a commonly used method for determining the trend occurring in time series for study areas such as climatology and hydrology (Salamiet al, 2016). The Mann-Kendall test is a statistical method proposed by the World Meteorological Organization (WMO). In many studies on trend analysis, this method has demonstrated superiority among other methods used (Pielke, 2002 and Hendricks, 2015). The Mann-Kendall test statistic (S statistic) is formulated with the following equation:

$$s = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k)$$

The S value in the equation shows an almost normal distribution with the mean and variance values stated below in cases where n is greater than or equal to eight ($n > 8$). The value of n corresponds to the data length in the equation in years. If the value of n is greater than or equal to thirty ($n \geq 30$) the z test approaches the t-test. The sign function is indicated by a sign data test performed on an (xj) data set, which is sorted by a set of (xi) and (xj)data as specified in the following equation (Özfidaner, 2007).

$$sgn(x_j - x_k) = \begin{cases} 1 \;\; if \;\; x_j - x_k < 0 \\ 0 \;\; if \;\; x_j - x_k < 0 \\ -1 \; if \;\; x_j - x_k < 0 \end{cases}$$

The following equation determines the variance of S:

$$VAR(s) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right]$$

In the above equation, the numbers of the relative groups in the data set are denoted by the value of p and the connected observations in a series i are indicated by the value of t. The use of the collection term shown in the equation only occurs if there is observation in the data. The Z value that denotes the standardized Mann-Kendall test statistic can be calculated by the following equation (Özfidaner, 2007):

$$Z = \begin{cases} S > 0 \;\; \Rightarrow \;\; \dfrac{S-1}{\sqrt{VAR(S)}} \\ S = 0 \;\; \Rightarrow \;\; 0 \\ S < 0 \;\; \Rightarrow \;\; \dfrac{S-1}{\sqrt{VAR(S)}} \end{cases}$$

- The Holt-Winters prediction method predicted the future precipitation data in the Dohuk Governorate stations. There are several ways to smooth each method that corresponds to a particular type of time series data (stable and unstable); when the series is stable, it uses a simple single exponential boot method, but if the series shows a linear pattern that can be relied upon the Holt linear method or the exponential trend method, but when the seasonal pattern appears in the data, these methods give the wrong results for predicting, and to avoid this problem, another method of exponential preface is used. It has a triple exponential boot or holt winters seasonal method that relies on two data analysis models (Abdel, et al, 2012).
  - Multiplicative Seasonality Model $Y_t = M \times T \times C \times S \times I \pm E$
  - Additive Seasonality Model $Y_t = M + T + C + S + I \pm E$

DATA SOURCES

There are many sources of data on which the study relied, in line with the nature of the study’s objectives, including:

1. **Library Sources,** including books, references, master’s theses and doctoral theses, encyclopedias and geographical journals that deal with climate issues in general and the phenomenon of fluctuation in particular.

2. **Official and Semi-Official Sources** Official Sources include reports, statistics, and structural plans issued by government agencies, such as the Directorate of Meteorology and Seismic Monitoring and the Directorate of Agriculture in Duhok Governorate and the Department of Climate Statistics. At the same time, semi-official sources include reports, research and publications issued by research centers and studies Published in Arab and foreign courses.

3. Maps where the location of selected stations were determined accurately using the program (Arc Gis.10.4), by selecting the stations' astronomical locations (x, y) that are the study's focus.

PROGRAMS USED

1. **SPSS 23**. (Statistical Package for Social Sciences) It is a statistical program for the social sciences. It is an integrated computer package for data entry and analysis.

2. **GIS Software**. (Geographic Information System), it is a computer-based system that collects, stores, analyzes, outputs and distributes spatial data and information.

3. **Excel**. Excel is a spreadsheet program used to manage, analyze, and plan data.

4. **Minitab**. It is a program used to analyze data statistically, which is characterized by the feature of interpreting the results.

STUDY STRUCTURE

The research plan consisted of four chapters, in addition to the introduction, conclusions and recommendations, as follows:

The First Chapter. It covers the theoretical framework, including three sections. The first topic will be the definition of the study area. In contrast, the second topic is devoted to the types of rainfall in the study area. The third topic sheds light on the location analysis of the study stations according to the geographical environment (the plain and mountainous environment).

The Second Chapter. It is concerned with the natural determinants that affect the rainfall in the study area. It included two sections. The first section will deal with the constant climatic factors affecting the rain in the study area, including the astronomical and geographical location and the Topography in the study area. While the second topic focused on the (dynamic) climatic factors that affect rainfall, the most important are depressions, temperatures, atmospheric pressure and humidity.

The Third Chapter. This chapter covers the spatiotemporal rainfall fluctuation in the study area. It consists of two sections. The first section specified the temporal fluctuation of rainfall in the study area, which is divided into two parts: temporal fluctuation of the annual average of rainfall. The second part will be specified for the temporal fluctuation of the monthly rainfall averages. The second section will be devoted to the spatial fluctuation of rainfall.

Chapter Four. This chapter focus on the correlation between rainfall and other climatic elements, in addition to the statistical analysis of precipitation and their future predictions in the stations of Duhok Governorate. It includes three sections: The first topic was devoted to the correlation between rainfall and some other climatic elements, including temperature, humidity and atmospheric pressure. The second topic was a statistical analysis of rainfall data in the stations of Duhok Governorate. The third and final section, it is about future forecasts of rainfall in Duhok Governorate stations.

PREVIOUS STUDIES

Many geographical studies were involved in studying the climate of a selected region in a certain governorate. In fact, there are several scientific articles on Iraq in general and the climate of Duhok Governorate in particular. However, none of them investigates the spatiotemporal fluctuations of rainfall in Duhok Governorate in a precise and detailed manner See (Table 1).

Table 1. Previous Studies

Author	Year	Title
Al-Bayati	1985	The Climate of Iraq’s Border Governorates
Al-Shalash	1988	Iraq’s Climate
Al-Asadi	1991	The Recurrence of Atmospheric Depressions and Their Impact on Iraq’s Weather And Climate
Mihelan	1995	Spatial Variation of Temperature and Precipitation in the City of Greater Amman
Ghanem	1997	The Probability Ratios of Decimal Rain in Jordan (The Rainfall During a Period of 10Days)
Sharif	1998	Climate of the Erbil Region
Bidawid	2000	The Climate of the Highlands in Iraq
Abdelbaqi	2001	Phenomenology of the Upper Atmospheric Layers and Their Impact on Forming and Drafting the Climate of Iraq
Ghanem	2001	Analysis of Rainfall Probabilities in Arid and Semi-Arid Areas in Jordan
Al-Sumaida’i	2004	Modeling of Winter Rainfall in the Mountainous Region of Iraq Using Remote Sensing Data
Ibrahim	2008	Geographical Analysis of the Climatic Variation Between the Stations of Al-Qaim, Samarra and Khanaqin
Alnajmawi	2008	The Spatial Correlation of Precipitation North of Latitude (35) in Iraq
Alsamarayi and Jiwan	2008	The Effect of the Large amount of Rainfall in Northern Iraq
Cosun	2008	Climate in Kahramanmaras Trend Analysis of Chang
Siddiq	2009	Climatic Potentials of Duhok Governorate for Cultivating Grains
Alalusy	2009	Elements and Phenomena of Iraq’s Climate, Their Modern Characteristics and Trends
Hadi	2011	Climate Fluctuation and Its Impact on the Variation of the Boundaries of Climate Regions in Iraq,

Ibrahim	2012	Climate Changes to the Rains of the Egyptian Coasts, a Study in Climatic Geography
Taha	2013	Climate of Duhok Governorate - Study in Climate Geography
Al-Louh	2014	Temporal and Spatial Fluctuations of Rain in the West Bank and Gaza Strip During the Period (1995-2014)
Abdulrahman	2016	The Cold Polar Air Mass Affecting the Weather and Climate of Iraq
Anwar	2017	Modeling and Analyzing the Effects of the Rainfall Intensity on Runoff in Duhok City-Iraq as Urban Watershed Using TR-55 & HMS Applications
Coşkun and Akbaş	2017	From Black Sea Coastal to Inland: Climatic Parameters of Kastamonu Surroundings
Yılmaz	2018	Trend Analysis of Temperature and Precipitation Data in Western Black Sea Region of Turkey
Özbunar	2019	Trend Analysis of Temperature Parameters of Florya, Sarıyer, Kumköy and Şile (İstanbul) Stations
Aljubouri	2019	Geographical Analysis of the Rainfall Characteristics of the City of Kirkuk
Coşkun	2020 a	The Trend Analysis of Average Temperature, Rainfall and Flow Datas of Kura-Aras Closed Basin (Turkey)
Coşkun	2020 b	Trend Analysis of Painting in Van Lake Closed Basin
Soliman	2020	Trend Analysis of Temperature and Precipitation in the Northern Part of Libya
Palani	2020	The Impact of El Nino and La Nina on Some Climate Elements at Sulaymaniyah Station in the Kurdistan Region of Iraq During the Period (2008-2018)
CoşkunGözalan, Öztekinci, and Coşkun, S.	2022	Trends in the Number of Tropical Days - Summer Days in the Susurluk Stream Basin and Modeling Under the RCP 8.5 Scenario, (in Turkish)

Al-Bayati (1985), “The Climate of the Border of Iraq's Governorates”. This study dealt with the prevailing climatic characteristics in (6) governorates. The study was concerned with the climatic conditions of the eastern border stations from north to south, approaching Erbil Governorate to Basra. In this study, constant and dynamic climatic factors affected the study area's climate, depending on the analysis of the temporal and spatial distribution of climatic elements such as temperature, atmospheric pressure, wind, precipitation and other weather phenomena.

Al-Shalash (1988), “Iraq’s Climate” Translated into Arabic. The study included the phenomena that dominate the climate of Iraq, which were represented by the geographical location, astronomical location, altitude above sea level, atmospheric pressure, and other elements.

Al-Asadi (1991), “The Recurrence of Atmospheric Depressions and Their Impact on Iraq’s Weather and Climate”. This Master’s thesis in 1991 was concerned with the study of the atmospheric depressions in Iraq, emphasizing that the frontal and Mediterranean depressions affected the northern region of Iraq where the Mediterranean depressions cause cold waves and Sudan and the combined pressures cause high temperatures that heat.

Mihelan (1995), “The Spatial Variation Of Temperature and Precipitation in the City of Greater Amman”. It was based on the climatic data of twelve stations spread in the city of Greater Amman for the period (1960-1994), using the analysis of variance. It was found that the longitudinal factor was the main factor that affected the difference in the average of rainfalls from one region into another in Amman, that the concentration of most snowfall in the months of (January and February) was due to the low temperature in these two months due to the cold polar air masses rushing towards the south and meeting the warm air masses over the Mediterranean Sea, which lead to the increase in the formation and deepen the depressions that affect Jordan.

Ghanem (1997), “Probability Ratios of Decimal Rain in Jordan(The Rainfall During 10 Days)”. In five stations distributed over the geographical regions in Jordan, the results showed that the percentages of the probability of wet periods in the stations, where the annual rainfall rate was less than (200) mm, was small if compared with the stations where the rainfall rate was more than that. It was also found that the length of the return periods increased as the increased in the amount of rain.

Sharif (1998), “Climate of the Erbil Region”. It was a doctoral thesis concerned with the study of the local climate in Erbil region by comparing the climate of the city center, the outskirts, the suburbs, the mountain and the countryside, and the variations of its components

Bidawid (2000), “The Climate of the Highlands in Iraq”. The study focused on analyzing the reasons for the discrepancy in the climatic elements between these stations in order to reach the effect of the geographical location and the altitude of the terrain on the variation in the rates of the climatic elements of stations.

Abdelbaqi (2001), “Phenomenology of the Upper Atmospheric Layers and Their Impact on Forming and Drafting the Climate of Iraq”. It investigated the correlation of upper weather phenomena with the movement and effectiveness of surface systems and the variance of their climatic elements, including the Sudanese and seasonal thermal depressions with high frequency in summer and associated with upper air dents. These contributed to the significant reduction of total rainfall rates over the country, which was related to drying the accompanying masses up, especially during the months of June, July and August.

Ghanem (2001), “Analysis of Rainfall Probabilities in Arid and Semi-Arid Areas in Jordan”. This study analysed monthly and annual data available for the longest period in eight rain monitoring stations in the arid and semi-arid regions of Jordan. It considered the probabilities of precipitation in desert and semi-desert areas based on precipitation data analysis.

Al-Sumaida’i(2004), “Modeling of Winter Rainfall in the Mountainous Region of Iraq Using Remote Sensing Data” . It became clear through this study that the Mediterranean depressions and air masses were the main cause of rainfall in the study region, accompanied by high mountain ranges and their axes variation

Ibrahim (2008), “Geographical Analysis of the Climatic Variation Between the Stations of Al-Qaim, Samarra and Khanaqin”. The study analysed the spatial variation of the climatic elements between the stations located on one geographical latitude. It was assumed that the stations were equal in their recordings of the climatic elements and concluded that the integrated models could not be reached to identify the most extreme stations or the ones that tended towards positive moderation. It turned out that most of the variations were explained by the local factors. These factors are the altitude above sea level, the percentage of reflected radiation, the surface shape, the type of prevailing wind direction, the nature color of the soil and the location of the station. They also represnt the kinetic climate factors such as pressure distributions, the movement of atmospheric depressions and their paths, and the type of air masses to which the stations are exposed.

Alnajmawi (2008) "The Spatial Correlation of Precipitation North of Latitude (35) in Iraq". Precipitation is the basis of life due to the diversity of its uses and the increasing demand for it to meet human needs, especially after the technological revolution and the population explosion. People began trying to invest in every drop of water by building dams on rivers and creating artificial lakes to invest in water in times of scarcity. They also began to dig canals and ponds to collect rainwater. This was done in areas where surface water is not available as in the regions of dry climate, where they are fluctuated between the humid and desert climate, with periods of declining precipitation.

Alsamarayi and Jiwan (2008) "The Effect of the Large amount of Rainfall in Northern Iraq". The high amount of rainfall in northern Iraq made it a distinct climatic region in terms of agriculture, tourism and water potentials. The northern region depends on rainfall for its cultivation, and there are successful tourist possibilities, especially in summer, and it also provides large quantities of water to Tigris. this is what gives the region exceptional climatic importance due to its altitude .

Cosun (2008),"Climate in Kahramanmaras Trend Analysis of Chang". Because of its multifaceted effects, climate change is one of the most important problems on which intensive research has been carried out till today. In general, climate change can be defined as 'Long-lasting and slowly developing changes in climatic conditions, whatever the cause, with large-scale and significant local effects'.

Siddiq (2009), presented a study about "Climatic Potentials of Duhok Governorate for Cultivating Grains". This study focused on studying the variation in climatic requirements for crops of winter and summer grains, rice, and yellow corn. The study concluded that the governorate occupied winter grains in cultivated areas with the gradation of ranks according to the quality of the crops. The study also concluded that the capabilities of Duhok Governorate to grow summer crops were appropriate with the climatic elements, while they were not suitable with some winter crops, but some conservative climatic characteristics negatively affected the cultivation of all winter and summer crops.

Alalusy (2009), "Elements and Phenomena of Iraq's Climate, Their Modern Characteristics and Trends", The study, which extended for thirty years (1978-2007) and included ten climatic stations, showed that there are three factors that affect in different ways, the climate of Iraq (88-89%). This indicates Iraq is the farthest from the navy. The second factor was the kinetic factor, which was responsible for the fluctuation of climatic elements and, thus the climate changes.

Hadi (2011), “Climate Fluctuation and Its Impact on the Variation of the Boundaries of Climate Regions in Iraq”. The study aimed to identify the extent of the fluctuation impact on the annual change in the borders of the climatic regions in Iraq. A sample of nineteen climatic stations was chosen to represent the sections (1970-1971 /1999- 2000), as the calculation of the total annual rainfall was based on a rainy year starting from October to May and not on a calendar year. On this basis, annual average temperatures were also calculated from September to August. The values of the fluctuations were calculated according to the standard degree and the amount of its deviation from the average. It was found that there is fluctuation in the rates of temperature and the amounts of rain from one year into another.

Ibrahim (2012), “Climate Changes in Rains of the Egyptian Coasts, a Study in Climatic Geography”. Part from its extreme patterns, recurrence rates, and intensity through the use of a large number of statistical calculations and mathematical equations, as it was relied on (26) climatic stations and for the period (1951-2006), the study came up with a large number of results, the most important of which was the presence of seasonal rain in the Egyptian coasts. The majority of stations were characterized by a clear equalization in the distribution of rain during winter. There was no change in the period of concentration of coastal rain, although there was a decrease in the quantities of the rainfalls, as it turned out, a relationship between coastal rain changes with the most important fluctuations of air cycles. In addition, there was a correlation with the phenomena of the North Atlantic Oscillation.

Taha (2013), “Climate of Duhok Governorate - Study in Climate Geography” master thesis in 2013. The study analyzed the climatic characteristics of Duhok Governorate and clarified the most important climatic elements affecting the region’s climate through annual, seasonal and monthly data of climatic elements represented by (precipitation, solar radiation, temperature, atmospheric depression, wind, evaporation and relative humidity). The analysis was applied to ten climatic stations, including agricultural stations, distributed over the province by providing it with complete data of these elements. The monitoring period for the stations was from (2001-2013).

Al-Louh (2014), "spatiotemporal Fluctuations of Rain in the West Bank and Gaza Strip During the Period (1995-2014)". The study aimed to clarify the temporal fluctuations in the amounts of rainfall in the study area. It also aimed to know the spatial differences between the rainfall stations and determine the nature of annual rainfall changes and the factors affecting the fluctuation of rainfall. The results showed the clear time fluctuation of the amount of rainfall from one year to another, where it recorded a large rate for some years and a small rate for others, negatively affecting life activities. The annual average of the temporal fluctuation of rainfalls in the West Bank governorates was about 478.6 mm between (1995-2014) with the rainfall regression in which the rate of decline was about (3.5) mm. As for the governorates of Gaza Strip, the annual average amount of rainfall was about 352.2 mm, with a downward trend in which the decrease was about (-2.3). In 1995, it recorded the highest amount of precipitation.

Abdulrahman (2016) "The Cold Polar Air Mass Affecting the Weather and Climate of Iraq". The research aimed to study the polar, continental and marine air masses affecting the climate and weather of Iraq for 11 years mini-climate cycle starting from 1992 to 2002. Three climatic stations were selected representing the sections of the surface of Iraq: Mosul, Baghdad and Basra. This study was based on the analysis of the (Synoptic) maps of the surface pressure level of 1000 millibars and the upper pressure of 850 and 500 millibars for the two (00) nighttime (1200) daytime observations.

Anwar (2017), "Modeling and Analysing the Effects of the Rainfall Intensity on Runoff in Duhok City-Iraq as Urban Watershed Using TR-55 & HMS Applications". The watershed of Duhok city was selected as a case study to model and analyze the effects of rainfall intensity on the runoff of this urban basin using two main contributions, TR-55 & HMS. The importance of studying this watershed in the city was to experience very fast urbanization in the northern region of Iraq, using the capabilities of modern technology to predict any future floods and stormwater in the center of Duhok.

Coşkun and Akbaş (2017), "From Black Sea Coastal to Inland: Climatic Parameters of Kastamonu Surroundings". A decrease in the amount of precipitation was observed from north to south. It was not possible to examine the entire research area in one category in terms of precipitation regime. In light of the data obtained from stations on the coast, it was noted that the precipitation regime of the Black Sea was seen even on the south-facing slopes of the Kor Mountains. It was also noted that the internal parts did not meet the characteristics of this precipitation regime and were similar to the precipitation regime of Eastern Anatolia with continental influence. The increase in rainfall especially in May in Azdavay, Devrekani, Kastamonu Merkez, Küre and Tosya stations supported this situation.

Yılmaz (2018), "Trend Analysis of Temperature and Precipitation Data in Western Black Sea Region of Turkey". The research aimed to analyze trends in the averages, the maximum and minimum average in temperatures and total average of precipitation for meteorological stations located within the boundaries of the western black sea region that have the necessary qualifications, and to reveal the trend and magnitude of specified trends .

Özbunar (2019), " Trend Analysis of Temperature Parameters of Florya, Sarıyer, Kumköy and Şile (İstanbul) Stations". The study found that the difference in temperature in the center of cities was higher than in the rural areas. Surface materials, roads, buildings and the industrial regions cause temperature changes in the city. The sunlight falling on the surface reflects back only 10%. The values of temperature, humidity and air masses in urban centers were lower than the ones in the regions.

Aljubouri (2019), "Geographical Analysis of the Rainfall Characteristics of the City of Kirkuk". The rain fluctuation is the first characteristic in the city of Kirkuk. It varied from month to another, but it increased as winter approaches, especially in December. The second month was the rainiest month of the year, in terms of rate and frequency, followed by February, then December. The total annual rainfall varied greatly from one year into another. This was indicated by measuring depression, such as the rate of deviation, which amounted about 3.106 and The standard, which amounted about 4.126. The general trend of these rain totals is decreasing.

Coşkun (2020a), "The Trend Analysis of Average Temperature, Rainfall and Flow Datas of Kura-Aras Closed Basin (Turkey)". The average temperature, total precipitation and flow values obtained from flow monitoring stations at State Hydraulic Works the Directorate General of Meteorology measured in the enclosed basin of Aras Kura were analyzed by statistical methods and their trends were calculated. Significant warming was observed in average temperatures throughout the basin, especially in spring and summer, both annually and seasonally.

Coşkun (2020b), "Coşkun,S 2020b Trend Analysis of Painting in Van Lake Closed Basin". According to the results obtained, there was a decrease in annual precipitation in Gevaş and Ahlat stations, while there was an insignificant increase in Van-Region. Seasonally, a significant decrease was detected in Erciş and Ahlat stations, while a negligible increase was observed in Van-Region. However, the downward trend in both annual and seasonal precipitation was across the basin, while a negligible increase was observed in Van Region station.

Soliman (2020), "Trend Analysis of Temperature and Precipitation in the Northern Part of Libya". The variability of years in temperature in the North African region is complex and is controlled by many factors, such as changes in the state of the climate system and the external natural causes (e.g variation in outside solar places and sun pots) and/or internal (e.g , atmospheric compositions, atmospheric and ocean oscillations and volcanic activity).

Palani (2020), "The Impact of El Nino and La Nina on Some Climate Elements at Sulaymaniyah Station in the Kurdistan Region of Iraq During the Period (2008-2018)". Through analyzing the data of temperatures, rain amounts, and El Niño and La Niña data for the mentioned period of the climate station in Sulaimaniyah, the study results revealed a direct correlation between the fluctuations of the El Niño and la Niña phenomena and similar fluctuations in temperatures and the amount of precipitation in the study area. As the amounts of precipitation and temperatures increased with El Nino seasons, while temperatures and the amount of precipitation decreased with la Nina seasons in the study area.

Coşkun, Gözalan, Öztekinci, and Coşkun, (2022), "Trends in the Number of Tropical Days - Summer Days in the Susurluk Stream Basin and Modeling Under the RCP 8.5 Scenario". The study aimed to determine the direction and severity of the trends in the number of tropical and summer days in the Susurluk Stream Basin due to the warming that occurred in Turkey according to climate changes. The study contributed to the Turkish literature on examining tropical and summer day changes, as well as providing a database for tropical fruit cultivation and watershed management studies, which are increasingly produced in suitable areas.

1. THEORETICAL FRAMEWORK

1.1. Definition of the Study Area

Duhok governorate is one of the bordered governorates located in the far north and northwest of Iraq. It is bordered by the Turkish Republic from the north, the Syrian Arab Republic from the west, Erbil Governorate from the east and Ninawa Governorate from the south and south-west. (Siddiq, 2009). This location provides it with an important strategic location as it connects with the most of the provinces of the region and Iraq on the one hand, the outside world on the other. It has natural borders with neighboring countries and a governorate represented by mountains and rivers. It rises in its northern parts nearly between (3000-3500 m) above sea level, while there are low parts, not more than (400 m) above sea level. In general, it can be said that the lands of the governorate increase in height as we advance towards the north and north-east. The reason behind this is the governorate location at an altitude of (705 m) above sea level. It also reaches its northern parts according to the location of the climatic stations as in the station of Amedi to (1210 m) decreases in its southern parts to (379 m), as in the Bardarash station.

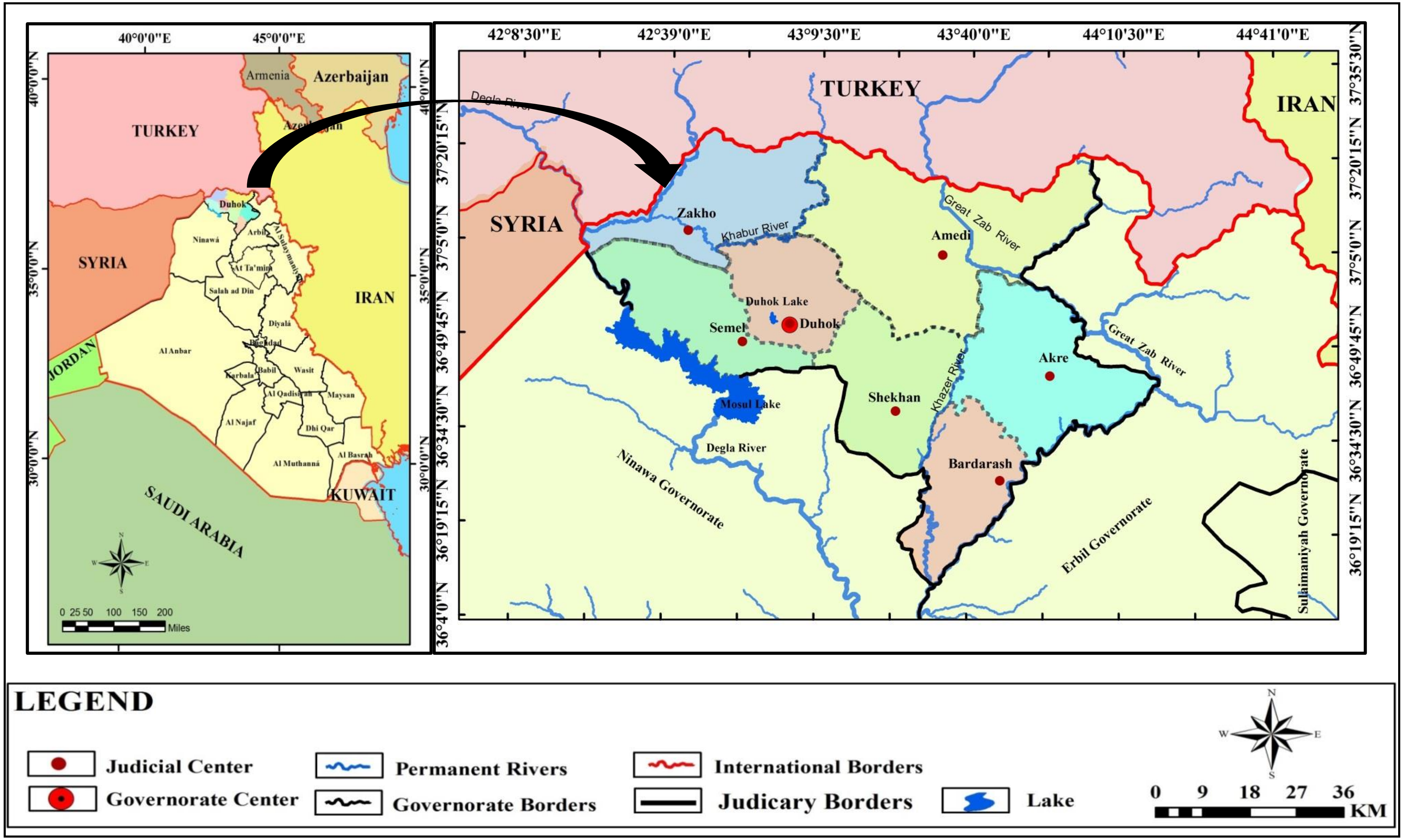
The area of Duhok Governorate is (11011) km^2, the general shape of the study area is an irregular rectangle, located between longitudes (42°8′ 30″E,44° 41′ 0″ E) in the north, between two latitudes (36° 19′15″N, 37°35′40″ N) to the east, Duhok governorate consists of seven districts: (Duhok, Semel, Zakho, Akre, Shekhan, Amedi, Bardarash), with a clear difference in areas, as the district of Amedi occupies the largest part of the area of the governorate, where its percentage reaches about (25.30%), while the Duhok district is one of the smallest districts, as it constitutes an area of (9.20%), this shown in (Table 2)(Map 1).

Because the geography of the study area is tectonically due to the Zagros mountain system in the northeast, there are great differences between it and the southern and central regions of Iraq in terms of natural features. The tectonic condition is one of those factors. The history of the study area dates back to the Mesozoic era. There are several geological formations in the area, including the Pilaspi Formation. There are some important plains in the region, such as (Sindi plain, Slivany plain, Setik plain and Khazar plain). In general, the plain areas constitute the most important topographical parts of the study area because they are rich in soil. The widest types of soil in the study area are litosol soil and its agricultural resources. A large part of the agricultural products of Iraq in general and the study area in particular may be produced. There is a significant difference between the natural plant species in the lower parts compared to the higher parts in the study area. This difference is also due to the influence of climatic factors such as (rainfall, temperature and humidity) as well as the effects of landforms, altitude, and direction of inclination on the surface of the region (Murad, 2020). As well as an impact on groundwater which is considered one of the most aspects of the natural environment affected by the amounts of rain. The fluctuation of rain reduces the amount of rain lost to the Al-Jawf water reservoir(Ibrahim, 2012).

Table 2. The Astronomical Locations (Coordinates) and the Area of the Districts of Duhok Governorate

Districts	**Longitude**	**Latitude**	**Area of the Districts iskm^2**	**Rate %**	**Height/m**
Duhok	°43′02	°36 ′52	1014 km^2	9.2	569
Semel	°42 ′50	°36 ′51	1450 km^2	13.3	381
Zakho	°42 ′44	°36 ′08	1375 km^2	12.4	442
Akre	°43 ′53	°36 ′44	1414 km^2	12.8	716
Shekhan	°43 ′18	°36 ′42	1833 km^2	16.6	520
Amedi	°43 ′29	°37 ′05	2774 km^2	25.3	1210
Bardarash	°43 ′35	°36 ′30	1151 km^2	10.4	379

Source: Northern Iraq Province, General Directorate of Meteorology and Seismic Monitoring in the city of Dohuk, data on the locations of weather stations



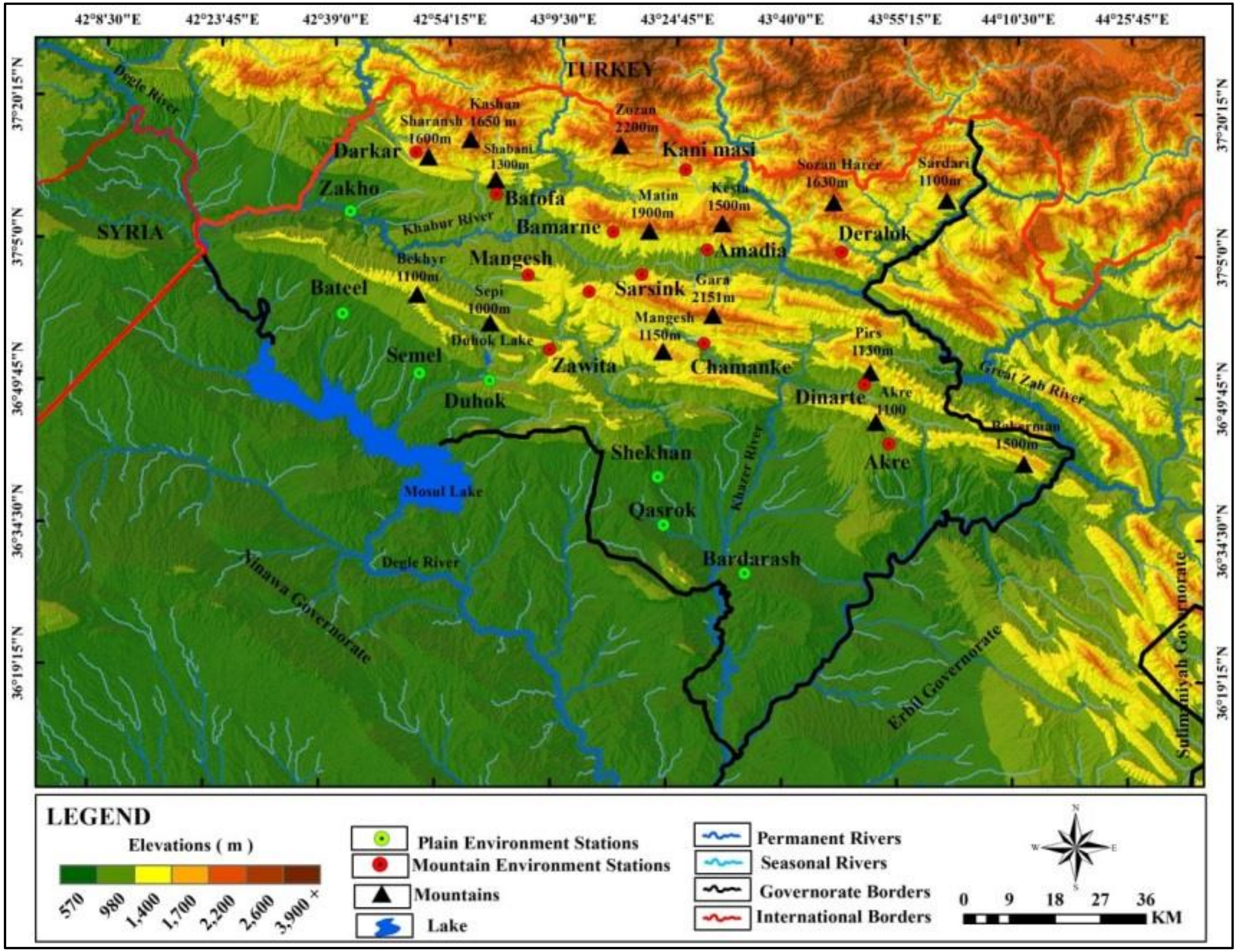
Map 1. The Location of Duhok Governorate in Relation to Iraq

Duhok contains (20) climatic stations distributed geographically across the governorate. These stations are located in different administrative units in their areas. The nature of their surface and other natural characteristics are relied on the to give a description of the rainfall element in the study region. The stations were selected based on the presence of records of the largest number of climatic elements in general and the rainfall element in particular, as it is one of the most important climatic elements in the study area. As shown in (Table 3) and (Map 2).

Table 3. Some Characteristics of Climatic Stations in the Study Area

Station	Longitude	Latitude	Altitude(m)	Data Period
Zakho	°42′41	°37′08	435	2000 – 2020
Bateel	°42′00	°36′50	510	2000 – 2020
Semel	°43′34	°36′45	456	2000 – 2020
Duhok	°43′00	°36′50	469	2000 – 2020
Shekhan	°43′20	°36′50	486	2000 – 2020
Qasrok	°43′40	°36′34	400	2000 – 2020
Bardarash	°43′31	°36′30	365	2000 – 2020
Zawita	°43′09	°36′54	890	2000 – 2020
Mangesh	°43′04	°37′02	948	2000 – 2020
Swaratoka	°43′13	°37′00	1211	2000 – 2020
Amedi	°43′29	°37′05	1202	2000 – 2020
Sarsink	°43′21	°37′07	1019	2000 – 2020
Bamarne	°43′15	°37′07	1220	2000 – 2020
Kani masi	°43′26	°37′13	1340	2000 – 2020
Chamanke	°43′41	°36′93	1000	2000 – 2020
Deralok	°43′65	°37′05	1600	2000 – 2020
Akre	°43′51	°36′43	636	2000 - 2020
Dinarta	°43′59	°36′57	771	2000 - 2020
Batofa	°43′00	°37′10	1300	2000 - 2020
Darkar	°42′82	°37′19	1670	2000 - 2020

Source: Northern Iraq Province, General Directorate of Meteorology and Seismic Monitoring in the city of Dohuk, data on the locations of weather stations



Source: From the Researcher's Work Based on the Data of (Table 3)

Map 2. Topography of Dohuk Governorate and how Stations are Distributed in the Plain and Mountainous Environment

1.2. Types of Rainfall in the Study Area

Rainfall is an important part of the water cycle in nature, which begins with the evaporation of water from large water bodies, soil and plants due to high temperatures. As a result of the lightweight of water vapour, it rises to the upper layers of the atmosphere. It condenses in the form of clouds until the appropriate conditions are available for it to return to its liquid state and condensation in the form of precipitation (Alsol, 2007). Precipitation is one of the manifestations of the condensation of water vapor in the atmosphere. It arises from water droplets of different sizes inside the cloud, whose diameters range between (0.5-5) mm. In order to rain, it should decrease the air temperatures and high humidity in the air (Alalusy, 2009). The rainfall starts when the components of the cloud become unstable, and then the drops gradually grow until they become large enough to begin to fall. The types of rainfall in the study area can be divided according to how the air is raised to the top, as follows:

1.2.1. Rainfall Frontal Cyclone

This type of precipitation is one of the most common type in the study area, which is resulted from the Mediterranean and the Atlantic Ocean depressions. This type of precipitation is characterized by its abundance and continuation for a long time. (Kerbal & Wali , 1986). These rains, which last for long periods of time, are very valuable in terms of agricultural activities and groundwater. (URL1) The topography of the study area plays an influential role in increasing the amount of this type of precipitation. Mediterranean and Atlantic depressions often lose their moisture content and effectiveness (Kerbal & Wali, 1986). The frontal depression consists of two main fronts:

1.2.1.1. Warm Front

This type arises when the warm air mass invades the area occupied by the cold air mass. The warm air begins to move slowly to push the cold air (Robert E. Gable. James F. Petersen & L. Michael Trapasso, 2004). Accordingly, the mass of warmer air is less dense and rises above the mass of cooler air (URL2), which tries to stay in contact with the Earth's surface, so the warm front's slope is much less than the slope of the cold front. Warm air can rise one meter to a vertical level for each of (100 to 200) meters to a horizontal distance. Thus, the frontal lift develops but is not as large as what occurs along the cold front (Robert E. Gable. James F. Petersen & L. Michael Trapasso, 2004). Because warm air hardly slides over cold air by a process called overrunning. (Danielson, et al, 2003), the warm air is often humid, so it does not rise much to form stratigraphic clouds. Rainfall begins to fall in the form of drizzle covering a large area for a period exceeding (12) continuous hours.

1.2.1.2. Cold Front

This front is caused by the cold air mass moving forcefully on the warm air mass, pushing it up. The colder and denser air replaces warm air on the surface pushing it strongly to rise, the cold front is usually steeper than the warm front which is able to raise warm air to a vertical level of one-meter per (40 to 80) meters for horizontal distance (Gabler, R. E., Robert. J. S, Daniel. L& Wise, 1997). If the warm air mass is unstable and has high moisture content, it causes severe thunderstorms, hailstorms, snowstorms and tornadoes (URL3). That coincides with cumulus clouds to develop afterwhile into funnel clouds with vertical growth causing hail rainfall for a short time and covering a small area. The mechanism by which the frontal depression develops represents the warm air rushes to the surface of the dividing front between cold and warm air masses in the form of successive waves. Thus, one develops after its emergence swells and attracts warm air forming a “warm sector” in the middle of the cold air. As a result of the rotational motion of the earth, the wind gains in this wave a hurricane movement and the warm air begins to rise. While the cold air penetrates below trying to raise it, when the warm sector area of depression decreases,all air will be raised and be faded. (Shahada, N.1996).

1.2.2. Terrain Rainfall

This type of precipitation prevails in the mountainous region represented in the northern and northeastern parts of Duhok Governorate. The terrain rains in the study area are characterized by their abundance in winter. This type prevails in the mountainous region, which traverses a height of more than (1200 m) above sea level, which includes the station (Amedi, Bamarani, Kani Masi, Deraluk, Bativa, Durkar), or the area between the mountain range Gara and Mateen range, this type of precipitation develops as a result of mountain heights obstructing the path of the wet wind perpendicular to its path. Hence, the warm, moist air passes this obstacle, so it rises strongly to the top, and its temperature drops due to self-cooling and reaches the dew point, and it begins to condense forming funnel clouds. Since rising air increases the cloud's saturation and prevents the fall of drops, it is often accompanied by lightning, thunder and hail. Thunderstorms are generated due to air raising strongly above the height (Park, 2003). It rains on the side facing the wind. When the wind falls on the back slopes, it is dry, so the area where the wind descends is described as (Rain Shadow), due to the force resulting from the air , the air compresses and heats up itself, its temperature rises above the dew point, so evaporation activity increases, and the relative humidity decreases on this side compared to the side facing the wind. There is also a type of terrain rainfall that develops as a result of the frontal low pressures, when the mountainous heights obstruct the path of the frontal low pressures heading east and perpendicular to them, which contributes to the survival of these depressions for a longer period over the mountainous heights, causing a precipitation called (cyclonic - terrain). The mountainous regions benefit from the small depressions more than others at the beginning of the rainy season.

1.2.3. Upward Rainfall

This type of precipitation is common in the study area in the two transitional seasons (spring and autumn) because the surface of the earth is affected by heating, so the warm air begins to rise to the top due to the activity of the convective currents that are developing. As a result of its rise, it is subjected to self-cooling, and its temperature decreases to reach the dew point, and condensation occurs, then the water vapor releases its latent heat and cumulus (CU) clouds are formed, which develop into cumulus (CN). Precipitation will be heavy for a period ranging from (30 to 60) minutes in a small area not exceeding (20 to 50) km^2 (Barry,R. Richard,J. 2003). This type occurs in cases including the decline of a cold air mass on a warm land due to the spring heat or the passage of the cold front from the Anatolian plateau to the back of the warm front. In all these cases, an imbalance occurs by relying cold air on less dense warm air. The warm air erupts upwards, forming Cumulus (CU) and Cumulonimbus (CN) clouds, resulting in heavy rainfall in the form of intense showers within a short time accompanied by lightning and thunder.

1.3. Analysis of the Location of the Stations of the Study Area According to the Geographical Environment

The meteorological stations occupied a vital space within the climatic and anaerobic studies regarding their relationship to geography. The situation of the station take a wide dimension in global and regional studies, especially after the establishment of the World Meteorological Organization (WMO) in (23 March 1950). This organization was responsible for issuing bulletins, courses and research related to the establishment of stations, their purpose, the nature and mechanism of their work, their types, the nature of measurement, devices types, and the geographical and astronomical position of the station's. However, the difference between countries in various geographical characteristics such as the nature of the prevailing climate, topography, the nature of the surface, natural vegetation, and soil quality, led to a clear discrepancy in the application of measurement specifications for the network of remote stations and thus the nature of the distribution of these stations and sometimes in the method or units of measurement and its time. However, there is almost complete global consensual of foundations and rules for collecting, and preparing spatiotemporal data and readings for these stations, internationally accredited according to the scale of the World Meteorological Organization.

According to the anaerobic stations in the study area, the total number of approved stations, according to the Directorate of the Meteorological Department in Duhok Governorate, is (23) stations. These stations were generated randomly according to the city or region's needs. As its geographical distribution lacks the approved international conditions and standards, the opinion of specialists (in climatic geography in particular) was not taken in setting these stations within the basic design of the city and the nature of its connection with other stations, as well as the area that each station must cover and as a result it was established in quiet neighborhoods and urban areas. It has become overcrowded and full of human activity, which affected the data in the station and some other factors, the most important of which is the terrain nature, which must be taken into consideration, especially in the study area, where the terrain varies (Abed, 2015). The amount of rainfalls in different stations with their heights rises due to the station's height above sea level. It is noted through the distribution of the climatological stations in the study area that they are located in different terrain areas and environments, including mountainous, plain, and areas located on the edges of forests. The variation in elevation is the main feature between the stations. For example the Darkar station is located on a land that rises (1670 m) above sea level. Whereas the Bardarash station is located on a plain whose height does not exceed (365 m) (Taha, 2013). Before entering into the analysis, it is necessary to mention to an important point related to the data of the stations, the stations that were selected for the study are (20) as in (Table 4). Despite the presence of (23) stations in the area, they were chosen on the basis of the presence of a recording of the largest number of climatic elements in general and rainy element in particular. As a result of the security conditions in the area, the recordings of all stations were not continuous, so there are many shortcomings in the recordings. The location of the study stations were divided according to the geographical environment in the study area as in the following:

Table 4. Selected Meteorological Stations in the Study Area for the Period Between (2000-2020)

Plain Environment Stations				
Station	Longitude	Latitude	Altitude(m)	Founding Year
Zakho	°42′41	°37′08	435	1972
Duhok	°43′00	°36′50	469	1974
Bateel	°42′00	°36′50	510	1991
Shekhan	°43′20	°36′50	486	1998
Semel	°43′34	°36′45	456	1999
Bardarash	°43′31	°36′30	365	1999
Qasrok	°43′40	°36′34	400	2000
Mountain Environment Stations				
Station	Longitude	Latitude	Altitude(m)	Founding year
Sarsink	°43′21	°37′07	1019	1970
Amedi	°43′29	°37′05	1202	1971
Zawita	°43′09	°36′54	890	1979
Akre	°43′51	°36′43	636	1982
Dinarta	°43′59	°36′57	771	1996
Kani masi	°43′26	°37′13	1340	1997
Swaratoka	°43′13	°37′00	1211	1998
Bamarne	°43′15	°37′07	1220	1999
Deralok	°43′65	°37′05	1600	1999
Batofa	°43′00	°37′10	1300	1999
Mangesh	°43′04	°37′02	948	2000

Chamanke	°43′41	°36′93	1000	2000
Darkar	°42′82	°37′19	1670	2000

Source: Northern Iraq Province, General Directorate of Meteorology and Seismic Monitoring in the city of Dohuk, data on the locations of weather stations

1.3.1. Station Located in the Plain Environment

1. Zakho Station

It is located in the center of Zakho district in the western part of Duhok governorate, in the plain region, which is one of the surface divisions in the northwestern part of the region in northern Iraq. It contains all the devices for measuring the elements of the climate. Zakho station is located in the south of the flat plain. Zakho station covers an area of (125 km^2). The station is open in an area surrounded by buildings and not close to a wide water body or a forest, see (Table 4)(Map 2)

2. Duhok Station

It is located in the center of Duhok at the southern part of the governorate center. It covers an area of 65 km^2.

3. Bateel Station

Bateel station is located in the center of Bateel subdistrict of Semel district. It was established by the Agricultural Organization (FAO). The station is located within an open plain area consisting of a vast plain area. It is famous for its fertility and abundant water, especially the Silevaney Plain and the Doban Plain. The station site covers an area of (231 km^2).

4. Shekhan Station

Shekhan station is located in the center of Shekhan district. It was built and operated within the Iraqi network of weather stations. The station was damaged several times and was rehabilitated and operated again. The station covers an area of (336 km^2).

5. Semel Station

Semel station is located on the outskirts of Duhok city. It covers an area of (200 km^2) located in the middle of open plains, surrounded by few buildings.

6. Bardarash Station

Bardarash station is located in the center of Bardarash district in the southeast of Duhok governorate. It belongs to the directorate of agriculture in Duhok and is established by the ministry of agriculture in northern Iraq. The station covers an area of (285 km^2) located within an open plain area.

7. Qasrok Station

Qasrok station is located in the east of shekhan district. It covers an area of (487 km^2) located within an open plain area.

1.3.2. Stations Located in the Mountainous Environment

1. Sarsink Station

It is situated in the south of Amedi district, at the foot of mountain Gara. The station contains some instruments to measure some elements of the climate, see (Map 2).

2. Amedi Station

It is located in the center of Amedi District. The station was established by the Food and Agriculture Organization of the United Nations (FAO) and contains devices for monitoring and measuring the elements of the climate. The station covers an area of (11 km^2).

3. Zawita Station

It is located in the center of Zawita district, one of the sub-districts of the Duhok district. The height of this station creates discrepancies between it and with stations, especially in temperature and precipitation. The station covers an area of (14 km^2).

4. Akre Station

This station is located in the center of Akre district which is in the southeast part of the center of Duhok governorate. It was built and operated within the Iraqi meteorological station network. The station was damaged several times and was rehabilitated and operated again with an area of (53 km^2). It records most of the climatic element around the clock, and this information is sent to the weather forecast center in the Department of Agriculture once every three hours with an average of eight times a day and works for 24 hours a day.

5. Dinarta Station

Dinarta station is located in the center of Dinarta subdistrict of Akre district in the eastern part of the center of Duhok governorate. The slopes of the mountains cover the entire region. The station covers an area of (260 km^2).

6. Kani Masi Station

This station is in the center of the Kani Masi district, one of the northwest sub-districts of the Amedi district. The station covers an area of (14 km^2).

7. Swaratoka Station

Swaratoka station is placed in the center of the Swaratoka, a sub-district of Duhok district. The station covers an area of (12 km^2).

8. Bamarne Station

It is located in the center of Bamarne district, one of the sub-districts of Amedi in the west. The station rises to (1220 m) above sea level. This height gives it a wonderful weather and low temperature throughout the summer. The station covers an area of (12 km^2).

9. Deralok Station

Deralok station is located in Deralok district, ehich belongs to Amedi district. It is located in the north-east of the center of Duhok governorate covering an area of (17 km^2).

10. Batofa Station

It is located in the center of the Batofa district, one of the sub-districts in the east of Zakho. The station covers an area of (5 km^2).

11. Mangesh Station

Mangesh station is situated in Mangesh district of Duhok. The station covers an area of (8 km^2).

12. Chamanke Station

The Chamanke station is positioned in Chamanke district of Amedi district, located at the eastern part of Duhok governorate. The station covers an area of (26 km^2).

13. Darkar Station

This station is located in the center of Darkar district which is one of Zakho sub districts. The station covers an area of (103 km^2).

2. FACTORS AFFECTING RAINFALL IN DUHOK GOVERNORATE

The amount of precipitation varies over time. Various factors play a significant and clear role in the characteristics and composition of rainfall in any region or an area on the earth. These factors vary concerning their importance and strength of influence from one region to another. Some of these factors are immovable, such as astronomical and geographical location and topography. Furthermore, these factors give the climate many characteristics; hot, mild, cold, continental or marine, or can be dynamic such as low pressure, air masses, temperature, atmospheric pressure, and humidity (Ibrahim, 2008). Generally, these factors contribute to the fluctuation of climate elements, specific rainfall in the study area.

2.1. Fixed Climatic Factors

The fixed climatic factors have a constant influence that are unchangable from time to time, but the strength of their influence varies from place into another even in the same latitudes (Alkinani, 2005).

2.1.1. Location

The effect of the location on the rainfall can be seen in several directions:

2.1.1.1. Astronomical Location

The astronomical location of Duhok governorate extends between longitudes (42° 8′30″E, 44° 41′0″ E) east, and between two latitudes (36°19′15″N, 37°35′40″N) north, see (Map 3), which affected its rainfall. During the cold season, the study area becomes an area to receive and meet air masses of varying physical characteristics, pushed by the western winds towards the east; this contributes to the formation of fronts and thus the rainfall. The area is also affected by the frontal depressions coming from the Mediterranean Sea in particular, which originates from the continental polar mass (CP) and the marine polar (MP) that follow northeastern and eastern directions, where a large number of medium depressions characterizes them, and the areas of these depressions are characterized to be more powerful, deeper and more rainy. Depressions move eastward because of the western winds, which gives the advantage to pass to the north of the latitude (35°) (Ismael, 1994).

During the hot season, due to the changes in the distribution of seasonal and permanent pressure areas, the region is influenced by semi-tropical high pressure, which contributes to the displacement of the passage of the frontal low depressions to the north during the cold season and the shortage of rainfall in summer. The astronomical site also determines the length of the insolation period (the number of hours of solar brightness), as it gradually increases after January and reaches its peak in July. During the rainy season, it runs in a manner that reverses the amount of rainfall (Alnajmawi, 2008).

2.1.1.2. The Geographical Location

The importance of the climatic geographical location is due to the proximity and distance from water bodies (Alshalash, 1988) and marine influences depend on the area of water bodies and their distance from it on one hand and on the direction of the prevailing winds on the other hand (Alnajmawi, 2008). These regions are humid and warm in winter and have more rain. As for areas far from the seas and oceans, the climate is hot in summer, very cold, and less rain in winter.

The location of Iraq including Duhok governorate, in the southwestern part of the continent of Asia, made it disposed to continental influences more than marine ones and surrounded by water bodies where some of them far from it, represented by (The Red Sea, The Black Sea, The Caspian Sea) (Mahmoud, 2003). Due to the separation of Iraq from it with large areas and the presence of complex terrain, they do not affect the study area; and others are close to it, represented by the Mediterranean Sea and the only water body adjacent to Iraq (the Arabian Gulf) (Alnajmawi, 2008) as shown in Map (4). Therefore, the geographical location of the study area made it vulnerable to direct marine influences from the Mediterranean Sea in the first degree and the Arabian Gulf in the second degree, especially in winter, while the influence of the previous three seas dosn't reach to the study area because the Red Sea is less wide, far and it is not located within the region of headwinds path. As for the Black Sea and the Caspian Sea are not affected by the influence because of their distance, the direction of the prevailing winds, and the occurrence of the Taurus - Zagros mountain ranges as a separating factor between them and the study area (Alsumidai, 2004). The Mediterranean Sea represents a region of emegenc of frontal depressions resulted from the meeting of continental polar air masses with the tropical continental air masses above the Mediterranean basin. In addition, the Mediterranean is a region in which the activity of the air depressions coming from the north of the Atlantic basin is renewed, especially the ones affecting the eastern part (Ghanem, 2001). This is due to their contribution in making most of the rainfall in the study area of the frontal cyclonic type, and the effect of the Arab Gulf is clear on the study area during the cold season. It is also a source of southeast wind blowing at the front of the frontal depressions, passing through the study area to represent the warm front of these depressions (Alnajmawi, 2008).

Map 3. Location of Duhok Governorate in Relation to Latitude and Longitude

Source: www.google.earth.com

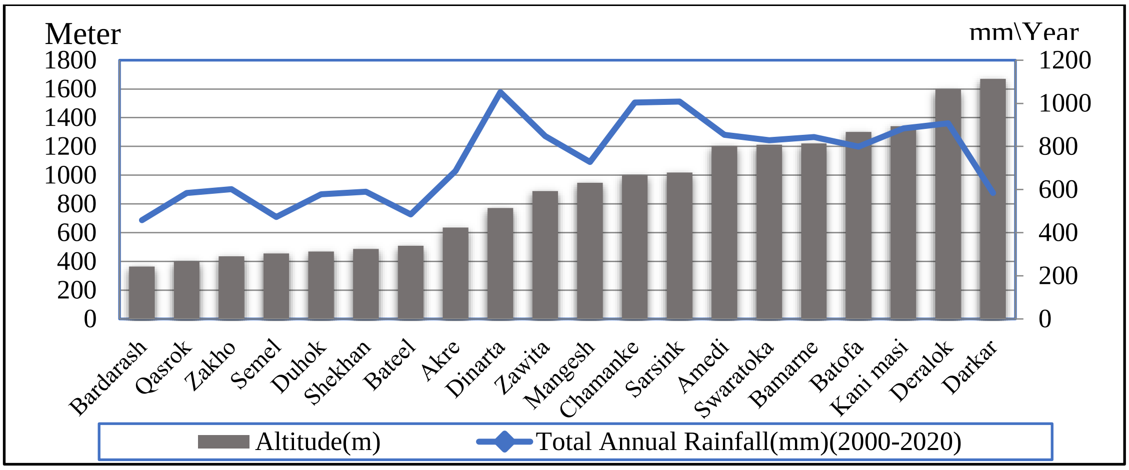
Map 4. Location of Duhok Governorate in Terms of Water Bodies

2.1.2. Topography

Topography is an essential factor that affects the amount of rainfall, as the climatic conditions vary greatly throughout a short distance (Alshaaeir, 2005). Topography contributes to drawing the features of the rainfall characteristics of the study area by affecting the different climatic elements (Alnajmawi, 2008). Duhok governorate is characterized by various terrains, such as high mountain ranges, flat plains, valleys and plateaus, as shown in Map (2).

This terrain diversity helped to emerge the climatic variations to emerge in the region. The most important characteristic of these mountains is that they are open to marine influences and have a principal role in the northern and northeastern sections, which contributed to providing opportunities for rainfall, as it stands as a dividing barrier in front of the marine influences coming from the Mediterranean and the Arabian Gulf to drain all its moisture (Alsumidai, 2004). The terrain factor increases the length of the rainy period (the rainy season), as it begins in September until the end of June compared to other regions, where the rainy season starts from October to the end of May. The amount of rainfall increases at the beginning and end of the rainy season during (October and May), because the air depressions in this period are few and shallow and do not affect the low areas, but instead, their impact is limited to the high places, so the number of rainy days increases in the mountainous area compared to other regions (Alnajmawi, 2008). As shown in (Appendix1).

The influence of the terrain appears clearly when comparing the rainfalls of regions with the ones in the low-altitude plain areas, as the amount of rainfall increases by (54 mm) for every (100 m). It is natural that the amount of rainfall increases as we advance from the south and southwest to the north and northeast of the study area (Işik, F. Bahadir, M & Cağlak, S. 2018), as the nature of the extension of these heights and their facing the headwinds vertically or close to the vertical provided suitable conditions for terrain and cyclonic rainfall, as the mountainous peaks force the coming wind to rise to the top, so its temperature get lower which lead to condensation, and thus its ability to carry moisture decreases, so it starts to rain, then the terrain factor affects the characteristics of the rainfall in the area, the rainfall rates increases to the heighest above sea level (Altawil, 2018), see Figure (1).



Source: From the Researcher's work Based on (Table 5)

Figure 1. The Amount of Annual Precipitation (mm) between (2000-2020) for to the Height above Sea level (m)

The longitudinal extension in the shape of Duhok governorate from the northwest to the southeast made the south and southwest parts far from the main paths taken by the air depressions coming from the Mediterranean Sea, which affected the gradual decrease in rainfall from the south to the north (Abdalbaqi, 2001), as shown in the Table (5).

Table 5. Physical Characteristics of the Stations of the Study Area

Station	Longitude	Latitude	Altitude (M)	The far of the Mediterranean (KM)	Total Annual Rainfall (MM)(2000-2020)
Bardarash	°43′31	°36′30	365	676,90	458.1
Qasrok	°43′40	°36′34	400	676,61	584.4
Zakho	°42′41	°37′08	435	611,47	602.6
Semel	°43′34	°36′45	456	627,52	473.5
Duhok	°43′00	°36′50	469	639,37	578.2
Shekhan	°43′20	°36′50	486	677,54	590
Bateel	°42′00	°36′50	510	603,47	485.3
Akre	°43′51	°36′43	636	708,10	685.8
Dinarta	°43′59	°36′57	771	723,57	1051.8
Zawita	°43′09	°36′54	890	635,78	848.1
Mangesh	°43′04	°37′02	948	634,81	727.5
Chamanke	°43′41	°36′93	1000	746,53	1003.7
Sarsink	°43′21	°37′07	1019	662,47	1008.3
Amedi	°43′29	°37′05	1202	672,33	853.3
Swaratoka	°43′13	°37′00	1211	633,99	828.7
Bamarne	°43′15	°37′07	1220	658,94	843.1
Batofa	°43′00	°37′10	1300	634,76	798.9
Kani masi	°43′26	°37′13	1340	665,85	884.1
Deralok	°43′65	°37′05	1600	690,20	907.4
Darkar	°42′82	°37′19	1670	625,38	584.1

Source: From the Researcher's work Based on the General Directorate of Meteorology and Seismic Monitoring in the city of Dohuk, Climatic Data Department, unpublished

Table 5 indicates the following:

1. Rainfall decreases in the low areas represented by the stations Bardarash, Qasrok, Zakho, Semel Duhok, Shekhan and Bateel. Their height is between (365-510 m) above sea level, and the annual total of rainfall is between (458.1-602.6 mm).

2. The amount of rainfall increases as we head towards the higher areas in the north and north-east of the study area represented by the stations (Akre, Dinarta, Zawita, Mangesh, Chamanke, Sarsink, Amedi, Swaratoka, Bamarne, Batofa, Kani Mas, Deralok, Darkar), their height Between (636-1670 m) above sea level, and the annual total precipitation are between (584.1-1051.8 mm).

It is clear that there are lower stations concerning the northeastern stations in the study area. The highest amount of rainfall is recorded among all stations of the study area as Dinarta station with height of (771 m) above sea level, the annual total of rainfall (1051 mm). As for Darkar station, it is one of the high stations in the northwest of the study area, it is about (1670 m) above sea level, and the annual total rainfall is (584.1 mm), which is contrary to what is expected. Because of the proximity of the northwestern sides to the Mediterranean and preserving depressions with their strength and moisture, the northern and northeastern stations have more rain than the northwestern stations in the study area.

Table 6. The Relationship Between Rainfall and Height

	Rainfall	**Height**
Rainfall Pearson Correlation Sig.(2-tailed) N	1 20	.573** .008 20
Height Pearson Correlation Sig.(2-tailed) N	.573** .008 20	1 20
Correlation is Significant at the 0.01 level (2-tailed).**		

Source: From the Researcher’s Work, Based on (Table 5)

The (Table 6) shows that the simple correlation coefficient was utilized to determine the correlation between altitude and rainfall during the study period (2000-2020). There is a robust direct correlation, the value of its correlation coefficient is (.573**), statistically significant at a level of less than (0.01).

2.1.3. The Relationship Between the Natural Variables Affecting the Rainfall in the Study Area

The effect of geographical factors on rainfall in the study area can be known through the variation in the amount of rainfall in the study stations. The contrast is clear by finding the correlation coefficient between the average amount of rainfall and its relationship to the topography factor, as well as its relationship to location (astronomical location), and (geographical location), that is the factor of proximity and distance from water bodies.

Table 7. The Value of the Correlation and Interpretation Relationship Between Rainfall and Natural Variables

Model	Correlation	Interpretation
1	.805[a]	**648.**

Source: From the Researcher's Work, Based on (Table 5)

It is clear from (Table 7) that the correlation factor of geographical factors with each other was recorded for the model = (805a.), which is a robust direct relationship. It became clear that the coefficient of interpretation was recorded = (.648), which means that the rainfall variable was recorded (60%) from the variance in other variables.

It was found that the value of the analysis of variance test = (9.802), and the level of significance = (0.001), this means that the model is statistically significant, as shown in (Table 8).

Table 8. Value of Rainfall Variability Analysis Test and Natural Variables

Source	Sum of Squares(SS)	Average Sum Variance	Variance Analysis(F)	Indication
Between Groups	432966.269	144322.090	9.802	**.001**
Within Groups	235581.661	14723.854		
Total	668547.930			

Source: From the Researcher's Work, Based on (Table 5)

It can be noiced from the equation of the regression line for the natural factors that they represent:

Distance from the sea (0.030) + altitude (0.077) + latitude (274.374) = y (rainfall).

When considering the correlation coefficient between the variable of the amount of rainfall and the variable of location according to the latitude circle, it was found that there is a mid- direct correlation, the value of its coefficient was (0.514 *), with statistical significance at a level less than (0.05).

By finding the correlation coefficient among the variable of rainfall and the variable of the distance from the sea, it was found that there is a mid-direct correlation relationship, the value of its coefficient was (0.527*), with statistical significance at a level less than (0.05), as shown in Table (9).

Table 9. Relationship Between Rainfall and Natural Variables

Variable	Rainfall	Location	Far From the Sea	Height
Rainfall	1			
Location	0.514*	1		
Far From the Sea	0.527*	-0.151-	1	
Height	0.573**	0.813**	0.043	1
***Correlation is Significant at the 0.05 Level. ** Correlation is Significant at the 0.01 Level.**				

Source: From the Researcher's Work Based on Table (5)

It was shown when analyzing the correlation coefficient between the variable distance from the sea and the altitude variable, that there is no correlation between the two variables, which means that there are other variables that affect and are related to these variables. Correlation between the two variables is due to the distance between the study area and the water bodies. When analyzing the correlation coefficient between the altitude variable and the location variable, it turns out that there is a robust direct correlation, the value of its correlation coefficient is (0.813**), statistically significant at a level of significance less than (0.01).

It is concluded that the altitude variable is an important and effective factor on the rainfalls in the study area, and is one of the most positive variables seasonally and monthly.

2.2. Dynamic Climatic Factors

The dynamic or (Movable Factors) refers to the movement of air resulting from the uneven heating of the surface of the earth and the rotation of the planet around itself, which results in a continuous movement of the components of the atmosphere and clouds from one place into another and from time to time (Alalusy, 2009). There are major climatic factors that have a clear impact on the amount of rainfalls. Those meteorological factors that affect the rainfall of the study area can be classified into several types such as:

2.2.1. Depressions

It is the large volume of the air in which the atmospheric pressure drops significantly from what is adjacent to it (Alsultan, 1986); that is the pressure slope from the edges towards the center is severe, so the air moves from the high-pressure area (the extremities) to the low-pressure area (the center), and the air inside it rises rapidly with a swirling movement (Smithson, P. Kenneth, A. Kenneth, A. 2002), and the depression covers an area ranging in diameter from (1500-30000) km, and its life spans between (4 to 7) days (Barry, 2003).

In general, atmospheric depressions appear in moderate latitudes between (30˚- 45˚) in the north of the hemisphere. These widths accompany the western winds from west to east (Sharaf, 1985). The characteristics of the depression are related to the nature of the different air masses, which are formed as they are faced to the fronts , and is developed later into (the frontal depression).

The air depressions, especially the ones of the middle latitudes, are the main source of rainfall in the study area. It is one of the essential depressions affecting the study area because it determines the beginning of the rainy season in addition to its quantity and quality. These depressions differ from each other in terms of type, origin, and impact according to regions and ways of their emergence. In terms of style, there are three main types of atmospheric depressions (thermal, terrain, frontal). The first type has no effect within the study area due to the lack of requirements for its emergence. As for the she second type, it has little effect, while the third type affects the study area through the frontal Mediterranean depressions coming from the west within the Mediterranean and the Atlantic Ocean. These depressions are significant as they are the main source of humidity. The precipitation is not only on the study area but throughout the country, as the period of maximum rainfall occurs at the time when these depressions are at the peak of their recurrence, especially in January and February. These depressions become widespread and frequent (Ismael, 1994) as well as they affect the weather fluctuations, changing wind direction and the amount of precipitation (Anthes,1977). These depressions vary in their preparation, the beginning of their passage and their quality in terms of depth and shallowness; in addition, they vary in their practice from one season into season and from one month into month. The study area falls within the influence of some atmospheric depressions, and the most important are:

2.2.1.1. Mediterranean Depression

In winter, the Mediterranean Sea becomes a significant center of low atmospheric pressure, due to its warm water that separate two high atmospheric pressure zones. The first is located in the north of Mediterranean Sea and concentrated over Al Alb mountains, which are covered by snow, and over the Armenea and Al Anadoul plateau. The second is in the Azorean atmospheric height, which shifts in the winter season to the south and extends eastward to connect with the large range of high atmospheric pressure that sites over Central Asia and from it a huge arm extends towards southwest Asia in winter. As a result of this distribution of atmospheric pressure, the Mediterranean Sea is not only a preferred area for crossing the Atlantic depressions but also a suitable area for the emergence and development of the Mediterranean depressions in winter. A front is formed above the Mediterranean Sea extending from southwest towards northeast. Thus, most of the rains of Mediterranean depressions are accompanied by the cold front and these rains are formed because of a continental polar air mass comming to the Mediterranean basin gaining some humidity as it moves over its warm water. Thus, these masses often become unstable because of their wet lower layers and the low humidity of their upper layiers (Shahada, 1985). When they meet with the tropical continental masses, they both form a secondary Mediterranean front belonging to the main polar front, and about (91%) of the atmospheric depressions affecting the eastern basin of the Mediterranean, including the study area, arise on this secondary front (Ismael, 1994).

The British Meteorological Department estimates the annual average of these depressions formed in the basin (76). The source of these depressions is the North Atlantic Ocean, and they enter the Mediterranean basin through the (Carson) Pass and the Strait of (Gibraltar) (Aldawri, 2002).

The Mediterranean basin has low pressure in winter, which facilitates the passage of atmospheric depressions, and due to the effect of these depressions after their formation by the general direction of the winds, they take an eastern and northeastern direction, in addition to the formation of local depressions in the east basin of the Mediterranean Sea in northern Cyprus and Italy, and later they take two paths.

The first: from the eastern mountains of Lebanon and the opening of Aleppo to the east, then Iraq. **The second**: it passes from Palestine and Jordan, then Iraq (Alnajmawi, 2008). Therefore, the Mediterranean depressions caused the largest percentage of the rainfall in Iraq, including the study area (Alsamarayi, 2008).

2.2.1.2. Atlantic Depressions

These depressions arise over the islands of Iceland and the North Atlantic Ocean and follow two main paths: the northern path towards Europe, and the southeastern path towards the Mediterranean basin (Ismael, 1994). These depressions, which reach the Mediterranean basin, do not constitute more than (9%) of the general depressions that reach the eastern Mediterranean (Zangana, 1999). Sometimes, they affect the amount of precipitation in the study area. The reason for the lack of recurrence of this type of depressions in the Mediterranean and their lack of access to the study area is the progression of the European groove to the upper layers of the gas envelope as well as the distance between the Atlantic Ocean and the study area, which prevents access to it (Alsumaidai, 2004).

2.2.2. Temperature

Temperature is the main climatic element on which almost all climatic conditions depend. (Coşkun & Akbas, 2017). Heat affects atmospheric pressure which is the engine and influencer of winds which in turns affect precipitation. Heat has a great relationship with weather disturbances, so temperature is the main driver for all climatic elements (Aljawhari, 1978).

Temperatures vary from one season into another. They increase in summer due to the length of the day and the angle of rays of sun, which reaches its peak in June in the northern hemisphere, and the sun is directly above the Tropic of Cancer. The opposite occurs in winter, when the day length decreases and the angle of the sun's elevation is reduced to the minimum in December, where the sun is perpendicular to the tropic of Capricorn, thus reducing the temperature to its lowest value. The temperature varies with location and season of the year, (Issa, 2006). The temperature decreases as it rises from the surface of the earth, on the contrary, as it descends, the temperature increases (Coşkun, M. Coşkun, S. & Gözalan, S 2020). Temperature is one of the climatic elements that affects the movement of air depressions and air masses and the accompanying characteristics of precipitation, drought and other natural phenomena (Aboud, 2005). On this basis, it can be said that the climate of any region is the result of a set of heat exchange and transfer processes that must be stored in this region (Hadid & Al-Husseini, 1984). These variables are achieved through the daily and annual distribution of temperatures, and all of these variables differ astronomically throughout the year by the effect of the apparent movement of the sun in the four seasons (Taha, 2013). Therefore, the temperature rates vary from one station into another as a result of being affected by the different pressure systems, as well as the geographical factors of the study area (Abdulrahman,2016).

Duhok governorate is characterized by its hot summers and cold winters, and by the large annual, seasonal and monthly range of temperatures. In general, the lowest thermal rates are recorded in the high parts, while the highest thermal rates are recorded in the low areas, and the range increases with the increase in the degree of width.

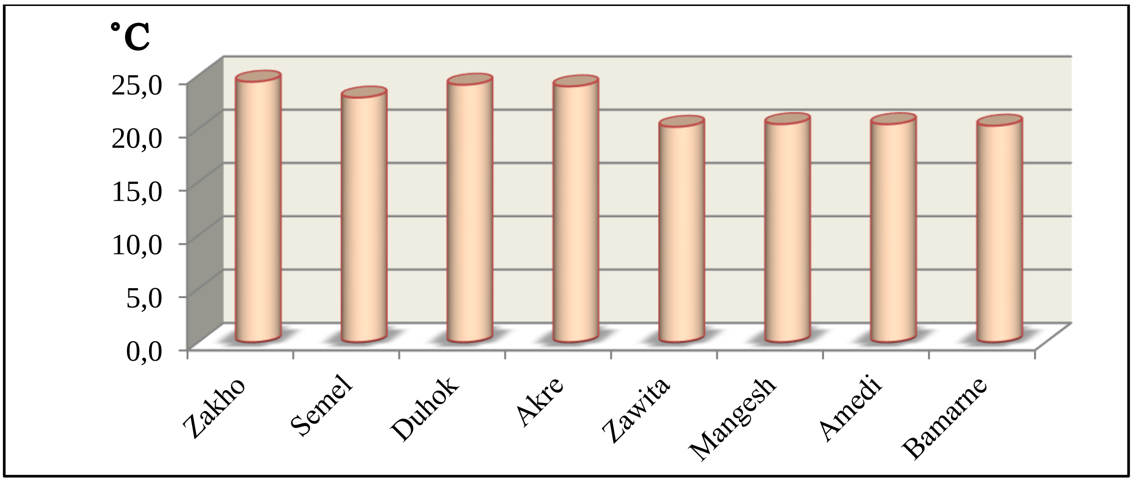
Table (10) Figure (2), represent the monthly and annual rates of temperature for (8) approved stations that record the temperature component for the period (2010-

2020), due to the lack of temperature data for many stations in the study area; so, we only adopted on stations where records of temperature values are available. It is noted that**:**

Table 10. The Monthly and Annual Average of Temperatures (°C) in the Available Stations in the Study Area for the Period (2010-2020)

Station	Zakho	Semel	Duhok	Akre	Zawita	Mangesh	Amedi	Bamarne	General Average
Altitude (m)	435	456	469	636	890	948	1202	1220	-
Longitude	°42′41	°43′34	°43′00	°43′51	°43′09	°43′04	°43′29	°43′15	-
Latitude	°37′08	°36′45	°36′50	°36′43	°36′54	°37′02	°37′05	°37′07	-
Jan	8.5	7.1	7.2	7.46	4.4	5.0	2.5	4.0	5.7
Feb	10.5	10.3	8.3	9.00	7.1	7.1	6.0	7.4	8.2
Mar	14.5	12.2	14.2	12.31	10.5	10.1	8.8	9.6	11.5
Apr	19.1	18.7	17.8	17.55	15.7	14.8	13.1	13.6	16.3
May	24.6	23.6	24.3	24.16	20.6	20.4	20.0	20.3	22.2
Jun	30.8	29.4	29.6	30.73	26.5	26.6	27.3	26.5	28.4
Jul	34.9	32.6	34.7	34.60	30.4	30.7	31.5	30.8	32.5
Aug	34.5	32.5	32.5	34.61	30.4	30.5	32.7	31.0	32.3
Sep	30.4	27.9	31.1	30.00	25.4	26.0	26.7	25.6	27.9
Oct	23.2	21.0	24.3	22.96	18.5	19.2	18.4	19.5	20.9
Nov	15.2	13.2	16.0	14.80	11.0	12.1	12.3	11.9	13.3
Dec	10.4	10.8	10.5	9.76	6.3	7.0	5.5	6.7	8.3
Annual Rate	21.4	19.9	20.8	20.7	17.2	17.4	17.0	17.2	18.95

Source: From the Researcher's work Based on the General Directorate of Meteorology and Seismic Monitoring in the city of Dohuk, Climatic Data Department, unpublished



Source: From the Researcher's work Based on (Table 10)

Figure 2. Annual Average Temperatures (°C) at Stations Available for the Period (2010-2020)

1. The annual average temperature of the stations available in the study area was (18.95°C). The stations which are Zakho, Semel, Duhok, Akre, Zawita, Mangesh, Amedi, and Bamarne, recorded the annual averages of temperatures reaching (21.4°C, 19.9°C, 20.8°C, 20.70 °C, 17.2 °C, 17.4 °C, 17.0 °C, 17.2 °C) respectively.

2. Zakho station recorded the highest average temperature of (21.4°C), higher than the general rates of the stations by a difference of (2.45°C), and this is due to its low surface, as Zakho station is located at an altitude of (435m) above sea level, while the lowest rates were recorded in Amedi station reaching (17.0°C), a difference of (4.4°C), and this is due to the altitude factor, as Amedi station is located at an altitude of (1202m) above sea level.

3. The stations Zakho, Semel, Duhok, Akre, Zawita, Mangesh, Amedi, Bamarne, recorded monthly average temperatures of (8.5°C, 7.1°C, 7.2°C, 7.46°C, 4.4°C, 5.0°C, 2.5°C, 4.0°C) respectively for the stations mentioned as monthly averages for January, the coldest month of the year, and the general averages for all stations during this month were (5.7°C).

4. In April, that represents one of the spring months, the temperature values recorded (19.1°C, 18.7°C, 17.8°C, 17.55°C, 15.7°C, 14.8°C, 13.1°C, 13.6°C), as monthly temperature equipment for stations Zakho, Semel, Duhok, Akre, Zawita, Mangesh, Amedi, Bamarne; the general average temperature for all stations during this month was (16.3°C).

5. In the last of July, the stations, Zakho, Semel, Duhok, Akre, Zawita, Mangesh, Amedi, Bamarne, recorded the monthly calorific values (34.9°C, 32.6°C, 34.7°C, 34.60°C, 30.4°C, 30.7°C,31.5°C,30.8°C), as monthly rates for the mentioned stations, respectively, and the general rates for all stations during this month were (32.5°C).

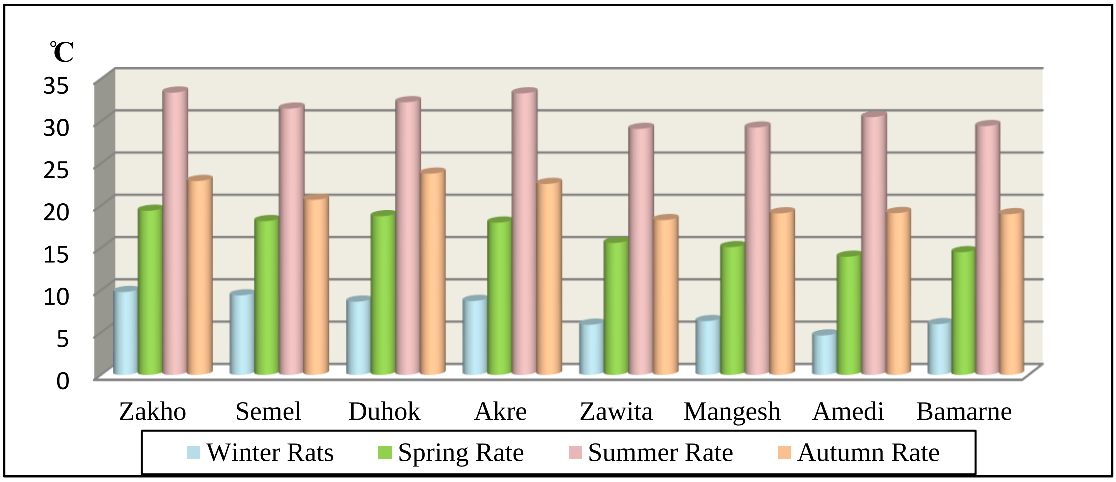
6. In autumn, which is represented in October, the stations Zakho, Semel, Duhok, Akre, Zawita, Mangesh, Amedi, and Bamarne, recorded monthly thermal rates for this month (23.2 °C, 21.0 °C, 24.3 °C, 22.96 °C, 18.5 °C, 19.2 °C, 18.4 °C, 19.5 °C) respectively, and the general averages for all stations during this month were (20.9 °C).

The seasonal rates of temperatures recorded in the stations available in the study area also vary among the different seasons of the year. This can be noticed through (Table 11)(Figure 3).

Table 11. Seasonal Temperature (℃) Rates for Stations Available in the Study Area for the Period (2010-2020)

Station	Winter Rats	Spring Rats	Summe Rats	Autum Rats
Zakho	9.8	19.4	33.4	22.93
Semel	9.4	18.18	31.5	20.7
Duhok	8.66	18.76	32.26	23.8
Akre	8.74	18	33.31	22.58
Zawita	5.93	15.6	29.1	18.3
Mangesh	6.36	15.1	29.26	19.1
Amedi	4.66	13.96	30.5	19.13
Bamarne	6	14.5	29.43	19
Semestr	7.44	16.69	31.1	20.69

Source: From the Researcher's work Based on (Table 10)



Source: From the Researcher's work Based on (Table 11)

Figure 3. Seasonal Temperature (℃) Rates for Stations Available in the Study Area for the Period (2010-2020)

- **Winter**

In winter, the average temperature varies from one month to another, as the seasonal average temperature for the stations in winter is (7.44°C). This average reached (4.66°C) for Amedi station and (9.8°C) for Zakho station, as shown in Table

(11). There are several reasons for recording the lowest thermal rates during winter, the most important of which are the low angle of sunlight, short day, increased cloudiness, and the cold air masses. It can also be seen in (Figure 3) that:

1. The highest seasonal averages of temperatures were recorded in winter in Zakho and Semel stations, as they reached (9.8°C, 9.4°C) respectively, followed by Duhok and Akre stations, which recorded (8.7°C, 8.7°C) respectively, followed by Mangesh stations, Bamarne, Zawita, and Amedi score (6.4 °C, 6.0 °C, 5.9 °C, 4.7 °C).

2- The lowest rates of seasonal temperatures for winter were recorded in the stations located in the high region as in Amedi, Zawita, Bamarne, Mangesh of the study area, ranging between (4-6°C), and this is confirmed by the role of the terrain factor in reducing temperatures. As shown in (Map 5).

- **Spring**

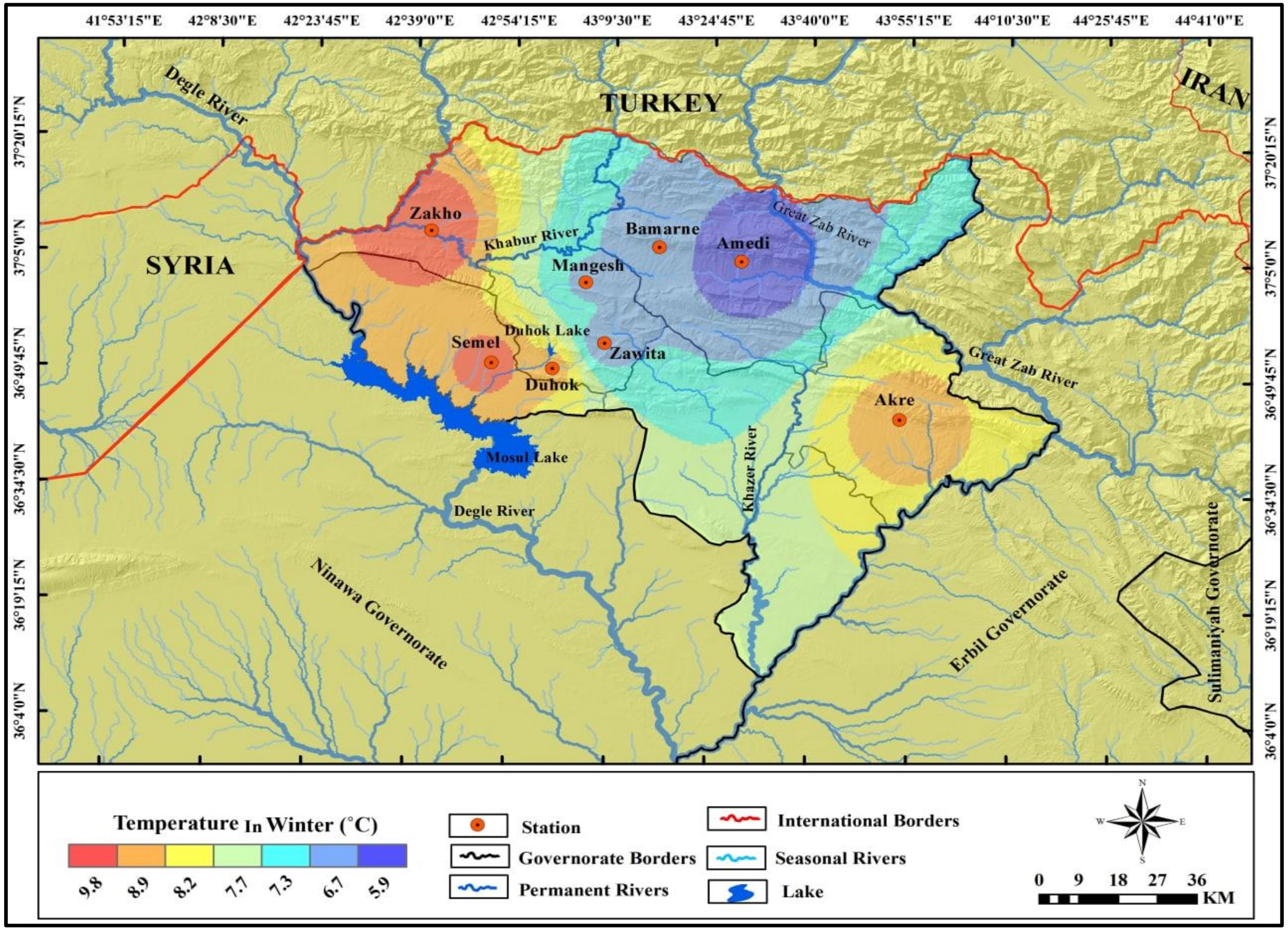
The climate of Duhok governorate is characterized by the presence of two transitional periods between the two main seasons (winter and summer), which are spring and autumn. Spring is a transition from the cold season (winter) to the mild season (spring). Amedi station recorded the lowest seasonal rates during this season as reached (14°C), while the highest rates were recorded in Zakho station, which amounted to (19.4°C), due to its lower area from sea level compared to the mountain stations. Spring in the southern regions of the province before the northern regions, as shown in Map (6).

- **Summer**

In summer, the highest seasonal average temperatures were recorded in all stations, due to several reasons, the most important of which is the lengthl of the day and the high angle of radiation, in addition to the lack of clouds, low levels of humidity, as well as the effects of other factors such as the warm air masses, especially the continental ones that prevail in the region. The stations of (Zakho, Akre, Duhok and Semel) recorded the highest seasonal average temperatures, which amounted to (33.4°C, 33.31°C, 32.3°C, 31.5°C) respectively, while the lowest rates were recorded in(Zawita, Mangesh, Bamarne and Amedi) stations, which amounted to(29.1°C, 29.3°C ,29.4°C and 30.5°C) respectively. The astronomical and geographical location affects the increase in the average seasonal temperature during summer, as well as the terrain elevation factor in the stations'. As shown in Map (7).

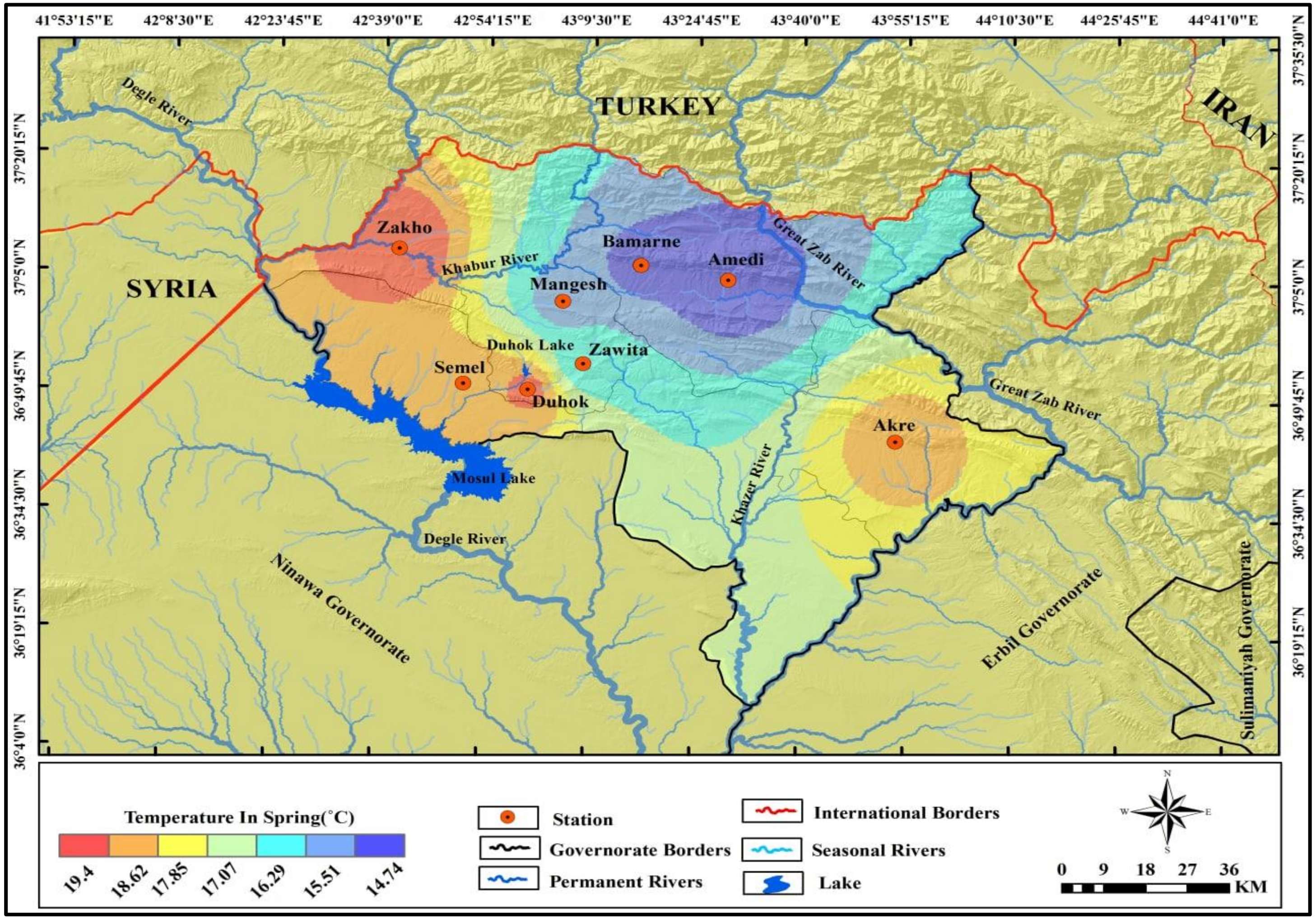
- **Autumn**

Autumn is a transition from the hot season (summer) to the cold season (winter). The gradual decrease in temperatures is observed, as the seasonal rates of the stations take a gradual decline, and this decline is more noticed during summer, where Zawita station records the lowest rates of temperatures (18.3°C), while Duhok station records the highest rates of seasonal temperatures at (23.8℃). It can be said that the temperature rates in autumn are moderate and similar to the rates of spring. As shown in Map (8).



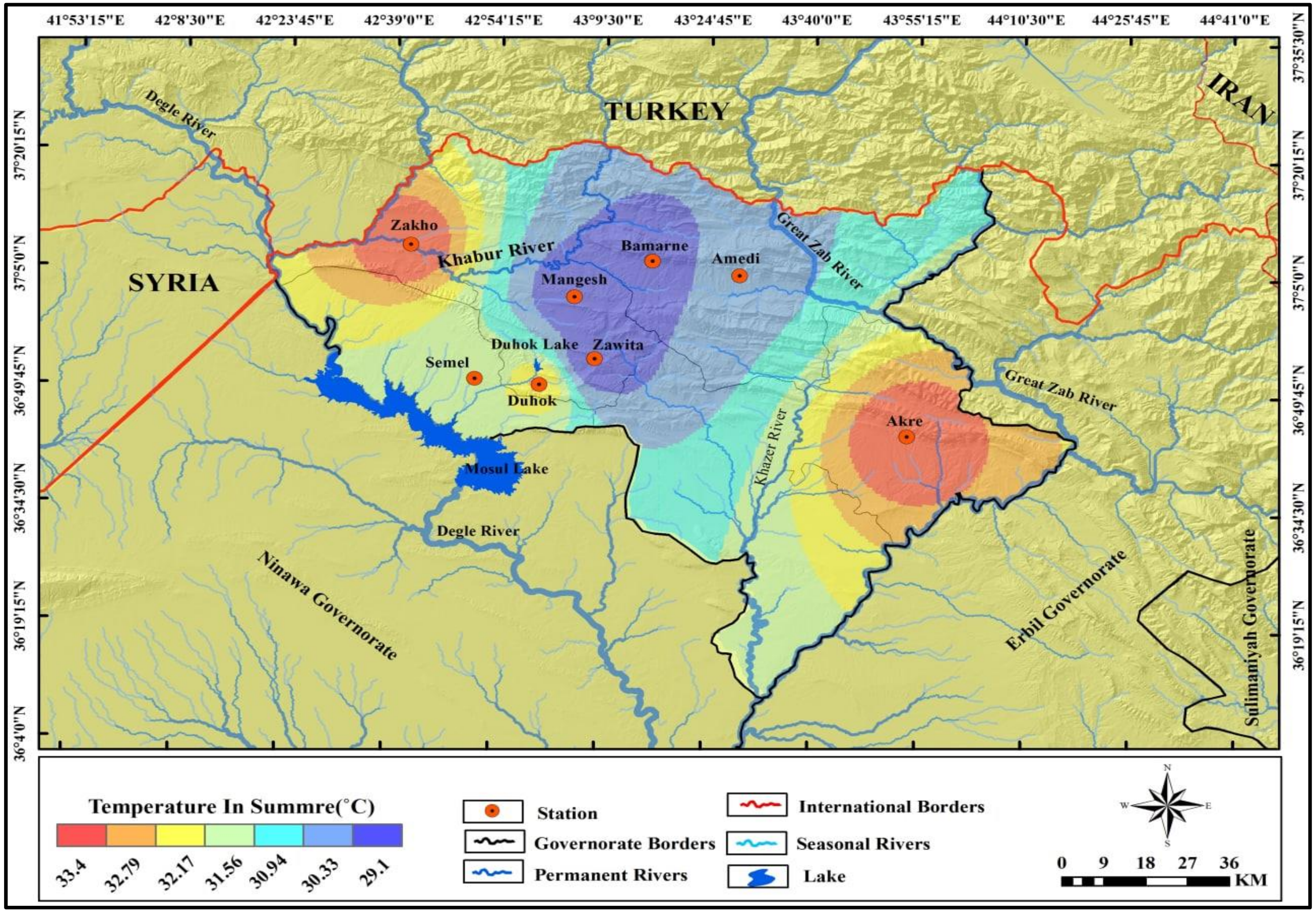
Source: From the Researcher's work Based on (Table 11)

Map 5. Average Temperatures of the Stations of Duhok Governorate for Winter Between (2010-2020)



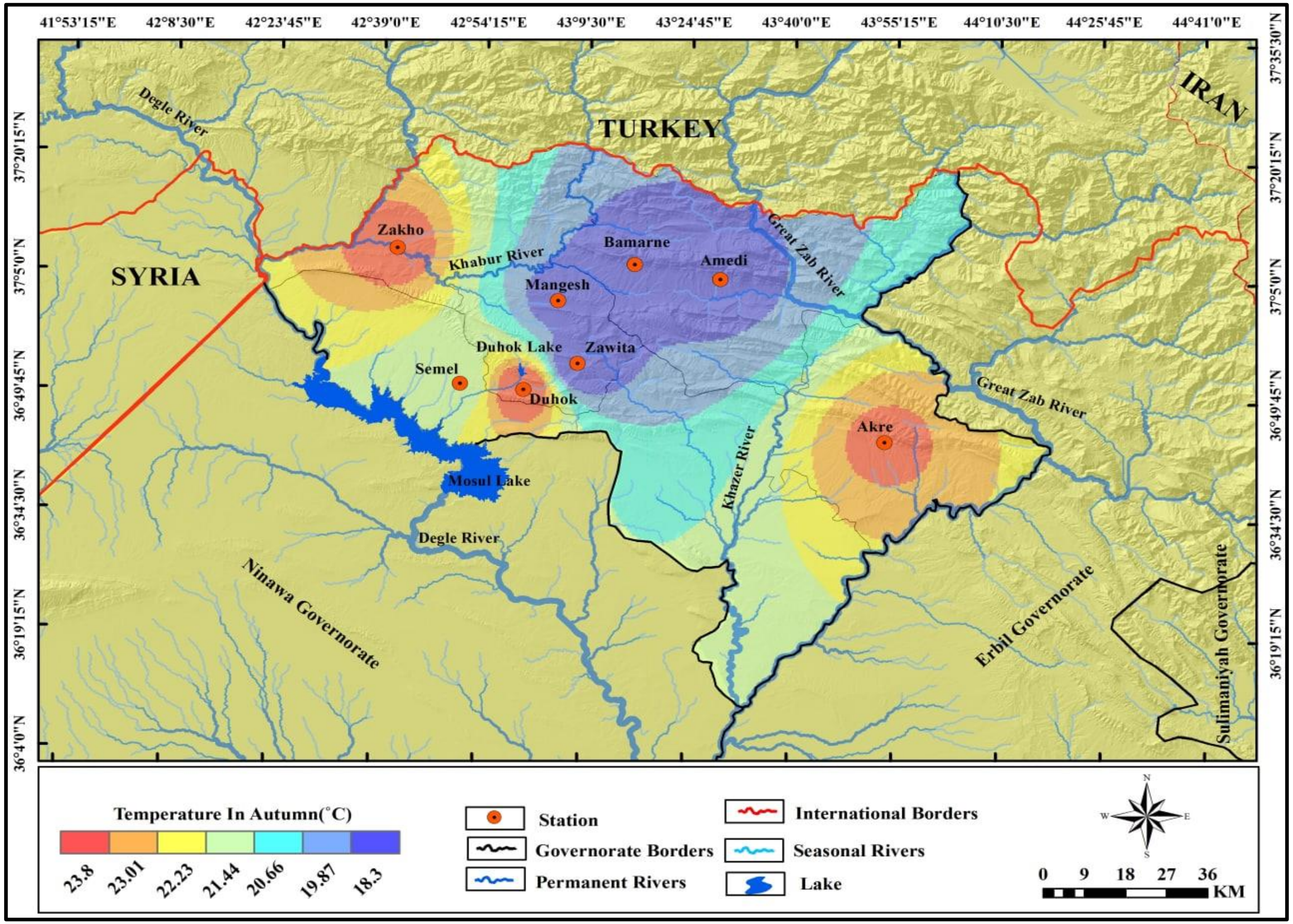
Source: From the Researcher's work Based on (Table 11)

Map 6. Average Temperatures of the Stations of Duhok Governorate for Spring Between (2010-2020)



Source: From the Researcher's work Based on (Table 11)

Map 7. Average Temperatures of the Stations of Duhok Governorate for Summer Between (2010-2020)



Source: From the Researcher's work Based on (Table 11)

Map 8. Average Temperatures of the Stations of Duhok Governorate for Autumn Between (2010-2020)

2.2.3. Atmospheric Pressure

Atmospheric pressure is the weight of the air column extending from the surface of the earth to the top of the gaseous atmosphere. Pressure is the force applied to a unit area estimated at ($1cm^2$) at sea level (Alsamarayi, 2008). Atmospheric pressure decreases as you rise above sea level (Öztürk, 1997). The study area is affected by the prevailing atmospheric pressure systems in the Mediterranean basin, such as the Azorean and Siberian high atmospheric pressure centers, as well as the Mediterranean and the Atlantic low pressures. They do not witness a great discrepancy among them, and the decisive and influencing factor in the pressure variations in the study area is the variation in altitude from sea level between the stations of the study area (Taha, 2013). The values of atmospheric pressure vary between the stations of the study area spatially and temporally, through Table 12 of atmospheric pressure, which represents the annual and monthly rates of atmospheric pressure for (6) stations that recorded the atmospheric pressure element and can be relied upon due to the lack of atmospheric pressure data for many of the study stations. Hence, we relied only on stations whose records of atmospheric pressure values were available. The following is noted :

Table 12. Monthly and Seasonal Rates of MB Atmospheric Pressure Values for Stations Available in the Study Area for the Period (2010-2019)

Station	Duhok	Zakho	Semel	Akre	Mangesh	Bamarne	Av
Altitude (m)	469	435	456	636	948	1220	-
Jan	1020.6	1020.3	1018.7	945.8	910.4	879.5	965.9
Feb	1019.3	1018.8	1017.4	944.7	909.8	880.9	965.1
Mar	1015.9	1015.1	1013.1	941.9	906.8	878.8	961.9
Apr	1013.9	1012.4	1010.2	940.7	907.1	878.1	960.4
May	1009.9	1008.8	1005.3	938.3	797.1	877.7	939.5
Jun	1003.8	1002.7	1000.4	934.1	902.2	874.5	952.9
Jul	999.5	998.3	1000.9	931.01	899.2	872.8	950.3
Aug	1001.7	1000.8	999.5	933.3	901.5	875.2	952.0
Sep	1007.9	1006.5	1004.8	937.8	905.3	878.2	956.7
Oct	1015	1013.6	1007.7	942.5	909.3	881.4	961.6
Nov	1020.3	1018.9	1016.7	945.66	915.52	882.52	966.6
Dec	1022.6	1021.4	1019.3	946.96	911.88	882.38	967.4
Annual Rate	1,012.5	1,011.4	1,009.5	940.27	898.05	878.53	958.3
Winter Rate	1020.8	1020.1	1018.4	945.86	910.74	880.95	966.1
Spring Rate	1013.2	1012.1	1009.5	940.4	870.4	878.2	953.9
Summer Rate	1,001.6	1000.6	1,000.2	932.83	901.00	874.19	951.7
Autumn Rate	1014.4	1013	1,009.7	942.02	910.08	880.74	961.6

Source: From the Researcher’s work based on the General Directorate of Meteorology and Seismic Monitoring in the city of Dohuk, Climatic Data Department, unpublished

1. The Variation in the Monthly Rates of Atmospheric Pressure Values Between the Stations of Duhok Government During the Different Months of the Year. Table (12) shows the following:

- In January, Duhok station recorded the highest monthly values of atmospheric pressure among the available stations, as it reached (1020.6 mb), a positive deviation from the general average of (8.07 mb), as shown in (Table 12). It reached (879.52 mb) with a positive deviation of (0.99 mb), note (Table 13). This discrepancy is due to the heterogeneous heating between stations, in addition to the varying topographical height and the difference in morphology between stations.

- In April, the atmospheric pressure rates are close to the general average, and the decrease in the atmospheric pressure rates is clear between the stations, as the monthly average of the atmospheric pressure values decreases during this month with a positive deviation from the general average of (1.37mb). Bamarne station recorded the lowest values of atmospheric pressure as it reached (878.17 mb), with a negative deviation of (-0.36 mb), and the reason is due to the terrain height between the stations.

- In July, Semel station recorded the highest values of atmospheric pressure as it reached (1000.9 mb), with a negative deviation from the general average by (8.6 mb). The reason is that the sun's rays perpendicular to the Tropic of Cancer are close to the vertical position.

- In October, Duhok station recorded the highest values of atmospheric pressure of (1015 mb), with a positive deviation from the general average of (2.47 mb), while Bamarne station recorded the lowest values of atmospheric pressure (881.41 mb), with a positive deviation of (2.88 mb).

The reason for the variation in the atmospheric pressure values between the stations of the study area is the variation in the geographical location, which had a clear impact, as well as the extensions of the continental air mass, which caused the high rate of temperature.

Table 13. Monthly Atmospheric (mb) Pressure Rates in mb and the Deviation from Their Annual Rates at Available

Months	Duhok	Zakho	Semel	Akre	Mangesh	Bamarne
Jan	8.07	8.83	9.2	5.59	12.42	0.99
Feb	6.77	7.3	7.9	4.49	11.83	2.44
Mar	3.37	3.6	3.6	1.6	8.8	0.3
Apr	1.37	0.93	0.7	0.52	9.1	-0.36
May	-2.63	-2.67	-4.2	-1.88	-100.91	-0.77
Jun	-8.73	-8.77	-9.1	-6.09	4.16	-4.02
Jul	-13.03	-13.17	-8.6	-9.26	1.2	-5.72
Aug	-10.83	-10.67	-10	-6.97	3.48	-3.29
Sep	-4.63	-4.97	-4.7	-2.46	7.33	-0.24
Oct	2.47	2.13	-1.8	2.32	11.3	2.88
Nov	7.77	7.43	7.2	5.39	17.47	3.99
Dec	**10.07**	**9.93**	**9.8**	**6.69**	**13.83**	**3.85**

Source: From the Researcher’s work Based on the General Directorate of Meteorology and Seismic Monitoring in Dohuk, Climatic Data Department, unpublished

To compare the monthly averages of atmospheric pressure values recorded in the stations (Duhok, Zakho, Semel, Akre, Mangesh, Bamarne) for the period (2010-2019), it was relied on the records of the months January, April, July and October, which represent winter, Spring, summer and autumn respectively.

2. The Variation in the Seasonal Rates of Atmospheric Pressure between the Available Stations is as Follows

- **Winter Season**

During winter, the sun moves towards the Tropic of Capricorn in the areas north of the Tropic of Cancer, as it is perpendicular to it, which leads to lower temperatures, due to the tendency of the sun’s rays to the north of the Tropic of Cancer, and its low intensity and quantity. So the land of the study area, which is located in the north of the Tropic Cancer is suitable for the concentration of cells of heavy pressure, as for the water bodies there, they are suitable for the concentration of cells of light pressure, according to the property of heat gain and loss between land and water, so that the land is colder than water in winter (Sharaf, 2006). Duhok station recorded the highest values of atmospheric pressure in this season, amounting to

(1020.83 mb), and Bamarne station recorded the lowest values of atmospheric pressure in this season, which amounted to (880.95 mb), as shown in (Table 12)(Figure 4). The high values of atmospheric pressure in the stations of the study area in this season compared to other seasons are due to the decrease in temperature, high humidity and the variation in altitude from sea level (Aljubouri, 2019).

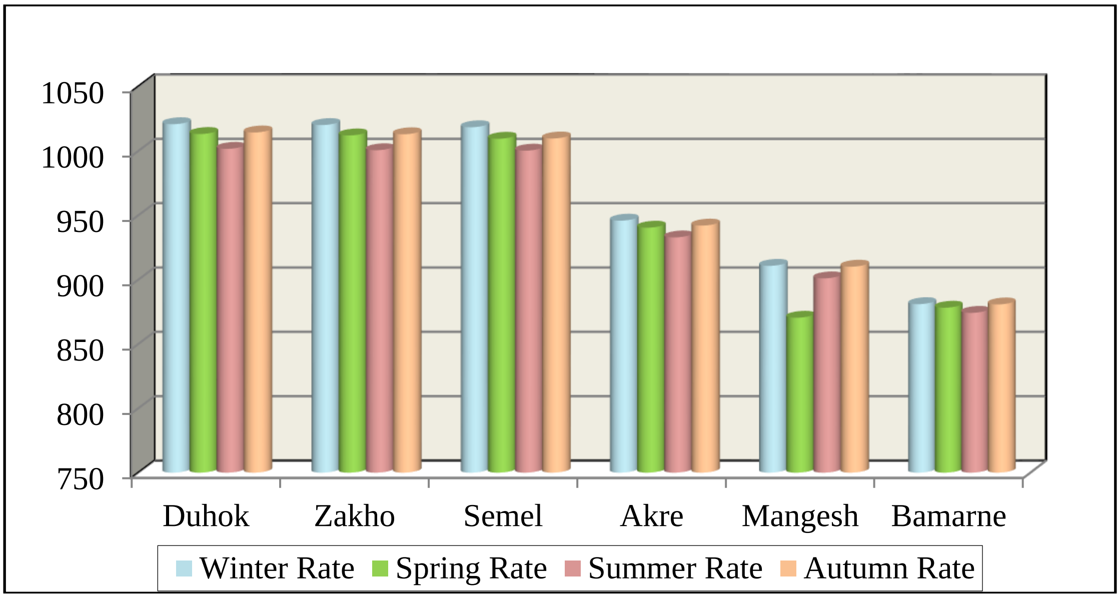
- **Summer**

The sun appears to move towards the Tropic of Cancer in summer, as it is perpendicular to it, which leads to a rise in temperature, due to the high angle of the sun's rays, and the increase in their density and intensity. The study area is under the influence of the semi-tropical heavy pressure area. Duhok station recorded the highest values of atmospheric pressure in the season, which amounted to (1001.67mb), and the lowest values recorded in Bamarne station amounted to (874.19 mb). The decrease in the atmospheric pressure values during summer in all stations compared with other seasons (where its lowest seasonal values are recorded) as shown in (Table 12), leads to a rise in temperatures during the summer (the highest seasonal rates are recorded), as hurricanes and atmospheric low pressures are absent in the study area in summer, in addition to the existence of variation in Topographical altitude, and evaporation values.

- **Spring and Autumn**

Both spring and autumn are transitional seasons with unclear definitions, where the weather fluctuates between summer and winter conditions, but they are characterized by moderate temperatures. Spring is considered a transitional season from winter conditions to summer conditions. Late atmospheric pressures (late winter), atmospheric pressure in this season decreases as a result of the gradual rise in temperature depending on the movement of the sun towards the equator. Mangesh station has a value of (870.4 mb), while autumn is considered an extension of the summer with its dry northern winds and bright sunshine, and it is a prelude to winter. Duhok station recorded the highest values of atmospheric pressure when it reached (1014.4mb), and the lowest values recorded in Bamarne station (880.74mb). The atmospheric pressure in this season increases from September, which has high values compared to the summer months and low values compared to the winter season.

These differences are due to the lack of air low pressures during spring and autumn compared to winter and their absence in summer, as well as the relative decrease in temperatures during these two transitional seasons compared to summer and their relative height compared to winter season, as well as the lack of humidity content of the air (Sharaf, 2006). The variation in the geographical location of the available stations also has a clear impact on the variation in atmospheric pressure values during the seasons.



Source: From the Researcher's work Based on (Table 12)

Figure 4. Seasonal Rates of Atmospheric (mb) Pressure Values of Stations Available in the Study Area for the Period (2010-2020)

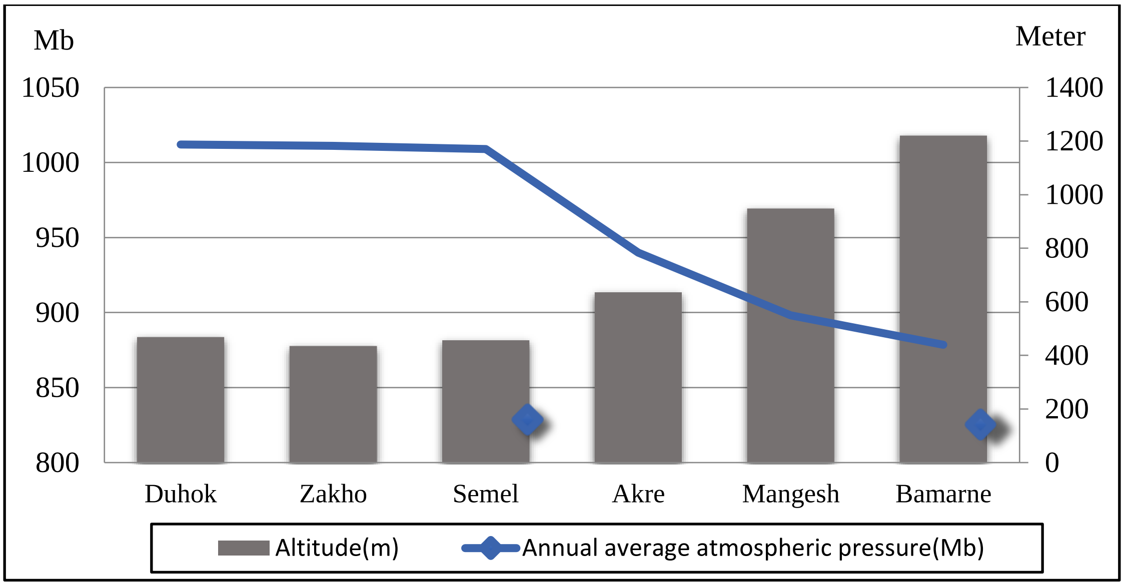
3. The variation of the Annual Range of Atmospheric Pressure Values Between the Available Stations as Follows:

- The annual average of atmospheric pressure in the study area was (947.42 mb).

- The highest annual atmospheric pressure values were recorded in the stations (Duhok-Zakho-Semel), reaching (1,012.53-1,011.47-1,00950 mb), respectively. This is due to the altitude factor above sea level, the atmospheric pressure increases with a decrease from sea level.

● The lowest annual atmospheric pressure values were recorded in the stations (Akre- Bamarne- Mangesh), which amounted to (878.53-898.05-940.27mb), respectively. This is also due to the altitude factor above sea level because the atmospheric pressure decreases with the increase of Sea level. As shown in (Figure 5).

The values of atmospheric pressure decrease at a rate of (24 mb) for every (150m̊) of altitude (Abu Radi, 2004). It can be said that atmospheric pressure values decrease as we head from the south to the north of the study area.



Source: From the Researcher's work Based on(Table 12)

Figure 5. Atmospheric (mb) Pressure Per Height of the Stations

2.2.4. Humidity

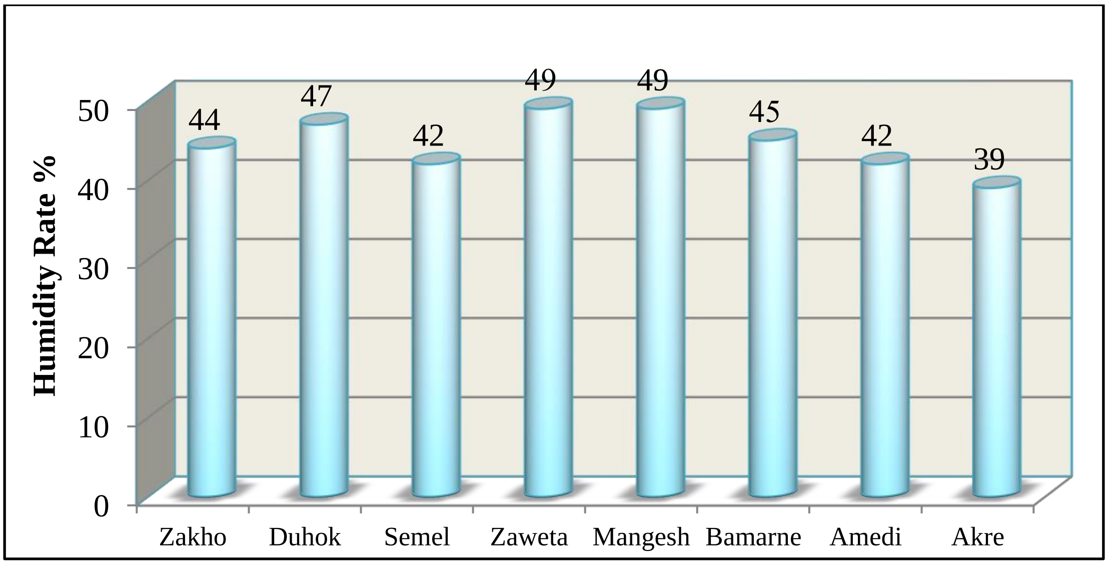
Relative humidity is defined as the percentage of water vapor in the air at a certain temperature and pressure until the air reaches the point of saturation and thus can carry it at the same temperature and pressure. It is considered as an effective factor on temperature as it maintains and cools the air (Sharaf, 1985). It constitutes an important component of the weather, as it plays a major role in the formation of clouds, fog and dew, and is responsible for all major weather manifestations such as hurricanes and other weather disturbances (AlLouh, 2017). Humidity affects the continuation of the evaporation process from the surface of water bodies. Whenever the humidity is low, the evaporation process continues quickly when energy is available. But if the humidity rises, the evaporation process weakens (Shahada, 2009).

So, humidity increases with increasing temperature (Coşkun, 2003). (Table 14)(Figure 6), represent the annual and monthly rates of (8) stations that record the humidity component and can be relied upon due to the lack of humidity data for many stations, so we relied on the stations in which humidity records are available for the period (2010-2020).

Table 14. Monthly and Annual Humidity Rates % for Available Stations in the Study Area between (2010-2020)

Months	Zakho	Duhok	Se mel	Zawita	Mangesh	Bamarne	Amedi	Akre	General Av
Jan	65	70	65	64	66	64	62	64	65
Feb	61	68	62	60	61	60	62	60	62
Mar	58	63	55	59	62	62	54	58	59
Apr	53	57	50	54	55	55	54	50	53
Ma	40	31	40	47	47	46	43	35	41
Jun	24	33	25	38	28	27	26	19	27
Jul	20	28	21	33	44	21	19	14	25
Aug	22	29	21	31	21	20	20	14	22
Sep	26	22	24	37	30	26	22	18	25
Oct	39	44	33	49	47	38	33	32	39
Nov	55	59	53	60	62	56	45	48	55
Dec	63	66	58	60	63	66	60	58	62
Annual Rate	44	47	42	49	49	45	42	39	45

Source: From the Researcher's work based on the General Directorate of Meteorology and Seismic Monitoring in Dohuk, Climatic Data Department, unpublished



Source: From the Researcher's work based on (Table 14)

Figure 6. The Averages of Relative Humidity for the Time Period Between (2010-2020)

It is noticed from the previous table and Figure (6) that the annual rates of humidity vary from one station to another, due to the influences of geographical location, as the stations located in the south of the study area (Zakho, Duhok, Semel), have reached the annual average humidity (44%, 47%, 42%) respectively. The openness of the terrain station to the plains of that region have a clear effect on making the region a transit area of the low pressuress, air mass and gusting winds that are not wet. In addition, the humidity values are related to the type of air mass dominating the region, whether it is a marine or continental. Humidity depends on the temperature and the amount of evaporated water. ln general, the humidity decreases in the direction from north to south. The average annual humidity in the stations located in the north (Zawita, Mangesh, Bamarne, Amedi, Akre) reached (49%, 49%, 45%, 42%, 39%), and this is due to the increase in temperature and the lack of vegetation cover (Taha, 2013).

Table 15. Seasonal Humidity Rates % in the Available Stations in the Study Area for Duration (2010-2020)

Station	Winter Rate	Spring Rate	Summer Rate	Autumn Rate
Zakho	63	50.33	22	40
Duhok	68	50.33	30	41.66
Semel	61.66	48.33	22.33	36.66
Zawita	61.33	53.33	34	48.66
Mangesh	63.33	54.66	31	46.33
Bamarne	63.33	54.33	22.66	40
Amedi	61.33	50.33	21.66	33.33
Akre	60.66	47.66	15.66	32.66
Rate tations	63	51	25	40

Source: From the Researcher’s work Based on (Table 14)

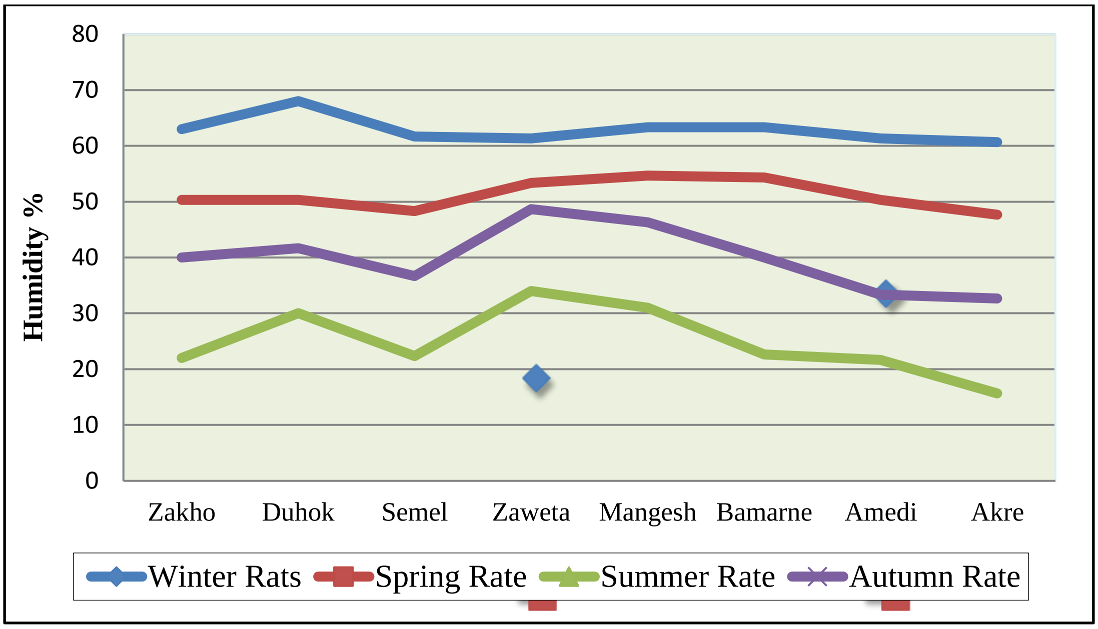
It is noted through (Table 15) the seasonal distribution of humidity in Duhok government, as follows:

● **Humidity in Winter**

The low temperature and the arrival of atmospheric low pressures and headwinds during winter lead to increase the humidity in this season, which is the most humid season in the study area, where the humidity reaches its peak during the winter months in all stations, where the average of stations is (63%), Duhok station records the highest seasonal average humidity in winter (68%), and Akre station records the lowest rate (60.66%), and January records the highest monthly average humidity during the year (65%), and monthly values range between (62%, 70%), as shown in (Table 14)(Map 9). This is due to the fact that as the temperature decreases, the humidity increases because the ability of air to absorb water vapor decreases (Shahada, 2009).

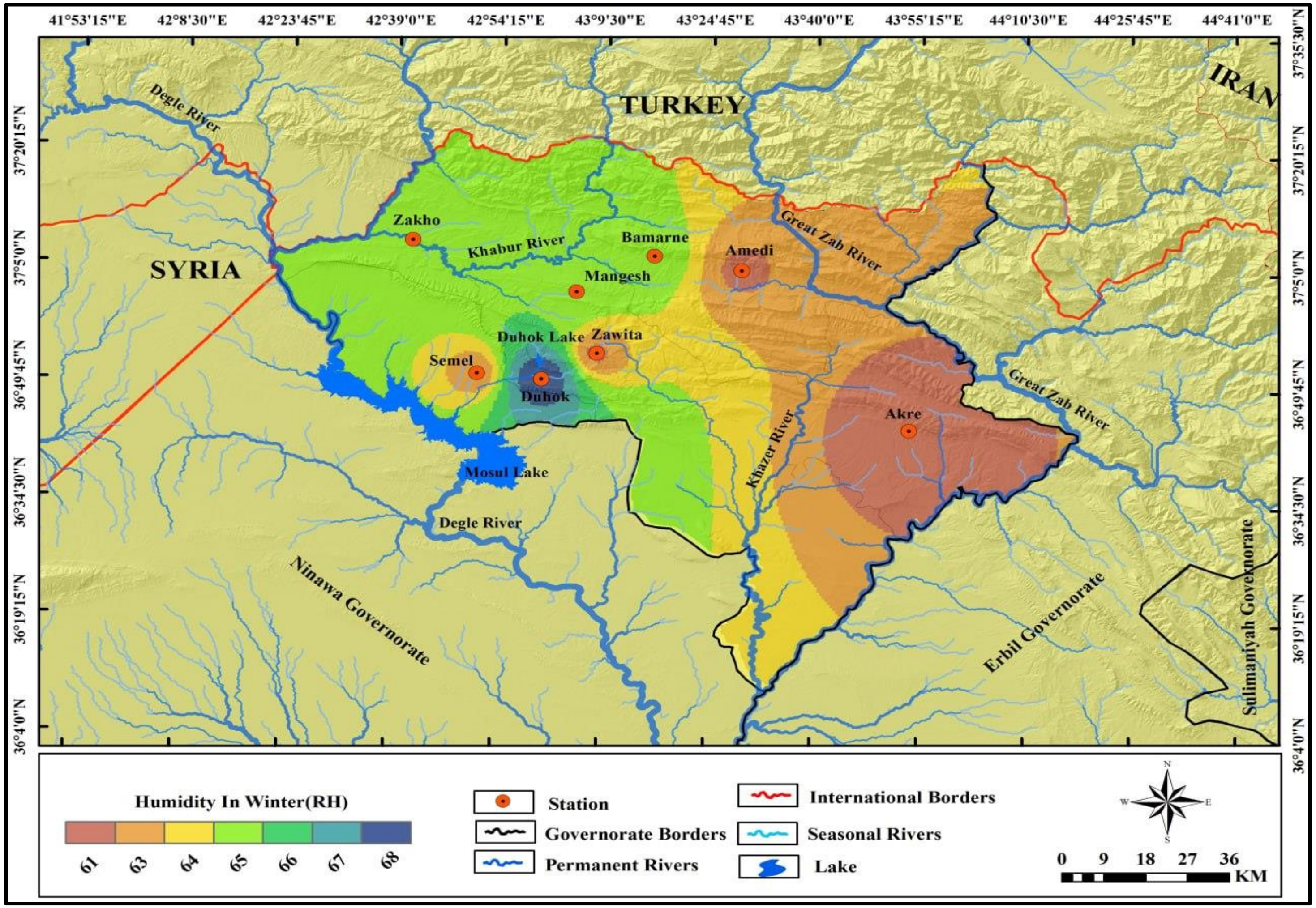
- **Humidity in Spring**

The humidity rates recorded in the stations of the study area in this season are higher compared to the dry summer season, as shown in (Figure 7), where the rate of stations for this season is (51%), and this is due to low pressures, cyclones and masses of moisture passing over the area and thus affecting characteristics of humidity. However, at a lower rate than in winter, Mangesh station records the highest rates of seasonal humidity among the stations of the study area, reaching (54.66%), and the lowest seasonal rates are recorded by Akre station (47.66%), while the stations Bamarne, Zawita, Zakho, Duhok, Amedi, Semel recorded (54.33%, 53.33%, 50.33%, 50.33%, 50.33%, 48.33%) respectively.as shown in (Map10).



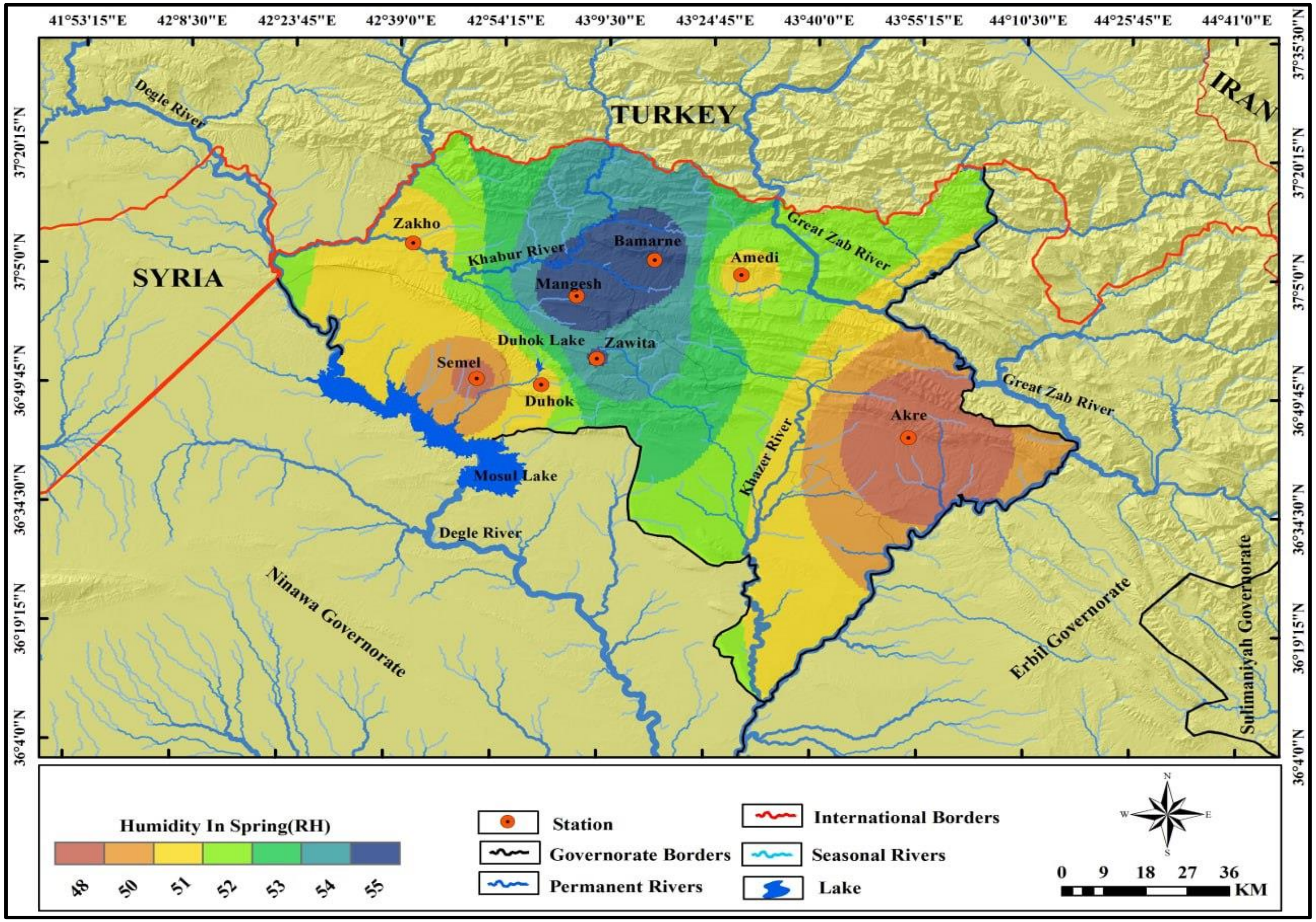
Source: From the Researcher's work Based on (Table 15)

Figure 7. Seasonal Humidity Rates for Available Stations in the Study Area for the Period (2010-2020)



Source: From the Researcher's work Based on (Table 15)

Map 9. Average Humidity of the Stations of Duhok Governorate for the Winter Between (2010-2020)



Source: From the Researcher's work Based on (Table 15)

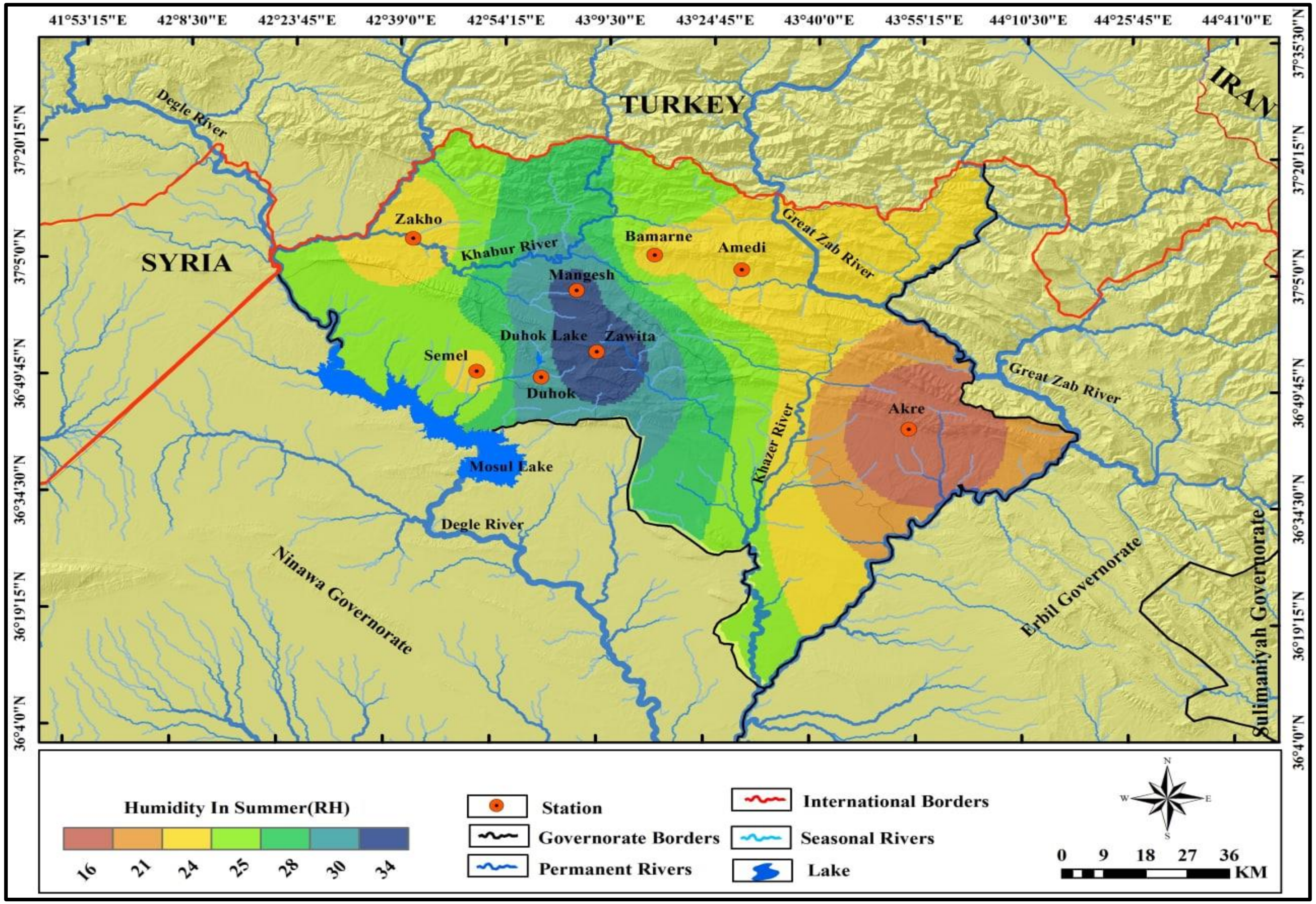
Map 10. Average Humidity of the Stations of Duhok Governorate for the pring Between(2010-2020)

- **Humidity in Summer**

The lowest values of seasonal humidity are recorded for all stations in summer, where the seasonal average of the stations in the study area is (25%). The low humidity in the hot season of the year are caused by the absence of rain and the increase of temperature as well as the air draught. The lowest seasonal rates recorded in this season is in Akre station, which reaches (15.66%), while the highest rates during this season are recorded in Zawita station (34%). The discrepancy in the stations' records in humidity rates is due to the high temperatures in general and the lack of rain due to the interruption of the effect of low pressures air as mentioned previously and as shown in (Map 11).

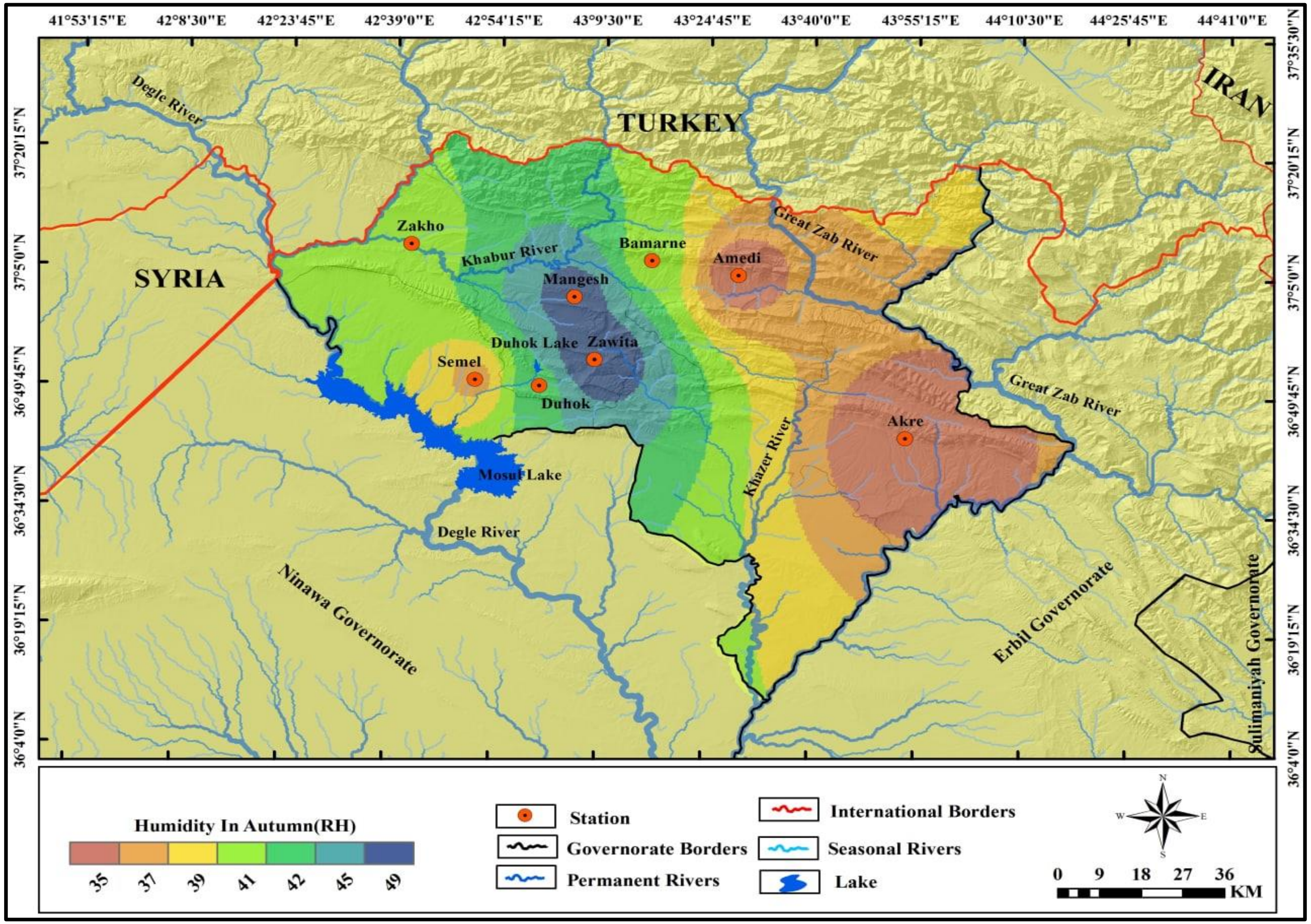
- **Humidity in Autumn**

Humidity begins to gradually increase during this season as a result of the decrease in temperatures and the trend towards the season of low temperatures, in addition to the beginning of the arrival of atmospheric low pressures. This is in line with the apparent movement of the sun towards the Tropic of Capricorn, thus reducing the amount of water vapor in the air, the relationship between humidity and the ability of the air to absorb an additional amount of water vapor increases. This relationship represents an increase in the rate of moisture in the air (Hadid & Al-Husseini, 1984). In general autumn is less humid than spring, so the seasonal average of the stations during this season reaches (40%). The highest seasonal rate is recorded in Zawita station (48.66%), and the lowest rate is in Akre station (32.66%), see (Map 12).



Source: From the Researcher’s work Based on (Table 15)

Map 11. Average Humidity of the Stations of Duhok Governorate for the Summer Between (2010-2020)



Source: From the Researcher's work Based on (Table 15)

Map 12. Average Humidity of the Stations of Duhok Governorate for the Autumn Between (2010-2020)

2.2.5. Air Masses

Air masses are defined as a great air body that extends for a distance of more than (1600 km) and its thickness is more than several kilometers. It is characterized by being homogeneous in its physical properties, especially heat and humidity (Karbil, & Wali, 1988). These characteristics are also identified as huge volume of air with a horizontal homoginity of temperature and humidity. They cover a wide area that sometimes exceeds several thousand kilometers, and their vertical width ranges between (300-3000m) (Alani & Wali, 1984).

Air masses affect the climatic characteristics in general and rainfall in particular for the areas they reach according to their characteristics, conveying to them the characteristics of the area on which they were formed. They contribute to change the climatic characteristics of the area to which it reaches especially rainfall (Alqshtini, 1998).

Air masses are largely responsible for the prevalence of unstable weather conditions and temporary weather changes in the study area. They are the reasons for the extreme drop in temperature (when a very cold or frozen mass invades an area) or the extreme rise in temperature (when a dry and hot tropical air mass invades the region (Taha, 2013). The air masses affecting the study area differ due to the small area covered by the governorate, so the impact of these blocks will be on all parts of the governorate, where it is not expected to invade clear weather discrepancies between the stations of the study area and of the air masses that invade Duhok governorate in the winter.

2.2.5.1. The Air Masses Accompanying the Warm Front Include

It is formed in areas of tropical high pressure called (horse shows) over land and water and therefore is divided into:

Continental Tropical Air Masses CT

It is one of the most important influential air Masses in the study area for most days of the year. These blocks arise over the Arabian Peninsula and the desert in

Africa. Their impact reaches the region from the southern and western sides (Ismail, 1994). These blocks are characterized by severe dryness and high temperature, and therefore rain is very rare (Fisher, 1950), except in some cases when it passes over the southern part of the Mediterranean, it pivots and becomes a marine tropical mass, and in the end it causes rainfall in the region (Alasidi, 1991). As shown on (Map 13).

Marine Tropical Air Masses MT

This air Masses are resulted from the Indian Ocean, where these blocks move towards the north and northwest from the Arabian Sea and the Arabian Gulf and enter the country from the south (Aljburi, 2002), then advance towards the study area. The effect of this mass starts from October until March. The lower layers of this mass are distinguished by their warmth and high humidity, while its upper layers are cold, which allows for the emergence of a state of instability, where warm currents rush quickly to the top, so their temperature decreases, thus when they pass over large bodies of water they cause heavy rains over the mountainous areas of the region (Ismail, 1994).

2.2.5.2. The Air Masses Accompanying the Cold Front. The Most Important types

Continental Polar Air Masses CP

These Air Masses are formed over the plains and wide flat lands such as the plains of Siberia and central Europe and move towards the study area attracted towards the continuous low pressure area on the Arabian Gulf and the Black and Mediterranean Seas and dominates in the fall and continues in the winter. It is a cold mass that reduces the temperature (Al-Naqshabandi, A, M. Amin, Muhammad, S,M. 1980). These blocks are moderate at the beginning of winter and cold during winter then become moderate again in spring. These blocks are accompanied by the polar fronts that move eastward, pushing the frontal low pressures in front of them. The atmosphere accompanying these blocks is clear after the associated low pressure has disappeared from the study area (Zangana, 2008).

Marine Polar Air Masses MP

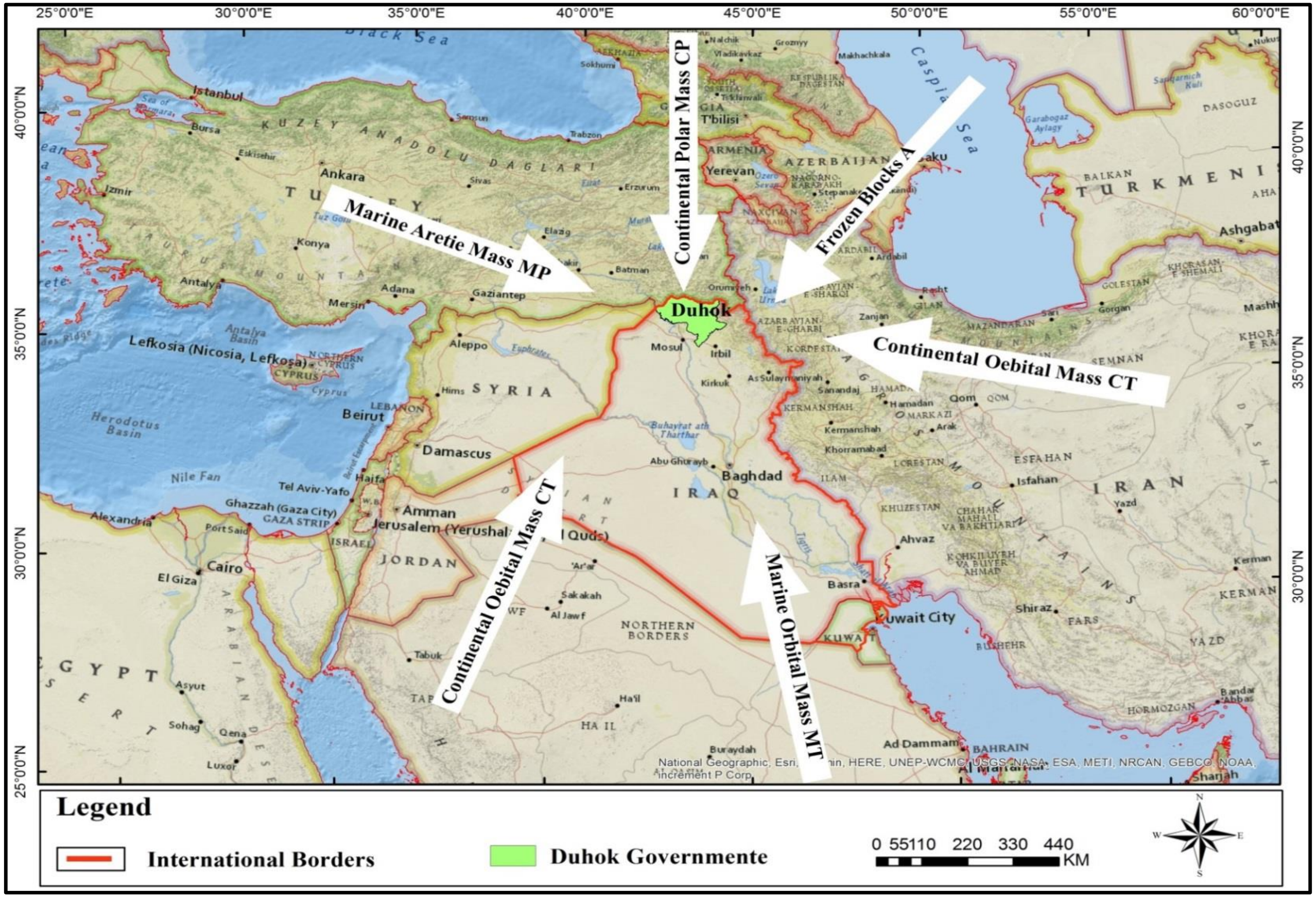
This Air mass comes from southern Iceland (Coşkun & Akbas, 2017), where it passes over the Atlantic Ocean (Çöleri, M. Yayvan, M. Deniz, A. Turgut, Ü. Eryılmaz, A. Geçer, C & Güser, A. 2005), and affects the study area in the winter months as it heads towards the region through two directions.

The first is through the Mediterranean, where the humidity increases and the result is the precipitation of large amounts of rain in the region.

The second passes through Europe. In this direction, the mass loses many of its marine characteristics, and accordingly its moisture percentage decreases, and causes rainfall indirectly (Ismail, 1994).

2.2.5.3. Frost or (Frozen Air Masses A)

It is formed in the Arctic region and affects the study area many times during the winter season of the year and enters the region from the north (Alasadi, 1991). It is rare to reach the region except in the case of deepening low pressures, as it works to withdraw this block. As these blocks advance towards the region, they reduce temperatures and they are primarily responsible for snowfall over mountainous areas and rainfall throughout the governorate (Alsamarayi, Q. M, Ahlam .J , and Huda. A. S.1995).



Source: Al-Rubaie, SH. A. M. (2000)

Map 13. Air Masses Affecting the Climate of Iraq and the Study Area in Winter

3. SPATIOTEMPORAL FLUCTUATION OF RAINFALL IN THE STUDY AREA

Rainfall is one of the most climatic elements that its quantities are obviously changeable whether at the temporal or spatial level. Many natural and atmospheric factors affect the distribution of rainfall. In the study area, rainfall is caused mainly due to the Mediterranean rainfall system, which is a system that concentrates most of its rainfall in the winter season. Rainfall of the study area is due to the passage of low pressures and cold fronts that accompany them.

Studying the spatiotemporal fluctuations of rainfall in the study area contributes to clarify and highlight the rainfall characteristics of the study area, in addition to know the fluctuation and seasonal change of rainfall (Al-Louh, 2017).

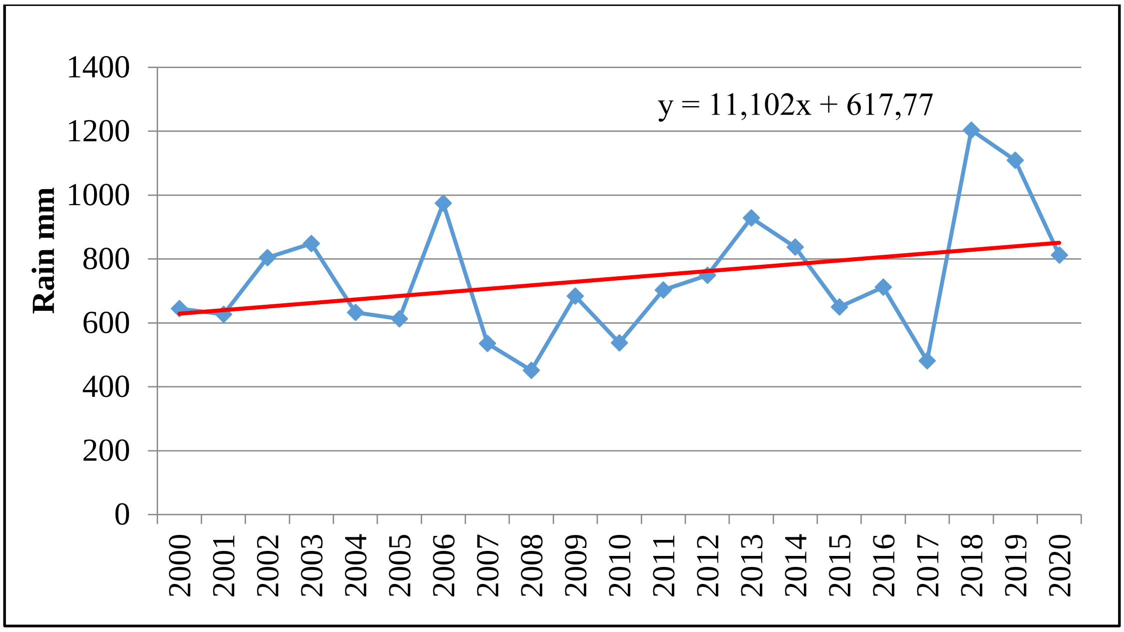
3.1. The Temporal Fluctuation of Rainfall

To show the extent OF temporal rainfall variation between the stations according to their participation in some years in which the amount of rainfall increased and the others in which this amount decreased as well as the proximity between these stations at the same duration (Hadi, 2011). Let us consider the following points:

3.1.1. The Temporal Fluctuation of the Average Annual Rainfall

The results of annual average Precipitation between (2000-2020) show high averages in some seasons, and low averages in others. This indicates a clear fluctuation in the amount of rainfall during the study period. The annual average of rainfall in the study area was about (739.8 mm) for the period (2000-2020) with an upward trend as shown in (Appendix 2) and (Figure 8). The rate of the increase reached about (11.102). It is indicated from the regression line equation that its value reached the following (Y=11.102x +617.77).

By analyzing the annual average of rainfall for the time period between (2000-2020) using the regression line equation, some results were deduced from the criteria of the rainfall stations scattered in the study area, which are the direction of the rainfall regression line tended to rise in all stations as shown in (Table16) (Figure 9), see the illustration in the following:



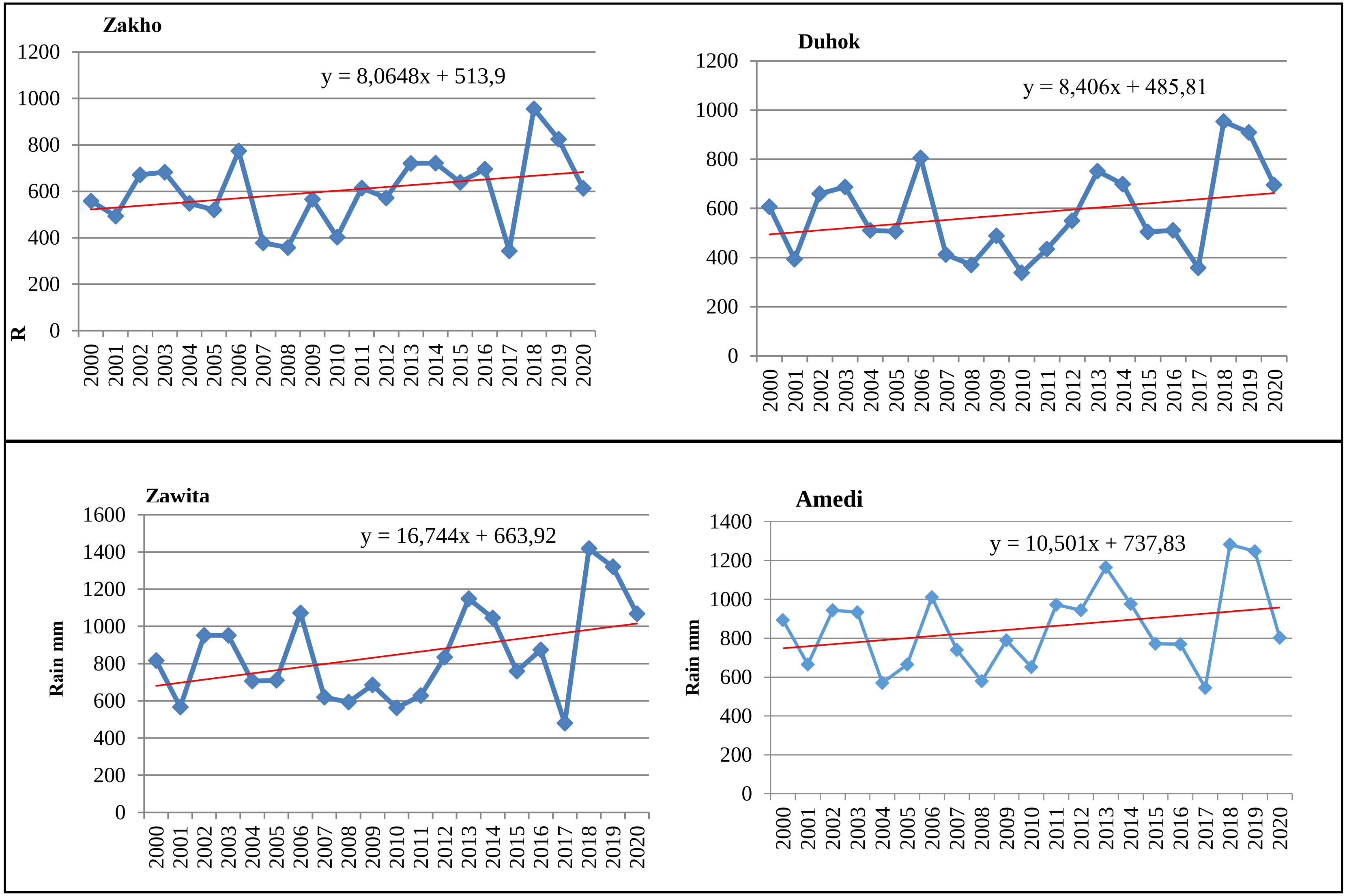
Source: From the Researcher's work based on (Appendix 2)

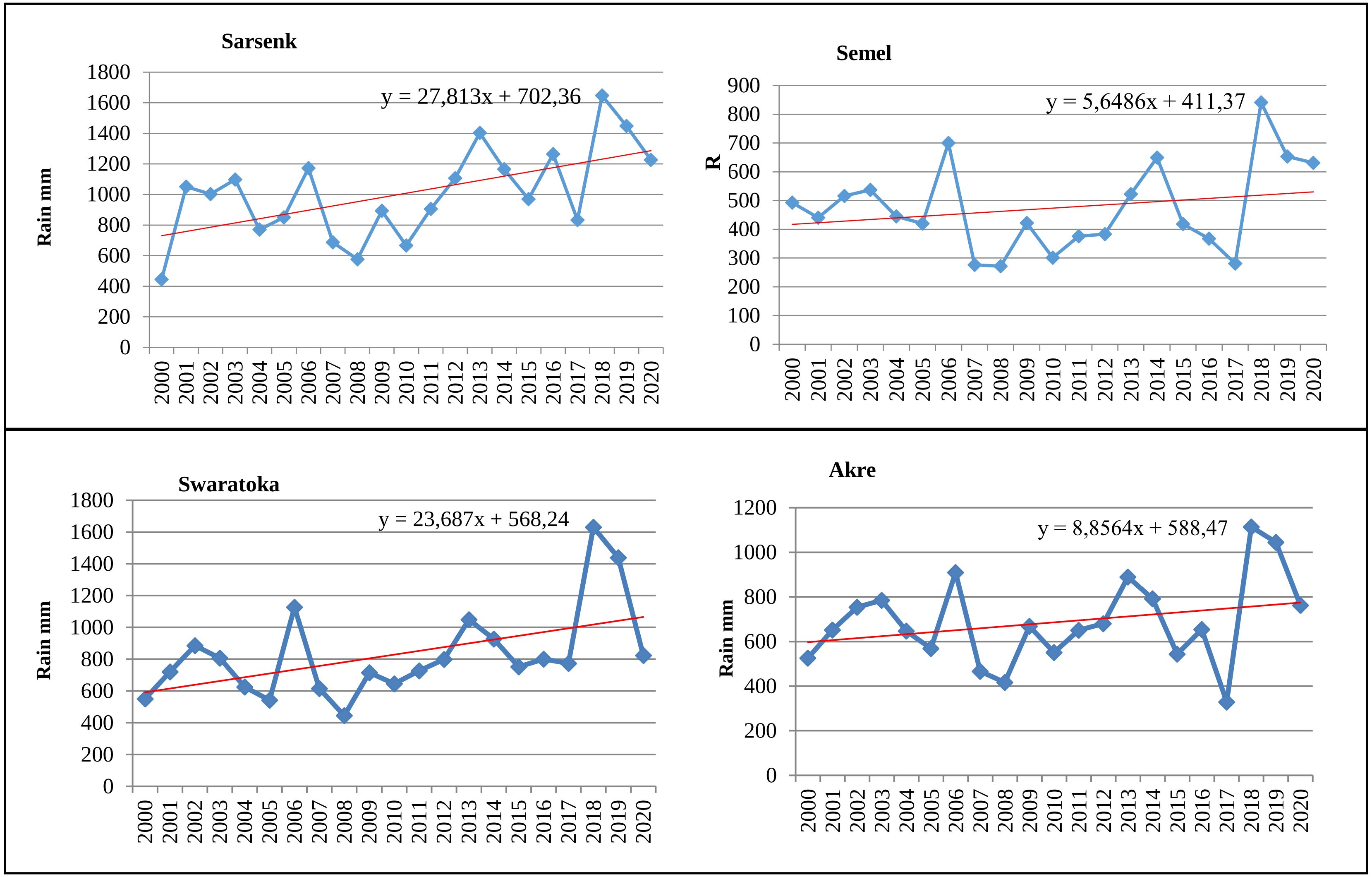
Figure 8. Temporal Fluctuation of Average Rainfall in Duhok Province During the Period (2000-2020)

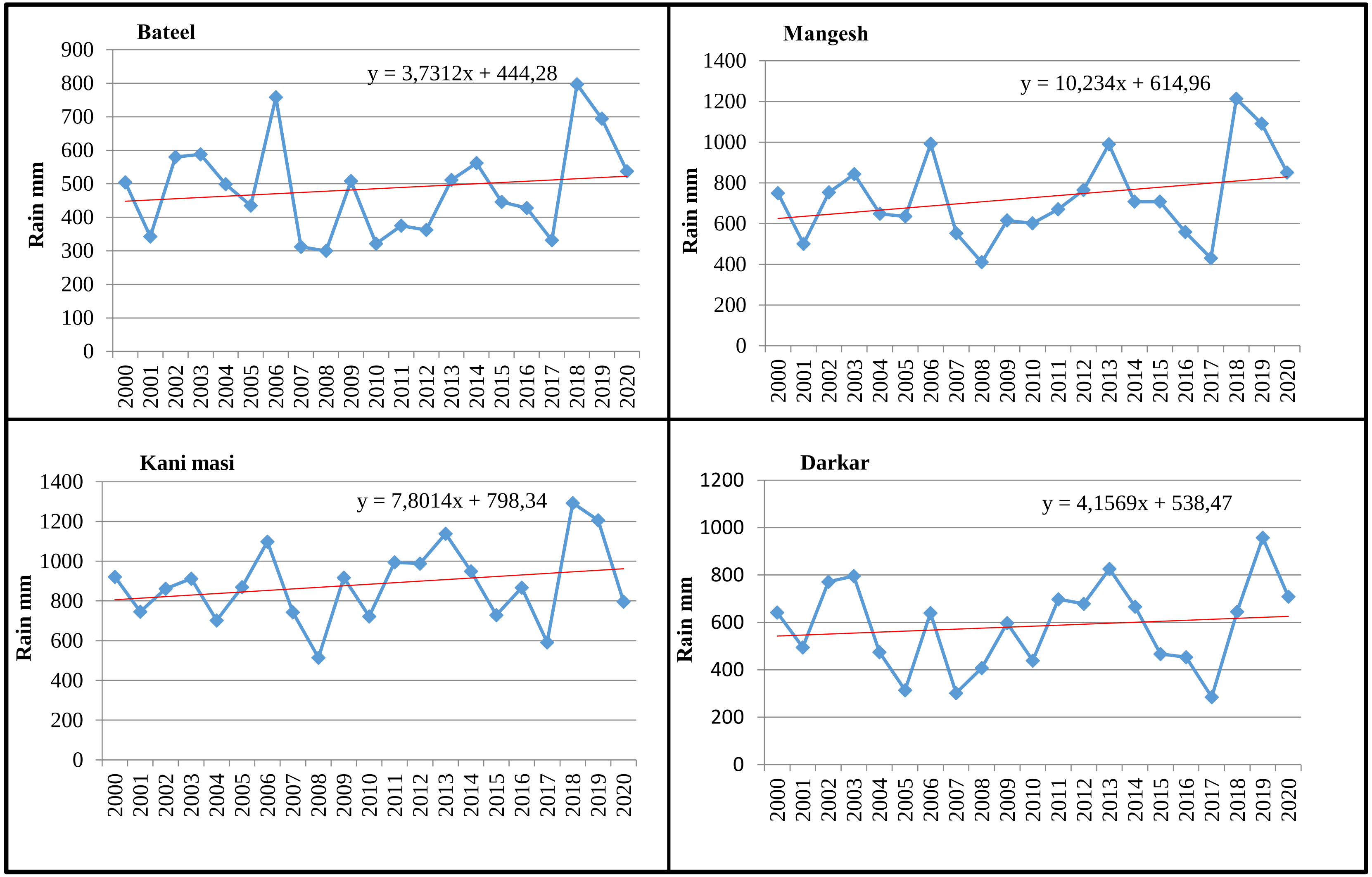
Table 16. Value (Y) in Duhok Government Between (2000-2020).

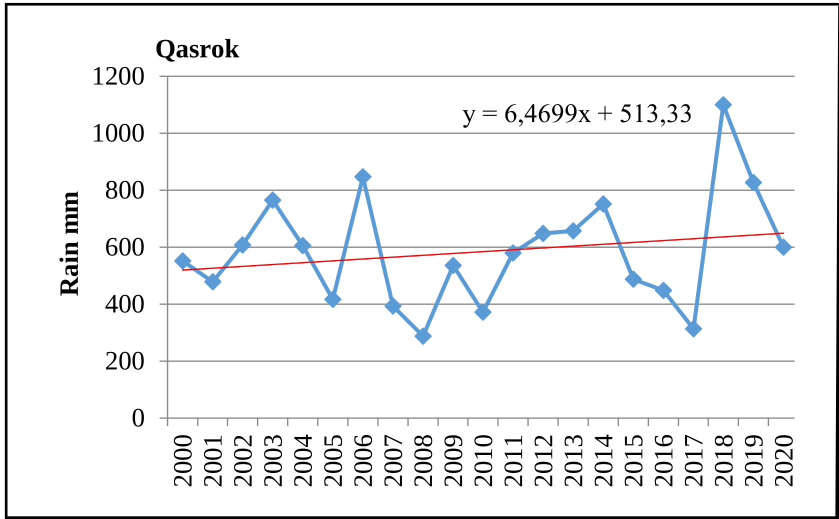
N	Station	Y value
1	Duhok	y =8.406x +485.81
2	Zakho	y =8.0648x +513.9
3	Amedi	y =10.501x +737.83
4	Zawita	y =16.744x +663.92
5	Semel	y =5.6486x +411.37
6	Sarsenk	y =27.813x +702.36
7	Swaratoka	y = 23.687x +568.24
8	Akre	y = 8.8564x +588.47
9	Bateel	y = 3.7312x +444.28
10	Mangesh	y = 10.234x +614.96
11	Darkar	y = 4.1569x +538.47
12	Kane masi	y = 7.8014x +798.34
13	Deralok	y=14.102x +752.31
14	Qasrok	y = 6.4699x +513.33
15	Batofa	y = 10.709x +681.12
16	Bamarne	y = 9.1056x +743.02
17	Denarta	y = 10.98x +931.04
18	Bardarash	y = 3.7292x +417.13
19	Chamanke	y = 22.988x +750.88
20	SHekhan	y = 8.3070x +498.61

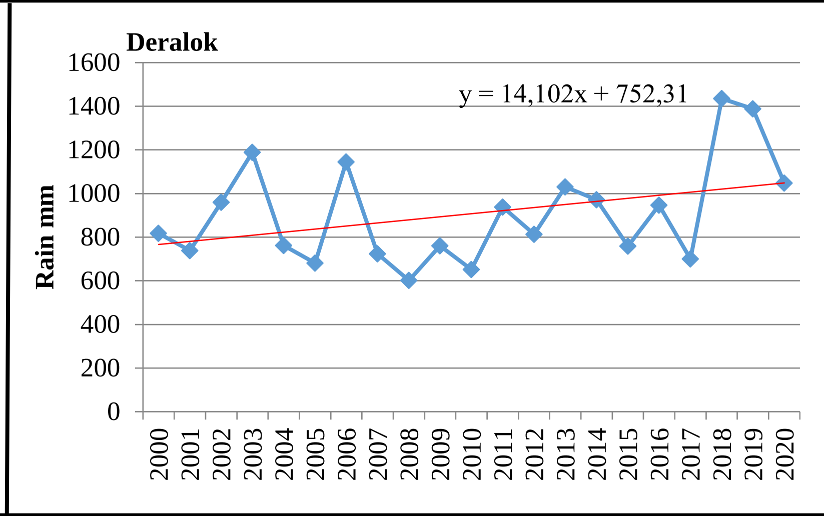
Source: From the Researcher's work Based on (Figure 9)

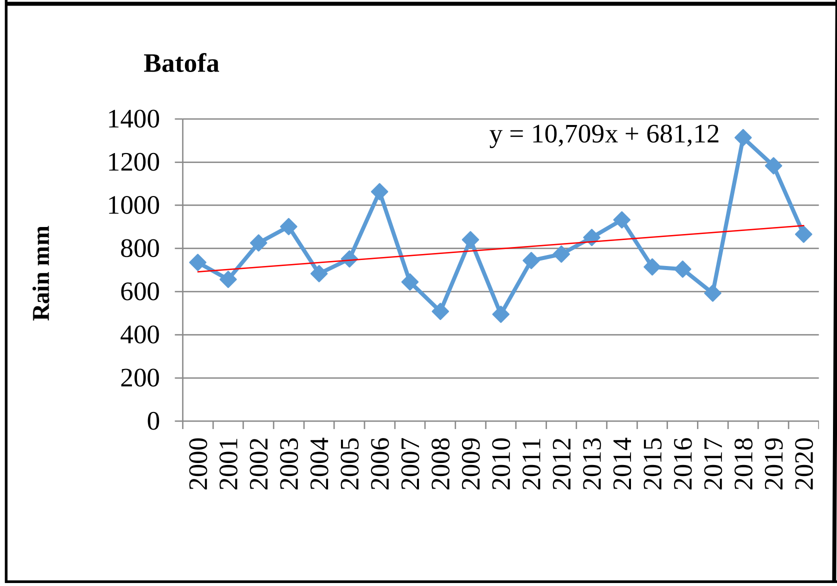

Zakho
y = 8,0648x + 513,9
R
Duhok
y = 8,406x + 485,81
Zawita
y = 16,744x + 663,92
Rain mm
Amedi
y = 10,501x + 737,83
Rain mm

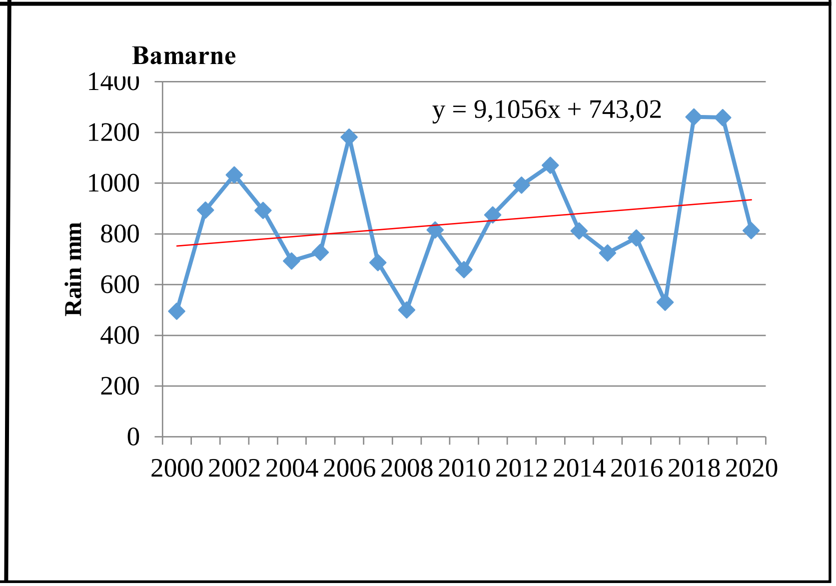

Sarsenk
Rain mm
y = 27,813x + 702,36
Semel
R
y = 5,6486x + 411,37
Swaratoka
Rain mm
y = 23,687x + 568,24
Akre
Rain mm
y = 8,8564x + 588,47

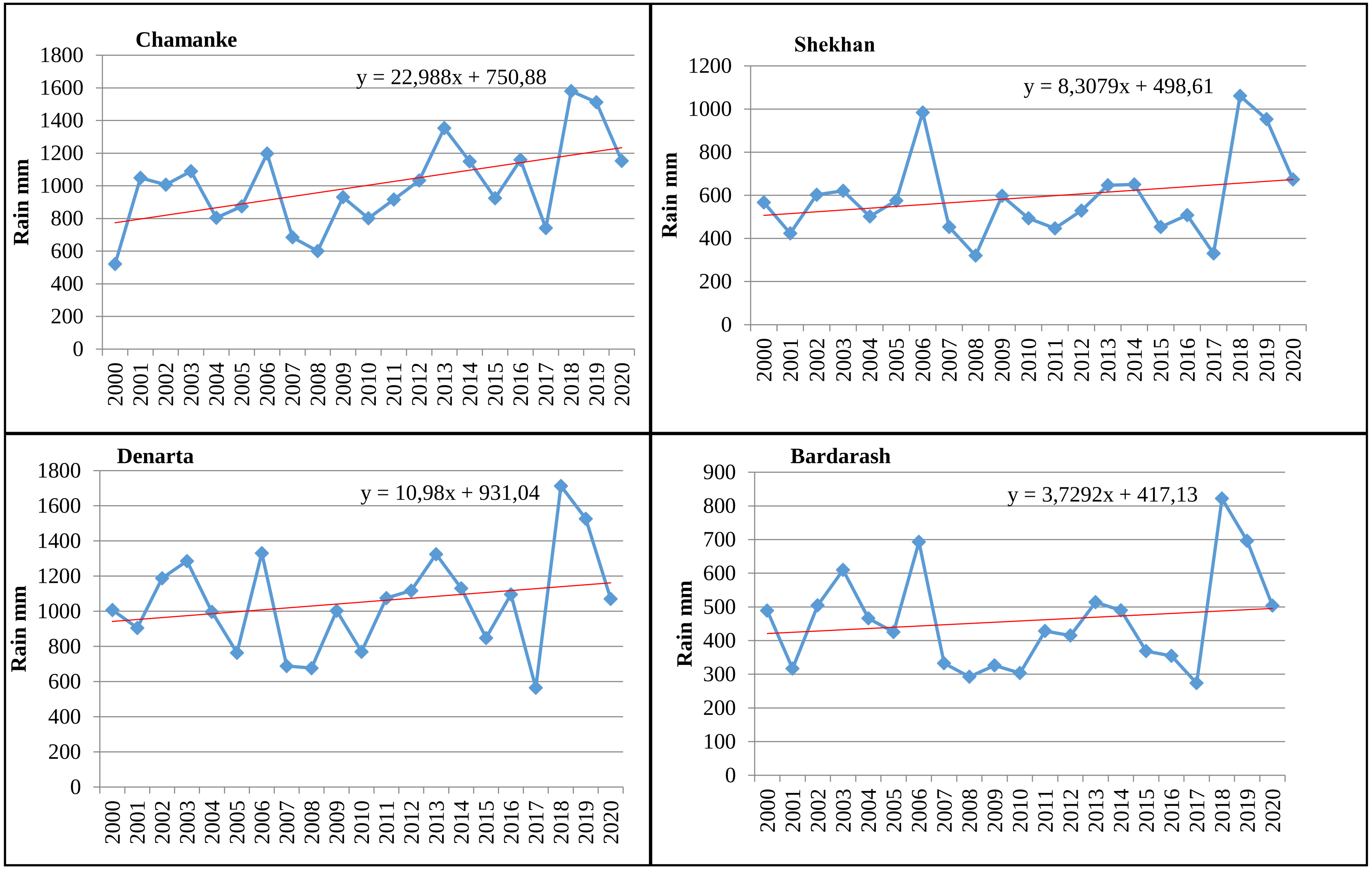

Bateel
y = 3,7312x + 444,28
Rain mm
Mangesh
y = 10,234x + 614,96
Rain mm
Kani masi
y = 7,8014x + 798,34
Rain mm
Darkar
y = 4,1569x + 538,47
Rain mm
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020


Qasrok
y = 6,4699x + 513,33
Rain mm
0
200
400
600
800
1000
1200
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020


Deralok
y = 14,102x + 752,31
Rain mm
0
200
400
600
800
1000
1200
1400
1600
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020


Batofa
y = 10,709x + 681,12
Rain mm
0
200
400
600
800
1000
1200
1400
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020


Bamarne
y = 9,1056x + 743,02
Rain mm
0
200
400
600
800
1000
1200
1400
2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020



Source: From the Tesearcher's work based on (Appendix 2)

Figure 9. Rainfall Fluctuation of Duhok Governorate Stations Between (2000-2020)

To Find Out the Temporal Fluctuation of Rainfall in Duhok Governorate, Some Statistical Transactions were Utilized Including:

- **Moving Averages of Annual Average of Rainfall.**

The annual fluctuation in the amount of rainfall and the difference in its values requires knowing if this deviation is random or follows a specific system and pattern. Therefore, the techniques of triple and five moving averages were used which is widely used in climatic studies. The triple and five moving averages are calculated by taking the annual total of rainfall for every three or five years, it is added and then divided by (3) or (5). The outcome represents the triple or quintile average. The calculation process starts from the beginning of the data of the study period to its end. This method is useful to know the changes and irregular climatic periods that cause drought (Masoud, 2015).

(Figures 10 and 11) show the graphic representation of the total annual rainfall in Duhok Governorate. It can be clearly noted that there are vibrations contained in the diagram.

Vibrations are generally eliminated and reduced by calculating the three - and five-moving averages from the average total of annual rainfall, where the shape of the moving averages becomes smoother and less volatile, as noted from the dashed graph, where it is possible to identify periods of rising and fall in the amounts of rainfall so that it becomes clear that there are periods when rainfall increases and other periods when the rainfall decreases in the form of cycles, but it seems that the duration of these cycles is irregular.

The result of studying the moving averages and the general trend line found that they reveal a general tendency towards the continuous variation in the majority of years, and the movement is still towards the clear difference between the falling years in the study area.

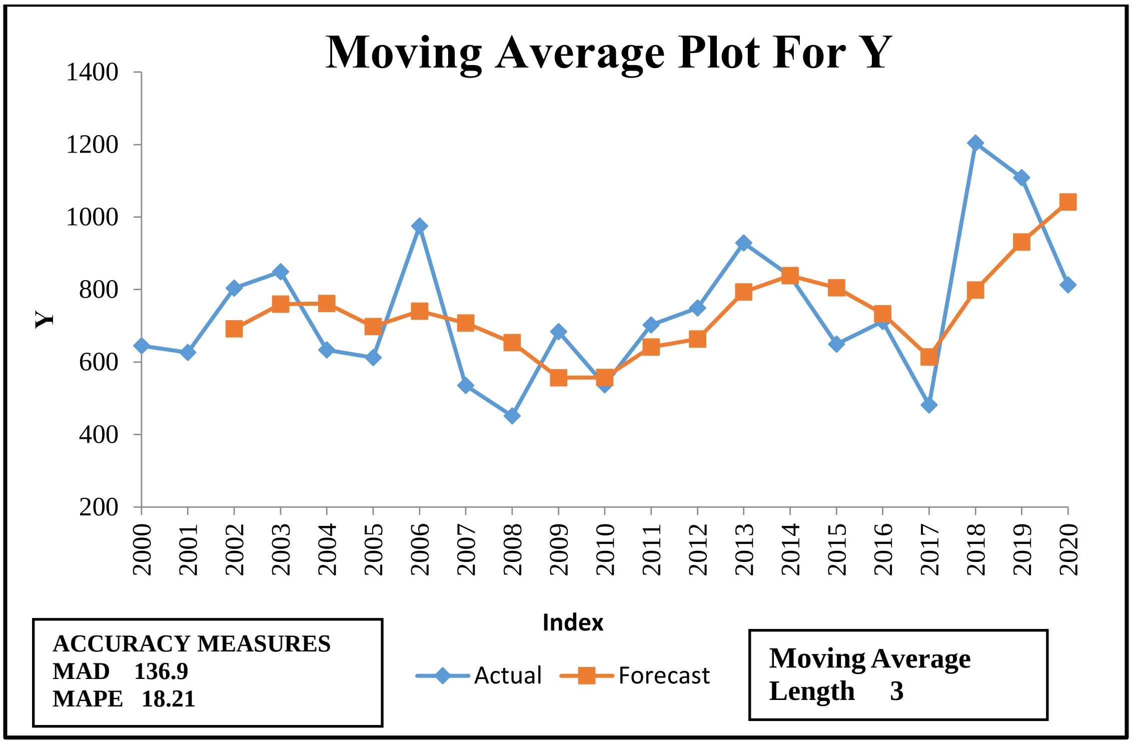
1. Moving Averages in Three Years.

It is clear through Table (17) that there are periods of increasing and decreasing the amount of rainfall in the triple moving averages, as these periods are irregular. That the rainfall begins to decrease in the first period between (2002-2006) and then increases in the second period between (2007-2010), then it goes back to decrease in the third period (2011-2015), then it goes back to increase in the fourth period in two successive years (2016-2017), then it goes back to decrease in the two consecutive years (2018-2019), then tends to rise in (2020). It is noted from the triple moving averages of the average annual rainfall amounts in the studied stations according to (Figure 10) that it is difficult to determine the regular or semi-regular cycles of rainfall, because the amounts of rainfall are among its most important random characteristics, whether seasonal temporal or geographical spatiotemporal randomness.

Table 17. Moving Averages of Rainfall for (3) Years

Year	The Annual Amount of Precipitation	(3)Year Moving Averages
2000	644.535	——
2001	626.375	——
2002	804.06	691.66
2003	848.635	759.69
2004	633.04	761.91
2005	612.505	698.06
2006	975.095	740.21
2007	535.635	707.75
2008	451.305	654.01
2009	683.825	556.92
2010	537.325	557.49
2011	702.505	641.22
2012	749.205	663.01
2013	928.17	793.29
2014	837.615	838.33
2015	649.44	805.08
2016	712.07	733.04
2017	481.315	614.28
2018	1203.73	799.04
2019	1108.98	931.34
2020	812.31	1041.67

Source: From the Researcher's work based on (Appendix 2)



Source: From the Researcher's work based on (Table 17)

Figure 10. Moving Averages of Rainfall for (3) Years

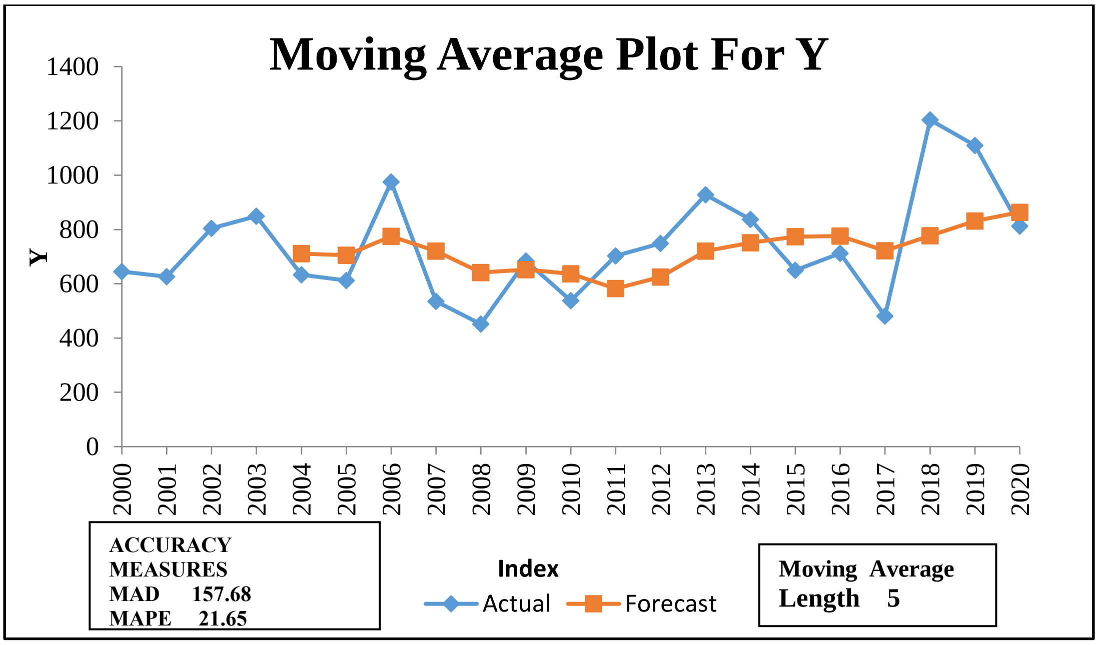
2. Moving Averages for 5 Years

It is clear through (Table 18) that there are periods of increase and decrease in the amount of rain in the five moving averages as these periods are irregular. Rainfall begins to increase in the first period between (2004) and (2008), then decreases in the second period between (2009) and (2011), and then continues to decrease in the third period between (2012-2016), and then returns to increase in (2017) and then decrease in two consecutive years (2018-2019), then increase in 2020. It is noted from the five moving averages of the average annual rainfall amounts in the studied stations according to (Figure 11) that it is difficult to determine regular or semi-regular cycles of rainfall in the study area, because the quantities of rainfall are among its most important random characteristics, whether seasonal temporal or geographical spatiotemporal randomness.

Table 18. Moving Averages of Rainfall for the 5 Years

Year	Annual Amount of Precipitation	(5)Year Moving Average	
2000	644.535	—	
2001	626.375	—	
2002	804.06	—	
2003	848.635	—	
2004	633.04	711.33	i
2005	612.505	704.92	
2006	975.095	774.67	
2007	535.635	720.98	
2008	451.305	641.52	
2009	683.825	651.67	
2010	537.325	636.64	
2011	702.505	582.12	
2012	749.205	624.83	d
2013	928.17	720.21	
2014	837.615	750.96	
2015	649.44	773.39	
2016	712.07	775.30	
2017	481.315	721.72	d
2018	1203.73	776.83	
2019	1108.98	831.11	
2020	812.31	863.68	

Source: From the Researcher's work based on (Appendix 2)



Source: From the Researcher's work based on (Table 17)

Figure 11. Moving Averages of Rainfall for a Period of 5 Years

The reason for using moving averages in this study is to get rid of short-term fluctuations in the time series of rainfall during the period (2000-2020), and to show the general trend without being covered by short-term fluctuations that distort the shape of the general trend. A period of 3-5 years was used to calculate the moving averages. Rainfall is one of the most climatic elements whose quantities change temporally and spatially due to several factors, the most important of which is the movement of atmospheric low pressures that lead to the formation of atmospheric instability as well as the effect of the terrain. One of the factors that lead to the lack of regulation of precipitation amounts in the study area between increasing and decreasing is the phenomena of El Nino and La Nina, although the impact of these phenomena is indirect on Iraq and within the study area because of the distance from the center of the phenomenon and its geographical scope located in East Pacific.

Precipitation data for the climatic stations used in the study area as shown in(Figures 10-11) indicate that they were affected by the El Nino and La Nina events, even in small proportions, so we note an increase in rainfall with the intensity of the El Nino phenomenon (Soliman,2020), and that the effect of LaNina is counterproductive to the amount of rainfall in the study area. That is, the decrease in the amount of rain in some years is due to the effect of the La Niña phenomenon (Palani, 2020).

- **The Change in the Amount of Annual Rainfall**

The amount of annual rain recorded by the stations of the study area affected by Mediterranean low pressures that cause rains which their quantity is changable according to the variety numbers of atmospheric low pressures and hurricanes passing through the region in addition to the varying quality of the low pressure in terms of shallowness, depth humid content duration and frequency. These factors are responsible of annual variations between years of heavy rains and others of rare rains .ln general the amount of rainfall in the study area increases as we head from the south towards the nothern parts not only because of the increase of the number of low pressures passing through the study area, but also by the terrain factor (Ismail, 1994). By calculating the change factor for precipitation and the marked decrease in the amount of rainfall during the period (2000-2020) showed the following:

In (Table 19) there was shown a noticeable decrease in the amount of rainfall during the period (2000-2009) according to the average rainfall, reaching (681.47) despite overlapping periods of apparent drought during this period, and a noticable increase in the amount of rainfall during the period (2010-2020) according to the average rainfall reaching (792.88) although clear droughts overlap. This will be mentioned in chapter four in details.

Table 19. Coefficient of Change in the Rains of Duhok Province During the Period (2000-2020)

Year	Average mm	Difference	Coefficient of Change%
2000	644.53	-95.3	-12.88
2001	626.37	-113.46	-15.33
2002	804	64.17	8.67
2003	848.63	108.8	14.7
2004	633	-106.83	-14.43
2005	612.5	-127.33	-17.2
2006	975	235.17	31.78
2007	535.63	-204.2	-27.59
2008	451.3	-288.53	-38.99
2009	683.82	-56.01	-7.55
2010	536.32	-203.51	-27.5
2011	702.5	-37.33	-5
2012	749.2	9.37	1.26
2013	928.17	188.34	25.45
2014	837.61	97.78	13.21
2015	649.44	-90.39	-12.21
2016	712	-27.83	-3.76
2017	481.46	-258.37	-34.92
2018	1203.73	463.9	62.69
2019	1108.98	369.15	49.89
2020	812.31	72.48	9.79

Source: From the Researcher's work based on(Appendix 2)

$$\frac{\text{Average Annual Rain - Average Rain Per Year}}{\text{Annual Average Rain}} \times 100 \text{ (shahada, N 1988)} = \text{Coefficient of Change}$$

It is also indicated the predominance of drought conditions during (12) rainy seasons out of a total of (21) seasons, by (57%) during the study period. Most of the drought periods were during the first time period between (2000-2009). As we mentioned earlier, the decrease in the amount of rain in some years in Iraq, including the study area, is because of the effect of the La Niña phenomenon. This is related to the fluctuation of rainfall quantities, which It negatively affects groundwater in general and the agricultural sector in particular, as it depends on rain-fed agriculture.

The positive change factor reached its highest rate during the rainy season (2018), with more rainfall than the overall average (62.69%), while the negative change factor was the highest during the rainy season (2008), with a rainfall that decreased from the overall average by) -38.99), as shown in Table (19).

3.1.2. Temporal Fluctuation of Monthly Averages Rainfall

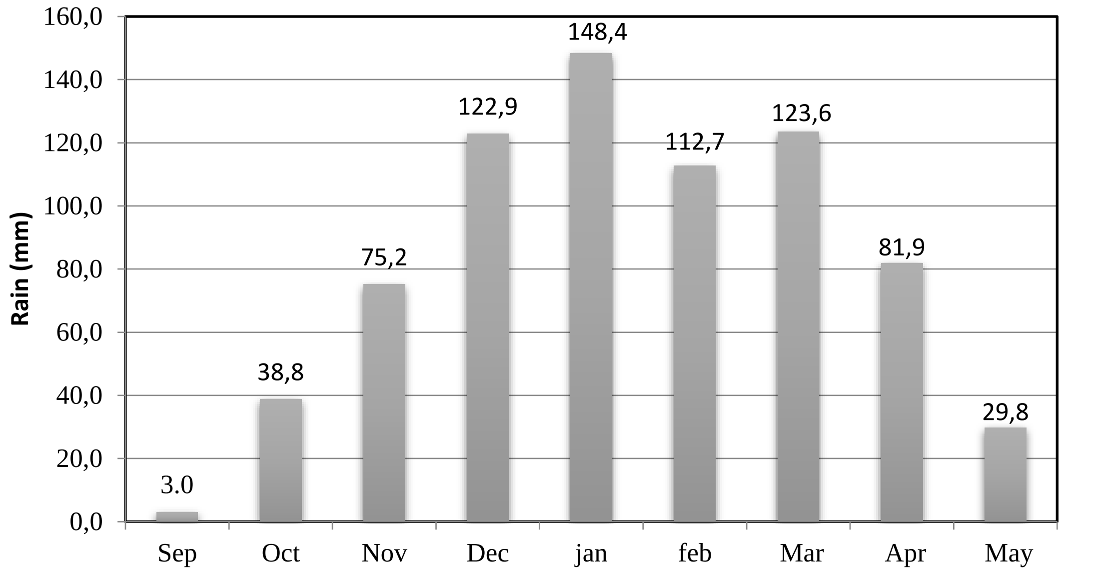
If the amount of precipitation that falls in a day is greater than (0.1 mm), then this day is considered a rainy day (Cosun, 2008). Therefore, rainfall element is one of the most climatic elements whose quantities vary significantly, whether with the monthly or annual extension of the study area, which leads to its fluctuation. This results in time differences in precipitation. Fluctuation in the amount of rainfall is associated with instabilities affecting the study area, which reach its peak and depth in January, and instabilities are consistent with the impact of annual atmospheric low pressures affecting the Mediterranean basin, and does not mean that all instability brings rainfall to the study area (Mushtahi, 2013). The monthly averages of rainfall during the study period (2000-2020) vary, as they recorded high averages for some months and low averages for others indicating a clear fluctuation in the amount of rainfall, during the study period.

3.1.2.1. General Temporal Variability of Monthly Averages of Rainfall

The average amount of monthly rainfall varies clearly, whether by increase or decrease, during the study period (2000-2020) and this explains the change in climatic factors affecting the amount of rainfall from month to month. This time period was adopted with monthly rainfall data available.

Monthly rainfall rates vary during the study period as the amounts of rain begin to gradually rise towards the rainy months, which start gradually from the month of September until reaching a significant increase in the amounts of rainfall in the month of December, January and February, a period during which instability continues, which leads to rainfalls, then its quantity begins to decrease gradually until it is almost rare at the end of May towards the dry months, and the amount of rainfall is absent in June, July and August, which are the dry months, a period that is not exposed to instability, as it dominates the Azorean high Mediterranean basin and if it is exposed it will be accompanied by dust, and it appears by tracking the rainfall data and the clear fluctuation of the monthly averages of rainfall.

Generally, the highest average is in January and the lowest average is in September, and this clear fluctuation corresponds with the monthly average values of rainfall for the study period (21 years) to the increase in the rainfall values starting from September (3.0 mm) until it reaches its peak in January (148.4 mm), then it decreases to reach its lowest in May (29.8 mm), as shown in (Figure 12).

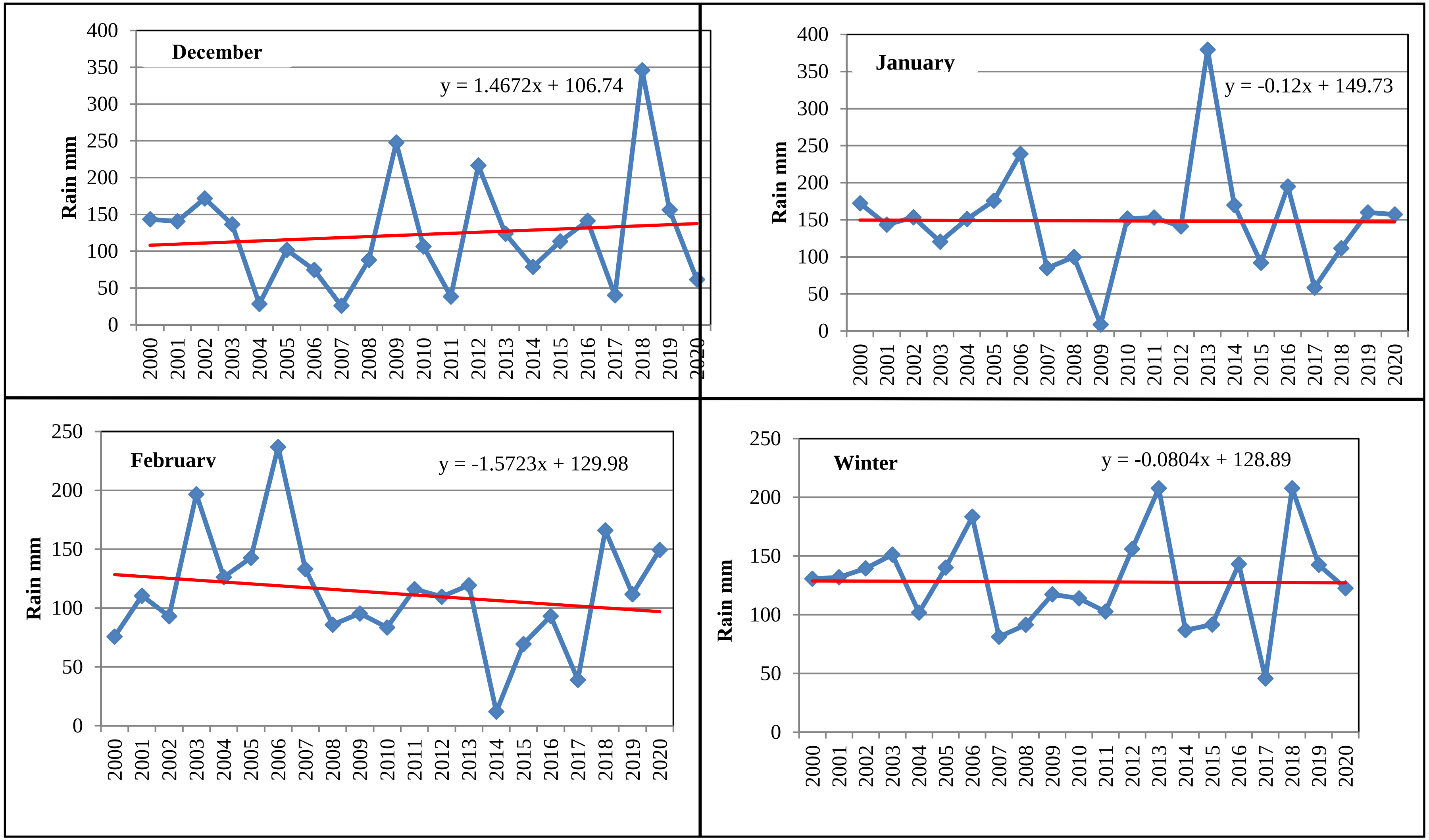


Source: From the Researcher's work based on (Appendix 3)

Figure 12. Analysis of the Monthly Average Rainfall in Duhok Province Between (2000-2020)

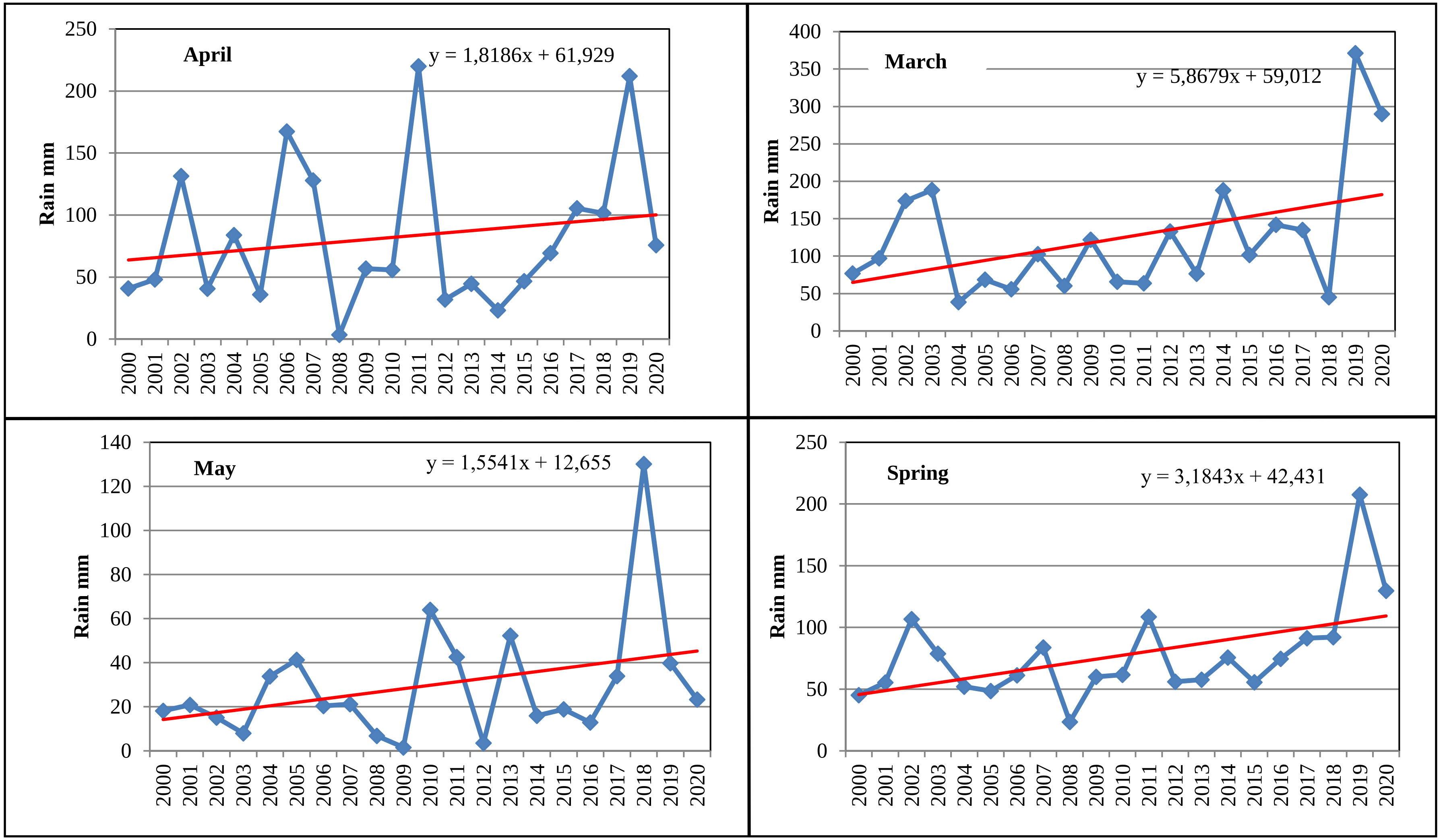
3.1.2.2. Monthly and Temporal Fluctuation of Rainfall

Monthly averages of rainfall are one of the means that clarify their values over a period of time because rainfall is one of the most climatic elements whose quantities change clearly. These changes are a result of the effect of several factors on the amount of rain, including continental and marine. The time of fluctuation of the monthly averages of rainfall can be analyzed as follows:



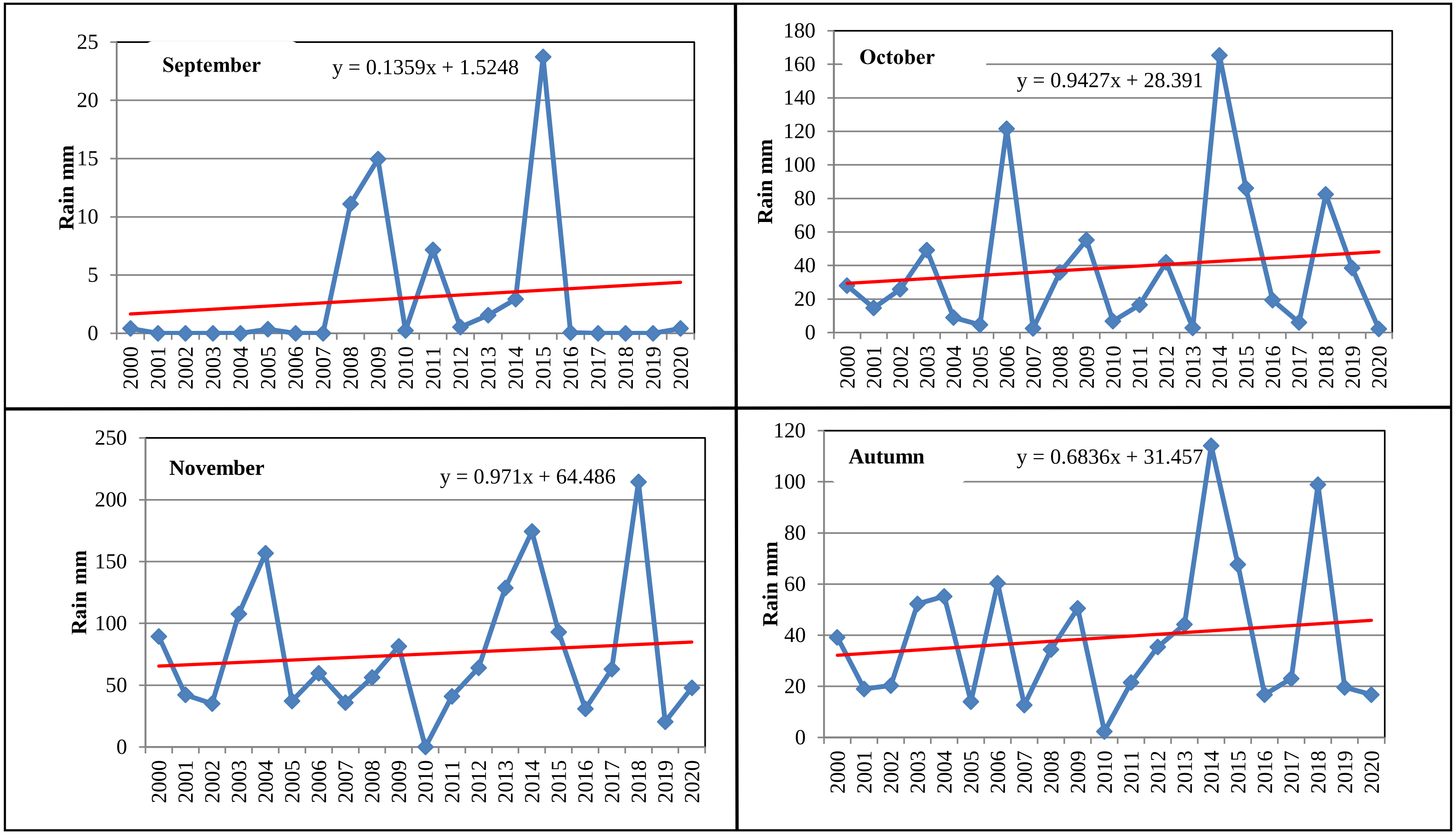
Source: From the Researcher’s work based on (Appendix 3)

Figure 13. Rainfall Changes in the Winter Months of Duhok Province During the Study Period (2000-2020).



Source: From the Researcher's work based on (Appendix 3)

Figure 14. Rainfall Changes in the Spring Months of Duhok Province During the Study Period (2000-2020)



Source: From the Researcher’s work based on (Appendix 3)

Figure 15. Rainfall Changes in the Autumn Months of Duhok Province During the Study Period (2000-2020)

The rainfall average values vary with the increase and decrease in the general monthly average during the study period, and the change in the monthly averages of rainfall around its general average means the instability of the factors affecting the amounts of rainfall from year to year. The monthly averages of rainfall are characterized by the presence of very high values than the general average, such as January (2013, 2006), February (2006, 2003), March (2019, 2020), April (2011, 2019) and May (2018), then the drought stage began and the humidity stage returned. The highest values were high in September (2015, 2009), and in October (2014, 2006). In November (2018, 2014, 2004), and December was the highest value in the year (2018, 2009). It is noted that there is no correspondence between years and months, meaning that the increase in a month is for a specific year, and the increase for another month is in another year, note (Figure 13, 14, 15).

It is also characterized by the presence of very low values compared to the general average, such as January (2009), February was the lowest value in (2014), March was (2004), and April was (2008). As for May, it had the lowest value in (2009, 2012), and after the end of the drought stage, all years were low in September except for (2015) and (2009), while October (2020, 2013, 2007), and November was the year (2010), and December was the least value in (2007). It is noticeable on these data that there is no correspondence in decrease between years and months. This means that the increase and decrease in the monthly averages do not follow a specific system that rains follow.

Table 20. (Y) Value of Rainfall Changes in Duhok Province During the Months of Study

N	Months	Y value
1	January	y = -0.12x + 149.73
2	February	y = -1.5723x + 129.98
3	March	y = 5.8679x + 59.012
4	April	y = 1.8186x + 61.929
5	May	y = 1.5541 x + 12.655
6	September	y = 0.1359x + 1.5248
7	October	y = 0.9427x + 28.391
8	November	y = 0.971x + 64.486
9	December	y = 1.4672x + 106.74

Source: From the Researcher’s work based on (Figure 13,14,15)

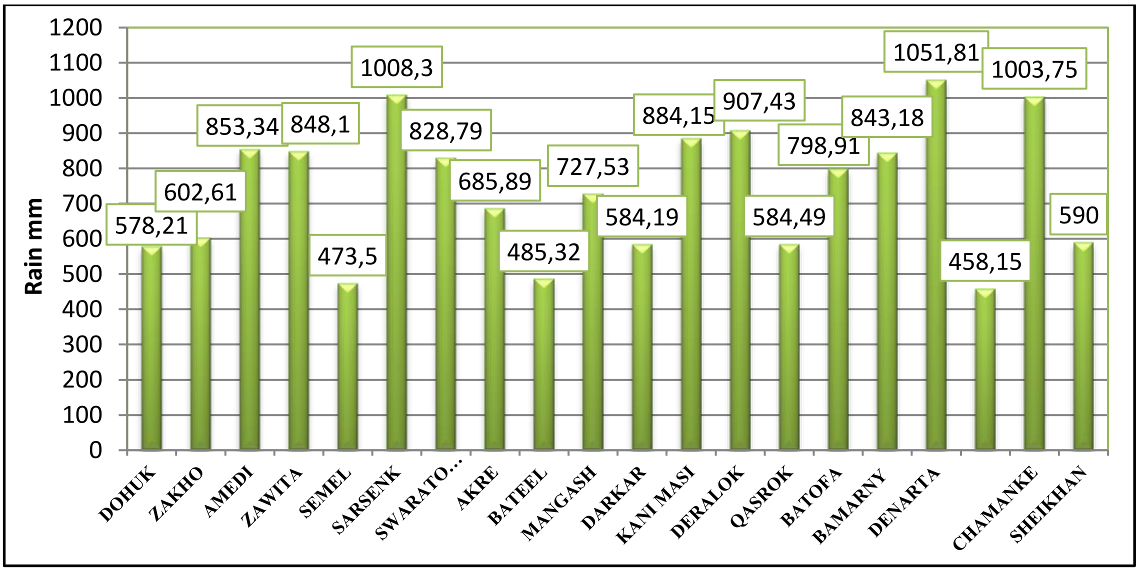
(Table 20) demonstrations that the direction of the rainfall slope line for monthly average rainfall in Duhok province during the study period (2000-2020) is moving upwards except for January-February, and their rainfall slope is declining.

3.2. The Spatial Fluctuation of Rainfall

The astronomical location affects the spatial variance of rainfall and the terrain variation between high and low stations. The spatial variation usually represents Similarities and complementarities on the one hand, and aspects of diversity and differences on the other hand (Khair, 2000). It appears in its clearest form in the study area, as the variation in the height of stations above sea level determines the possibility of benefiting from moist air masses, shallow low pressures of little depth and other factors that enhance the chances of rainfall (Alnajmawi, 2008).

3.2.1. The Spatial Fluctuation of Mean Annual Rainfall

The importance of studying rainfall in the study area is due to the limited water resources, in addition to the clear fluctuation in the amounts of rainfall, and its connection with regional and global variables. It is noted from (Figure 16) that there is a difference between the amounts of rainfall in the stations of Duhok governorate, as follows:



Source: From the researcher’s work based on (Appendix 2)

Figure 16. Spatial Variations of Average Rainfall in Duhok Governorate Stations

- The general average of the amount of rainfall during the period (2000-2020) ranges is (739.88 mm). There is a clear discrepancy in the rainfall registration in the study area between increase and decrease.
- The spatial distribution of rainfall varies in the study area. In Denarta station, the most rainy areas recorded in the study area about (1051.81mm), due to its location in a mountainous area covering the slopes of the mountains throughout the region, and due to its confrontation with the humid western winds coming from the Mediterranean Sea. The station Sarsenkit comes in second rank as it is about (1008.3 mm) located in a mountainous area at the foot of Gara Mountain, and Chamanke station is about (1003.75 mm), due to its encounter with the humid western winds coming from the Mediterranean Sea, which increases the amount of rainfall.
- The least rainy areas were recorded in the stations namely (Bardarash, Semel, Bateel), which amounted to (458.15 mm, 473.3 mm, 485.32 mm) in which the average rainfall was (458.15 mm), respectively, because they were located in the plain region and the rain lines are close to each other in the southern region.
- The rainy areas in the study area vary according to the rainy categories. Thus it was found that the category of less than (500 mm) includes the stations (Bardarash, Semel, Bateel), and the category of more than (1000 mm) includes the stations (Sarsenk, Denarta, Chamanke). As for the rest of the stations, they were confined between the second and sixth category (500-1000 mm), as shown in Table (21).

Table 21. Rainfall Categories in the Study Area

Rainy Areas	Category Rainfall
Semel-Bateel-Bardarash	first category is less than 500 mm
Duhok-Darkar-Qasrok-Shekhan	500-600 mm Second Category
Zakho-Akre	600-700 mm Third Category
Mangesh-Batofa	700-800 mm Fourth Category
Amedi-Zawita-Swaratoka-Kani masi Bamarny	800-900 mm Fifth Category
Deralok	900-1000 mm Sixth Category
Sarsenk-Denarta-Chamanke	seventh class is over 1000 mm

Source: From the Researcher's work based on (Appendix 2)

By calculating some mathematical variables, it is concluded that:

- The overall average rainfall difference in the study area was (29%), with the highest value at the Swaratoka station at (34.55%), due to the sea level rise factor, while the lowest value was seen in the difference factor at Kani Masi station, which ranged (22.12%), as shown in Table (22).

- By calculating the variance factor, it was noted that the most skewed data from the average in the study area were recorded at Sarsenk station (300.14mm), and the most variable was (90088.55), indicating that the northern part of the study area was one of the most different and fluctuating areas. In the amount of precipitation, while the lowest deviation rate was recorded from the overall average at Bateel station (144mm) and the least varied (20754.94).This indicates that Bateel station is one of the least different areas in the amount of precipitation. However, rainfall deviation from the overall average standard deviation during the study period (2000-2020) was recorded towards (202.13mm), this has implications for water resources and recorded a marked decrease in the study area.

Table 22. Some Mathematical Variables of Rainfall in the Study Area

Station	Average Calculation mm	Mediator mm	Standard Deviation mm	Variation Coefficient %	Variance	Bezel	Smallest Value mm	Highest Value mm
Duhok	578.2	511.1	178.8	30.92	32003.85	615.1	337.9	953
Zakho	602.6	613.2	157.51	26.13	24810.08	612.1	343.7	955.8
Amedi	853.3	803.2	213.45	25	45562.08	737.8	544.4	1282.2
Zawita	848.1	816.4	258.32	30.45	66730.34	937.6	480.1	1417.7
Semel	473.5	439.9	153.15	32.34	23455.59	569.5	271.6	841.1
Sarsenk	1008.3	1002.5	300.14	29.76	90088.55	1202.5	444	1646.5
Swaratoka	828.7	773.7	286.37	34.55	82009.94	1185.9	445	1630.9
Akre	685.8	653.8	195.74	28.54	38315.4	785.2	328.8	1114
Bateel	485.3	499.1	144	29.67	20754.94	497.3	299.7	797
Mangesh	727.5	707.2	210.44	28.92	44288.77	803.2	410	1213.2
Darkar	584.1	639.7	184.1	31.51	33895.59	672.3	285	957.3
Kani masi	884.1	869.8	195.6	22.12	38260.99	778.1	514.5	1292.6
Deralok	907.4	818.2	233	25.67	54335.43	833.5	601.5	1435
Qasrok	584.4	579.2	197.33	33.76	38941.36	812.2	287.8	1100
Batofa	798.9	751.2	202.86	25.39	41153.71	818	495	1313
Bamarne	843.1	813.2	226.73	26.89	51409.43	765.5	495.9	1261.4
Denarta	1051.8	1071	286.83	27.27	82275.75	1148.5	564.8	1713.3
Bardarash	458.1	428.4	147.89	32.28	21873.72	548.4	273.2	821.6
Chamanke	1003.7	1006.4	274.98	27.39	75619.01	1059.8	520.2	1580
SHekhan	590	566.8	197.28	33.43	38920.94	741	320	1061
Average	704.61	684	202.13	29	47235.27	806.2	413.15	1219.33

Source: From the Researcher's work based on (Appendix 2)

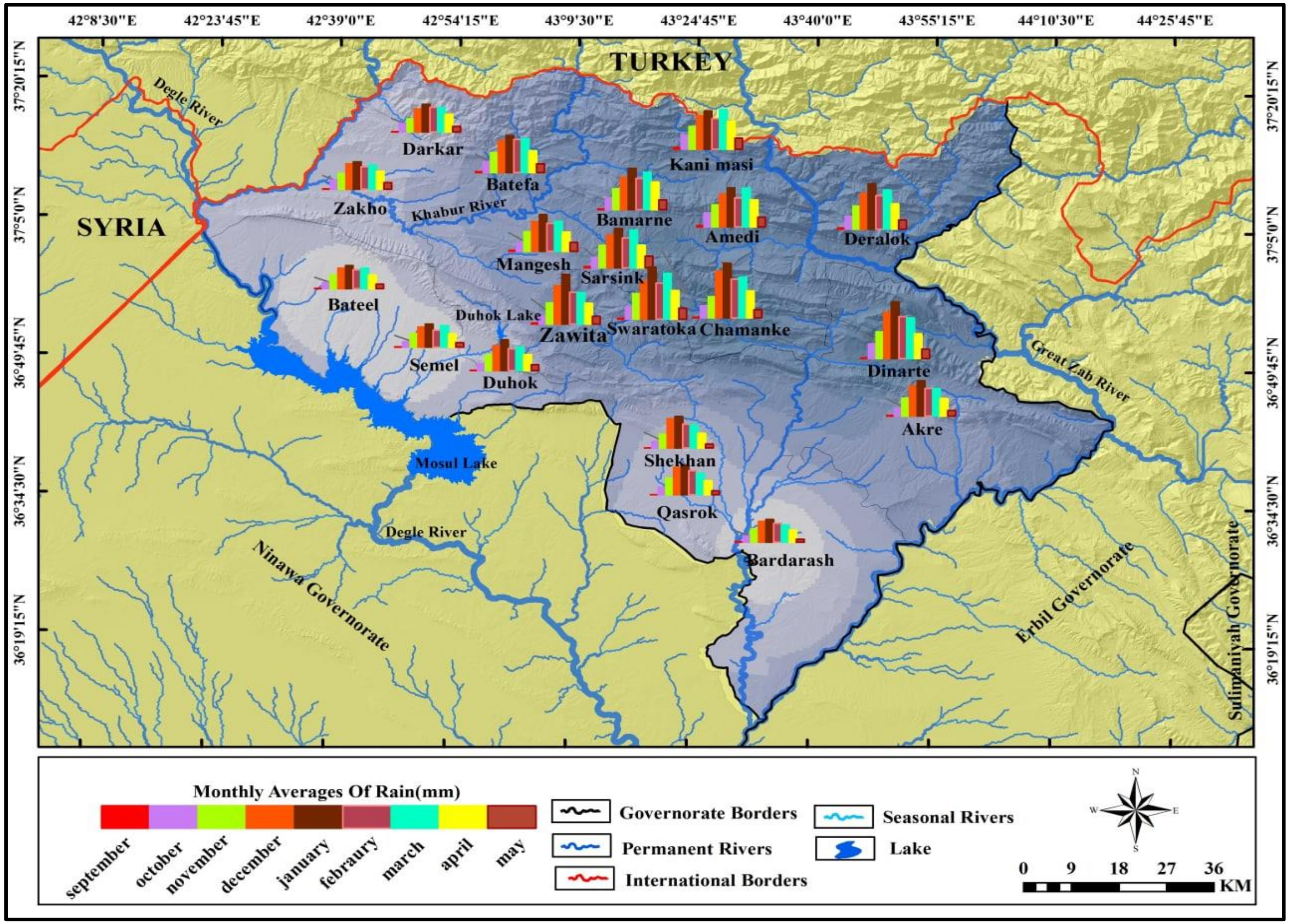
3.2.2. Spatial Fluctuation of the Average Monthly Rainfall

There is a difference in the spatial distribution of the monthly averages of rainfall. This difference is at the level of the months, and is investigated study area during the period (2000-2020). This is shown in Table (23) and Map (14).

Table 23. The Spatial Monthly Averages of Rainfall (mm) in Duhok Governoratet Between (2000-2020)

Station	Jan	Feb	Mar	Apr	Ma	Sep	Oct	Nov	Dec	Rate
Duhok	123	87	93	63	22	1.32	25.9	62	100	64.1
Zakho	110	90	96	72	26	2.36	36.46	63	102	66.6
Amedi	156	115	154	107	38	5.27	55.72	87	130	94.4
Zawita	199.7	128	126	83	31	3.98	32.7	85	153	93.6
Semel	91.68	67	85	53	18	1.15	21.32	54	80	52.5
Sarsenk	208.2	145	183	114	44	4.09	50.24	103	154	112
Swaratoka	156.5	119	150	90	46	4.47	41.63	89	131	91.9
Akre	142	111	110	71	23	2.59	31.93	72	121	75.9
Bateel	91.66	76	82	54	18	0.61	24.91	55	82	53.8
Mangesh	147.3	113	120	77	35	3.84	34.3	78	119	80.6
Darkar	110.3	99	98	71	23	2.2	34.44	54	92	64.8
Kani masi	153.2	123	158	112	45	6.02	57.07	92	134	97.8
Deralok	182.4	134	157	101	36	5.91	51.86	93	144	101
Qasrok	120.5	97	87	57	16	1.07	29.84	67	110	64.9
Batofa	148.6	133	135	88	35	3.78	45.02	80	128	88.5
Bamarne	164.4	124	149	110	39	2.4	43.62	82	128	93.5
Denarta	226.3	168	162	100	38	3.14	58.45	107	186	117
Bardarash	91	75	69	48	12	2.48	24.62	53	83	50.8
Chamanke e	219	155	163	108	34	3.42	48.2	85	186	111
SHekhan	126.4	95	93	59	16	0.47	26.95	55	117	65.5
Average	148.4	113	124	82	30	3.02	38.75	76	124	82

Source: From the Researcher's work based on the General Directorate of Meteorology and Seismic Monitoring in the city of Dohuk, Climatic Data Department, unpublished



Source: From the Researcher’s work based on data from (Table 23)

Map 14. Spatial Analysis of the Monthly Average of Rainfall in the Study Area

- There is a spatial difference between the monthly averages of rainfall, where the highest amount of rainfalls was in January (148.4 mm), and the lowest amount of rainfall was in September (3.02 mm). This can be explained by the high number of low pressures affecting the region during winter while the probability of low pressures decreases in autumn and spring to reach its minimum.
- The decrease in the monthly averages of rainfall from the general average of the monthly rains in several stations is represented by the stations (Bardarash, Semel, Bateel), as it reached (50.8 mm, 52.5 mm, 53.8 mm). This is explained by the decrease in their surface compared to the rest of the study areas, while the two regions recorded (Denarta, Sarsenk, Chamanke, Deralok), which amounted to (117 mm, 112 mm, 111 mm, 101 mm). An increase in the monthly averages of rain from the average monthly is due to its location and height above sea level.

The distribution of rain in Duhok governorate varies during the months of the year between (2000-2020), as shown below (Table 23) see also:

1. January. There is a fluctuation in the distribution of rain in Duhok governorate, the highest amount of precipitation was recorded in Denarta station, which amounted about (226.31 mm), while the lowest amount of rainfall was recorded in Bardarash station, which amounted to (91 mm). This month is one of the months that are subject to atmospheric instability, and the region is exposed to low pressures during this month see (Map 15).

2. February: Rainfall varies in the study area. The highest amount of precipitation recorded in Denarta station, which amounted about (168 mm), while the lowest amount of rainfall was recorded in Semel station, which amounted about (67 mm). This month is one of the months that Exposed to atmospheric instability (Map 16).

3. March. The distribution of rainfall varies between increase and decrease in Duhok governorate, as the highest amount of precipitation was recorded in Sarsenk station, which amounted to about (183 mm), while the lowest amount of rainfall was recorded in Bardarash station, which amounted to about (69 mm) see (Map 17).

4. April. The distribution of rainfall varies between increase and decrease in Duhok governorate where the highest amount of precipitation was recorded in Sarsenk station, which amounted about (114 mm), while the lowest amount of rainfall was recorded in Bardarash station, which amounted about (48 mm). This month is one of the months that is subject to a few cases of atmospheric instability see (Map 18).

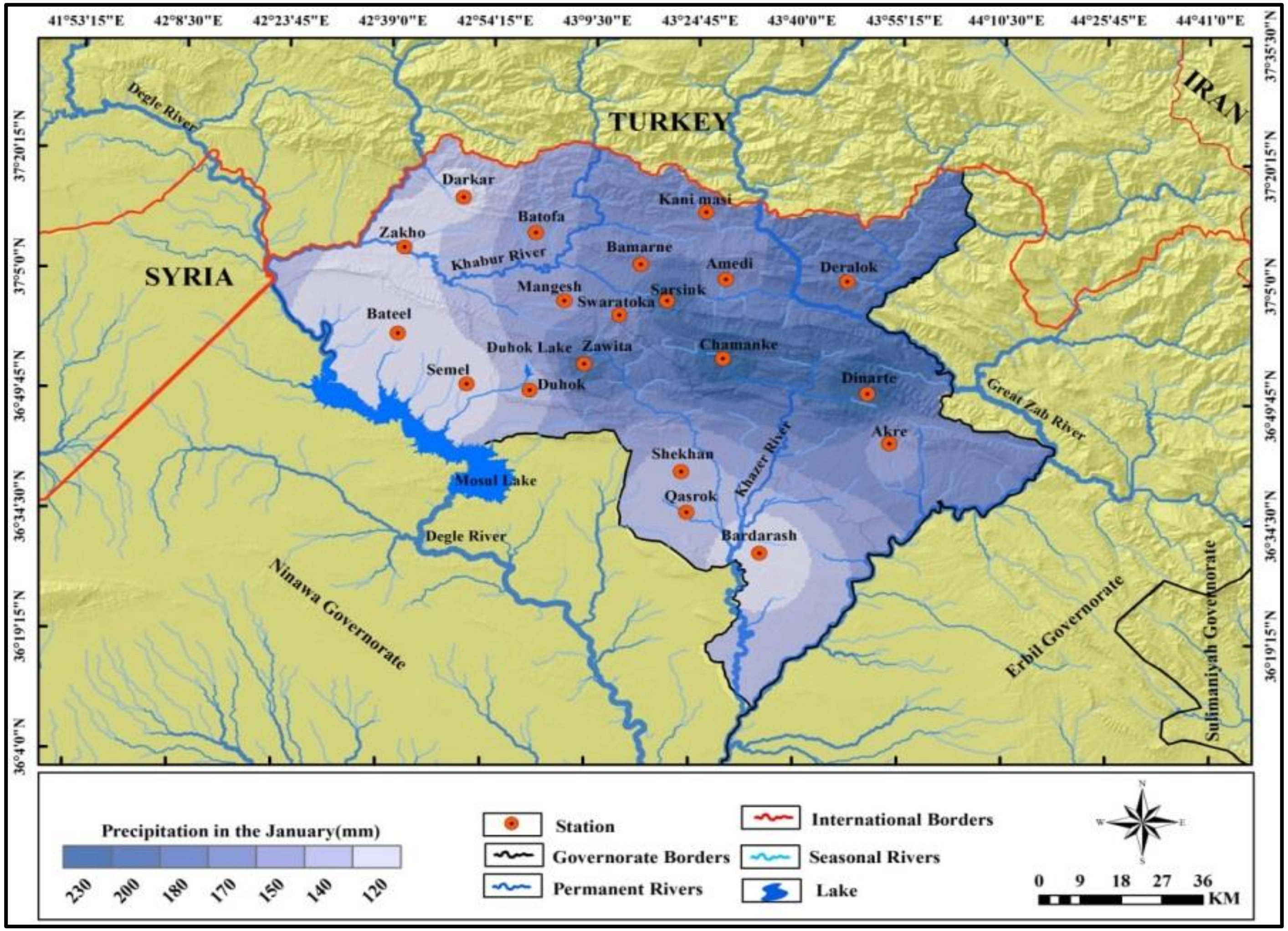
5. May. Its distribution also varies between increase and decrease in Duhok governorate. The highest amount of rainfall was recorded in the Swaratok station, which amounted about (46 mm), while the lowest amount of rainfall was recorded in Bardarash station, which amounted about (12 mm). This month is one of the months that is considered to be transitional period to the dry phase (the summer season) (Map 19).

6. September. The highest amount of rainfall was recorded in Kani masi Station, which amounted about (6.02 mm), while the lowest amount of rainfall was recorded in Shekhan station, which amounted about (0.47 mm), and Bateel station which amounted about (0.61 mm). This month is a transitional period to the wet phase (Map 20).

7. October. The highest amount of precipitation was recorded in Denarta station, which amounted about (58.45 mm), while the lowest amount of rainfall was recorded in Semel station, which amounted about (21.32 mm) see (Map 21).

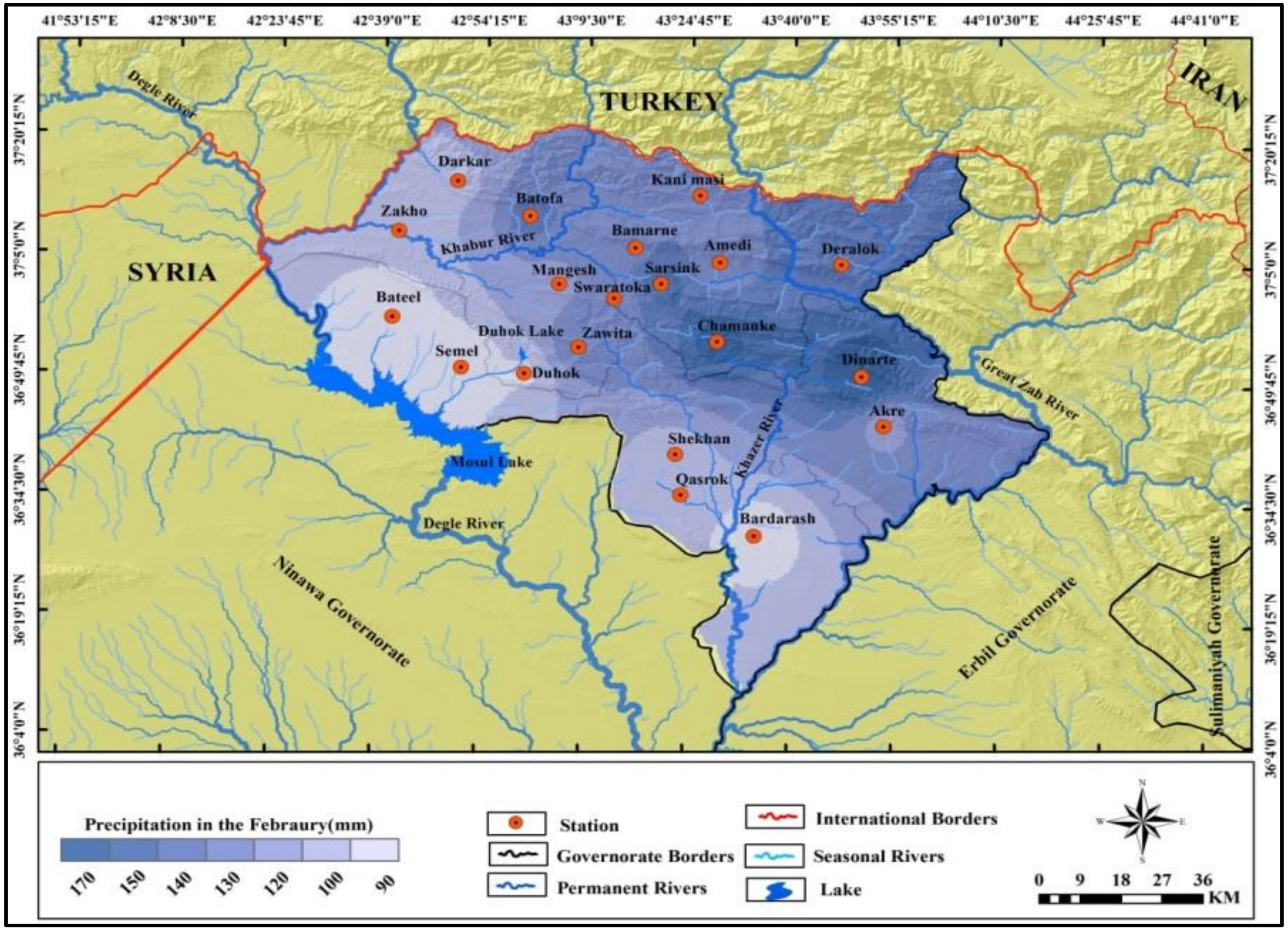
8. November. The distribution of rainfall varies in Duhok governorate, so that the highest amount of precipitation was recorded in Denarta station, which amounted about (107 mm), while the lowest amount of rainfall was recorded in Bardarash station, which amounted about (53 mm). This monthth is considered to be the beginning of the region's exposure to atmospheric instability as shown in (Map 22).

9. December. There is a clear fluctuation in rainfall in Duhok governorate that the highest amount of precipitation was recorded in the Chamanke station, which amounted to about (186 mm), followed by the Denarta station, about (186 mm), while the lowest amount of rainfall was recorded in the Semel station, which amounted about (80 mm). This month is one of the months that is always exposed to atmospheric instability see (Map 23).



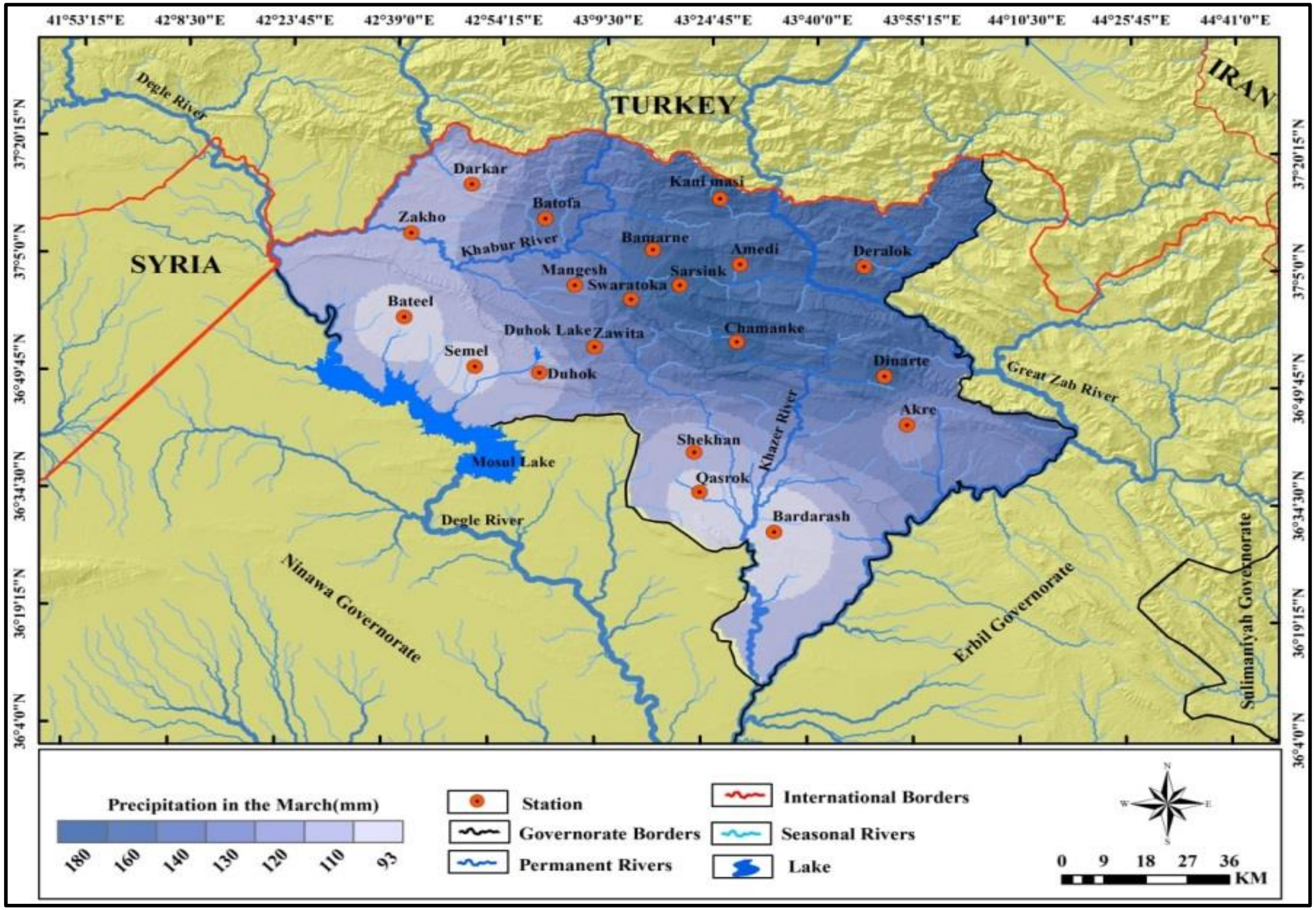
Source: From the Researcher's work based on data from (Table 23)

Map 15. The Spatial Distribution of Rainfall in the Study Area in January



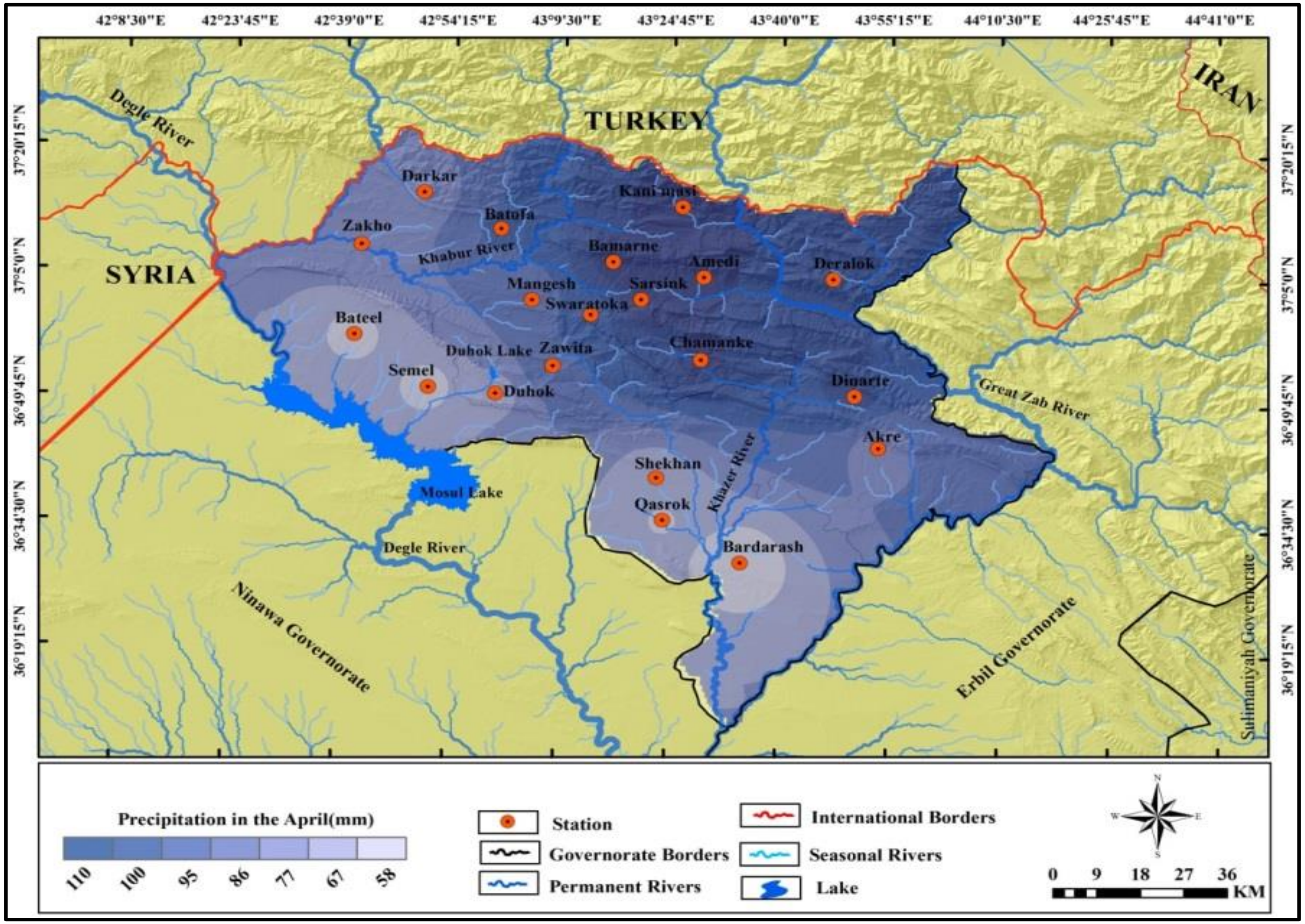
Source: From the Researcher’s work based on data from (Table 23)

Map 16. The Spatial Distribution of Rainfall the Study Area in February



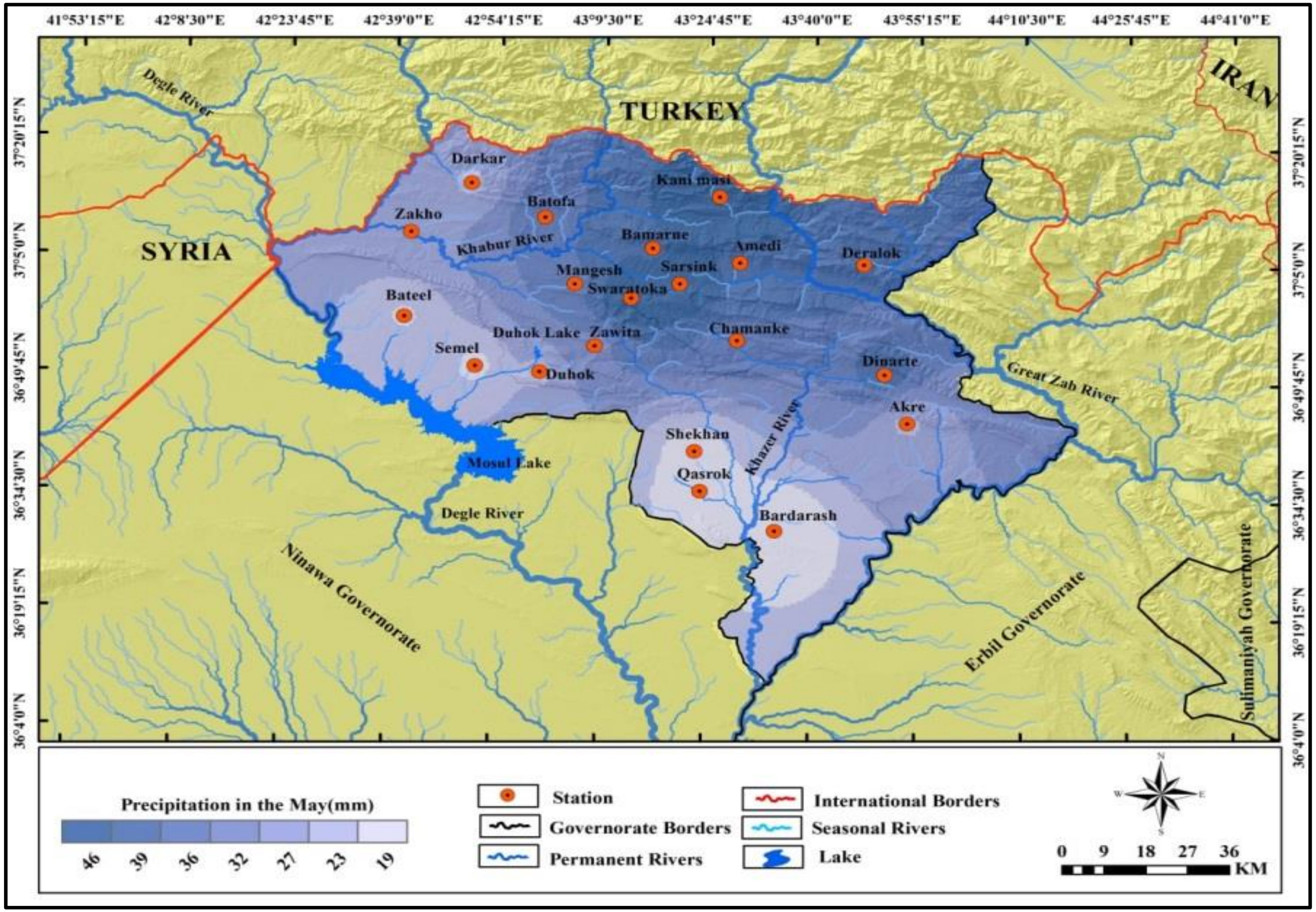
Source: From the Researcher's work based on data from (Table 23)

Map 17. The Spatial Distribution of Rainfall in the Study Area in March



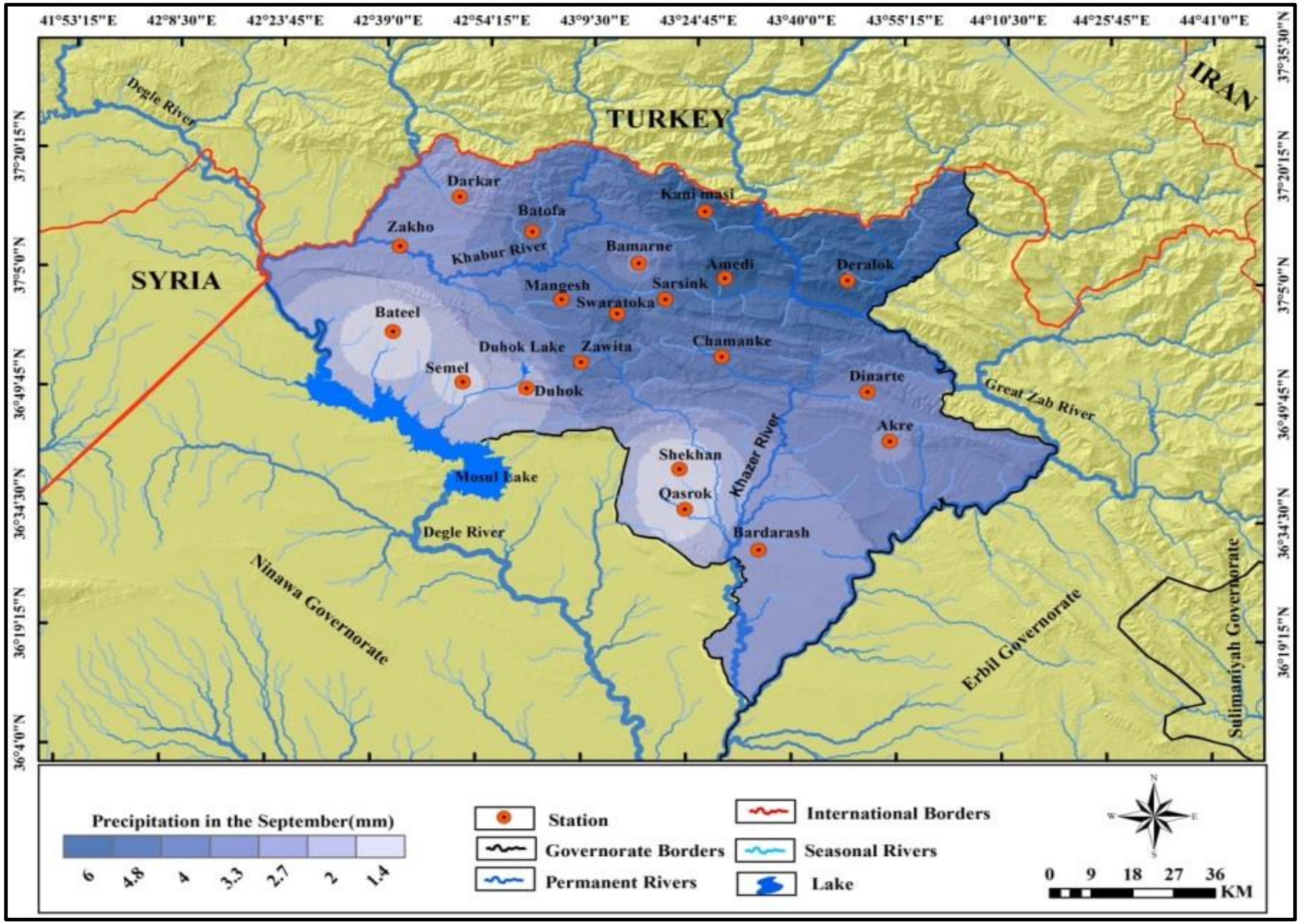
Source: From the Researcher’s work based on data from (Table 23)

Map 18. The Spatial Distribution of Rainfall in the Study Area in April



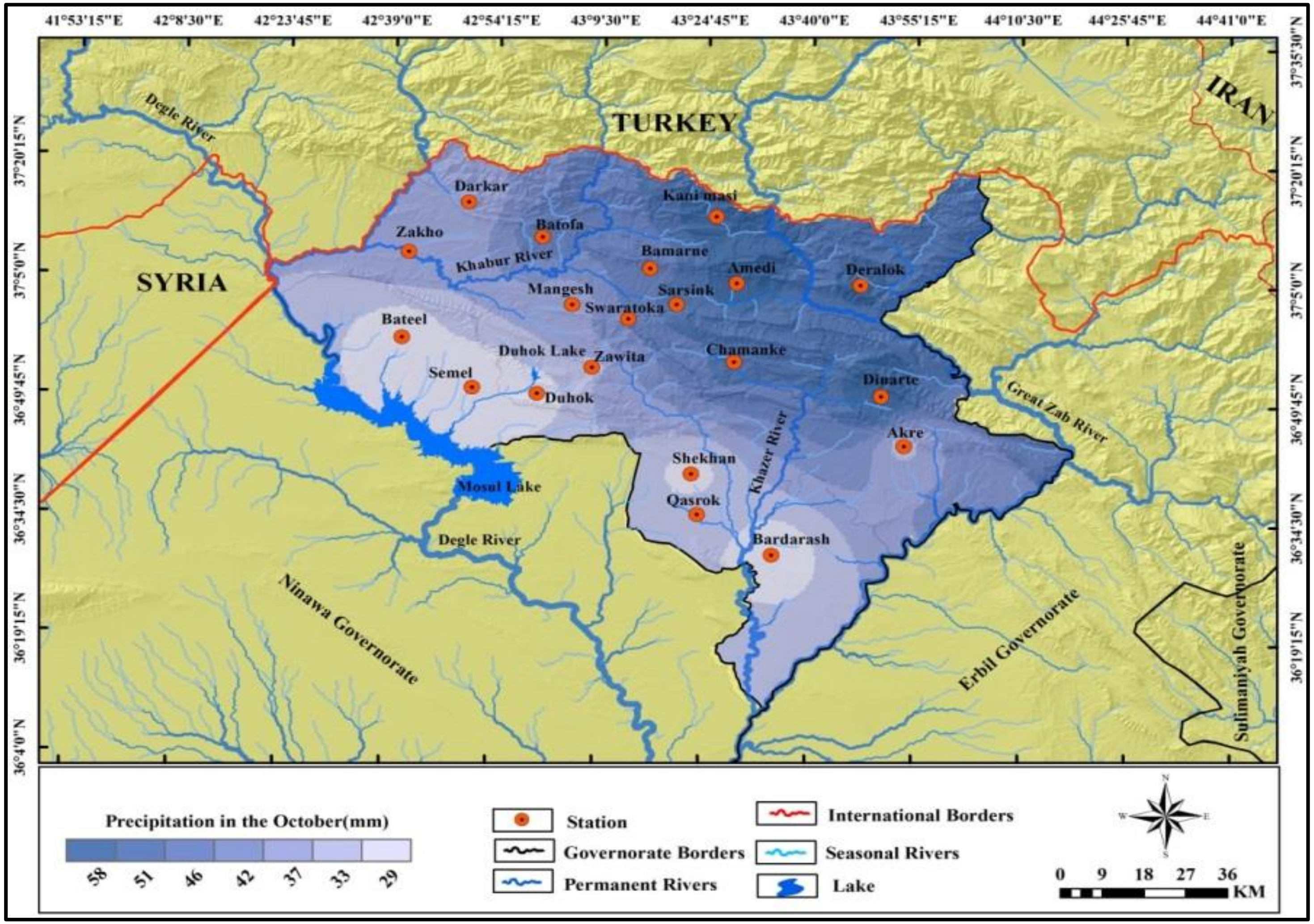
Source: From the Researcher’s work based on data from (Table 23)

Map 19. The Spatial Distribution of Rainfall in the Study Area in May



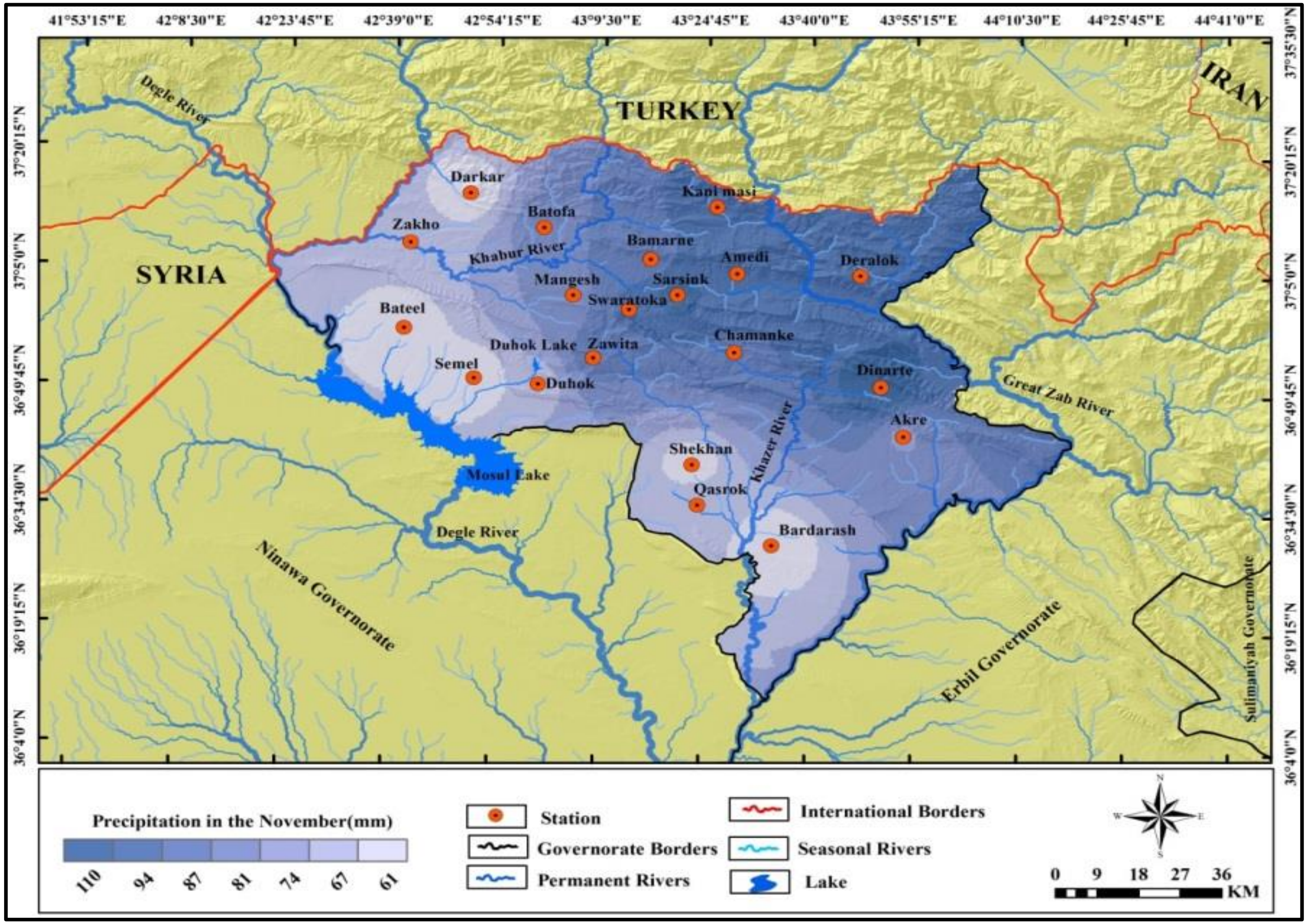
Source: From the Researcher's work based on data from (Table 23)

Map 20. The Spatial Distribution of Rainfall in the Study Area in September



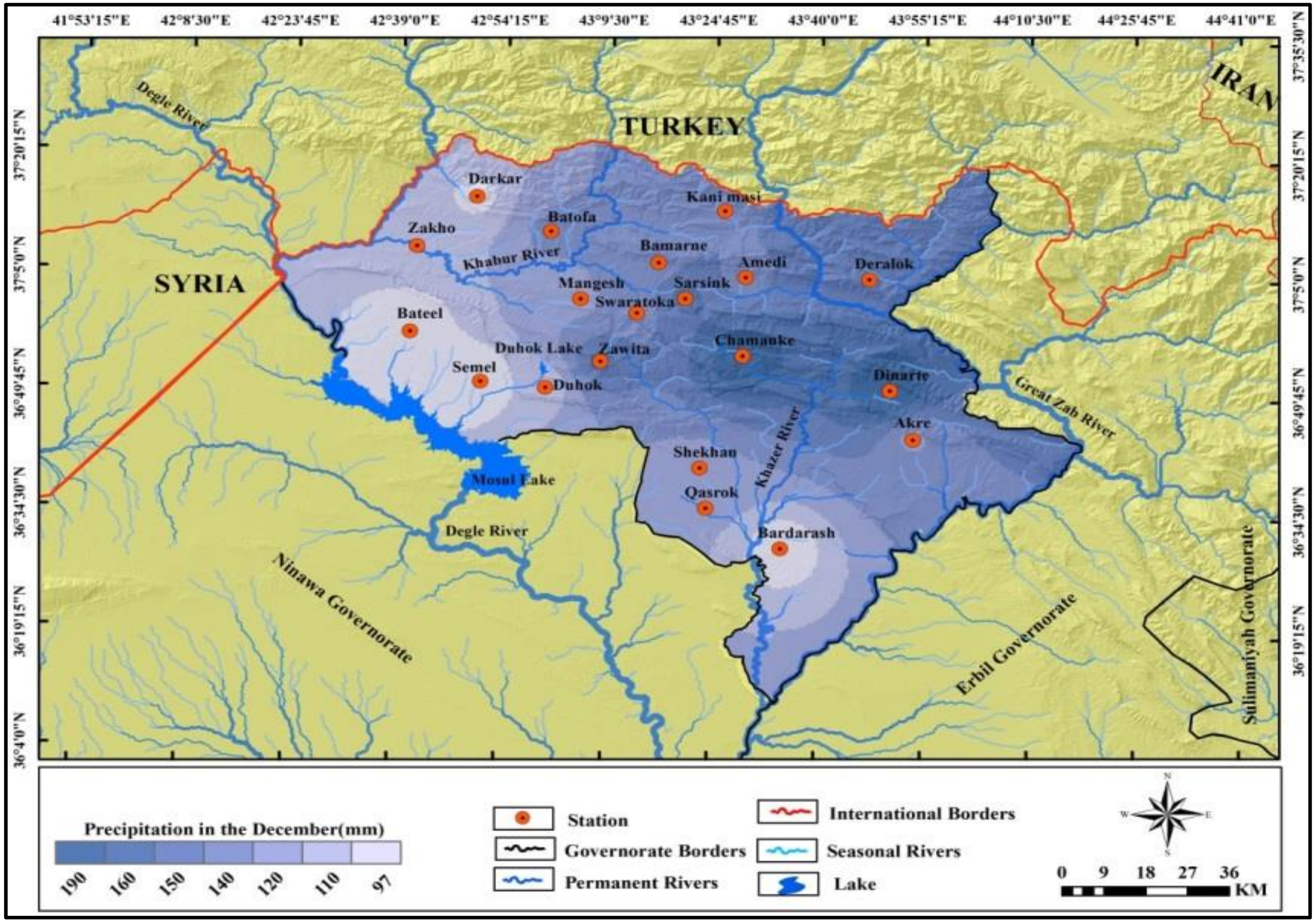
Source: From the Researcher's work based on data from (Table 23)

Map 21. The Spatial Distribution of Rainfall in the Study Area in October



Source: From the Researcher's work based on data from (Table 23)

Map 22. The Spatial Distribution of Rainfall in the Study Area in November



Source: From the Researcher's work based on data from (Table 23)

Map 23. The Spatial Distribution of Rainfall in the Study Area in December

4. CORRELATIONAL RELATIONSHIP AND STATISTICAL ANALYSIS AND THEIR FUTURE PREDICTIONS OF RAINFALL IN THE STATIONS OF DUHOK GOVERNORATE

Climatic phenomena study is important due to the direct effects of climate on the human daily activities. The climate elements such as (temperature, relative humidity, atmospheric pressure, evaporation and wind speed) also directly affect the surface of the earth, soil, and natural vegetation. In addition, it affects indirectly many human and natural activities (Alsamarayi, 2008). Therefore, climatic elements vary in their distribution, whicht is reflected in the geographical factors affecting these elements. The relationship between land and water with the climate elements is an overlapping and intertwined relationship consequently, the factors affecting the elements of the climate differ among themselves (Moussa, 2005).

4.1. Correlation Between Rainfall and Climatic Elements

The elements of the climate affect one another, some of them are concrete for human being such as (temperature, wind and rainfall). However, there are intangible climatic elements such as (relative humidity, evaporation and atmospheric pressure). By studying the relationship between the average annual rainfall and atmospheric variables in the study area, which was estimated by determining the correlation coefficient between rainfall as a dependent variable and Atmospheric variables as independent variables, it is possible to rely on data recorded for some climatic elements in some stations in the study area on the one hand, and unavailability of the data on the other.

4.1.1. The Relationship Between Rainfall and Temperature

The study emphasized that there is an overlapping relationships between the rainfall variable and the temperature variable, where each variable is linked with a positive or inverse relationship with the other variable, Table (24) shows that the relationship between rainfall and temperature is a weak direct relationship at Zakho-mangesh station, where the correlation value was less than (0.028), which is not statistically significant. Semel station recorded a weak inverse correlation, where the correlation value was (-0.042), which is not statistically significant, and a strong inverse correlation was found in Duhok and Akre stations, where the correlation value was less than (-0.147), which is not statistically significant. Zawita, Amedi and Bamarene stations recorded an average direct correlation, where the correlation value was less than (0.228), which is also not statistically significant, this is due to the effect of the distance factor between the study area and surrounded water bodies.

Table 24. The Simple Correlation Between Rainfall and Temperature in Duhok Governorate between (2010-2020)

Variable	Station	Correlation	Relationship Sig
Temperature	Zakho	0.028	0.934
	Semel	-0.042	0.902
	Duhok	-0.074	0.830
	Akre	-0.147	0.665
	Zaweta	0.228	0.500
	Mangesh	0.016	0.964
	Amedi	0.116	0.735
	Bamarne	0.146	0.671

Source: Researcher's work depends on (Appendix 4 to 11)

4.1.2. Relationship Between Rainfall and Humidity

The correlation relationship changes from one variable to another. Table (25) shows that the correlation between rainfall and humidity was a strong and directive in Zakho station, where the correlation value reached (0.790**), with statistical significance at a significant level less than (0.01). A medium direct correlation was recorded in Duhok and Akre station, which recorded the correlation value (0.682*, 0.707*), with statistical significance at a significant level less than (0.05), as well as a medium direct relationship was recorded between the two variables in the Mangish station, which amounted to (-0.744**), statistically significant at a significant level of less than (0.01). However, a weak direct relationship was recorded in the stations of Semel, Amedi and Bammerne, whose value was less than (0.455), which is not statistically significant. This difference can be attributed to the presence of other variables that have an effect on the amount of rain.

Table 25. Simple Correlation Between Rainfall and Humidity in Duhok Governorate between (2010-2020)

Variable	Station	Correlation	Relationship Sig
Humidity	Zakho	0.790**	0.004
	Semel	0.455	0.16
	Duhok	0.682*	0.02
	Akre	0.707*	0.015
	Zaweta	0.330	0.321
	Mangesh	-0.744**	0.009
	Amedi	0.359	0.278
	Bamarne	0.283	0.4
*Correlation is Significant at the 0.05 level. ** Correlation is Significant at the 0.01 level.			

Source/ Researcher's work depends on (Appendix 4 to 11)

4.1.3. Relationship Between Rainfall and Atmospheric Pressure

It is noticed from (Table 26) that the correlation relationship differs from one station to another, it may strengthen in some stations and weaken in others. There was a weak inverse correlation between the two variables in both stations, Akre and Mangesh, whose correlation value was less than (-0.460) which is not statistically significant, as well as a weak direct correlation relationship in each of the stations Zakho, Semel, Duhok and Bamarna, where it reached a value less than (0.403). This is due to the terrain factor in which the atmospheric pressure decreases as we rise upward.

Table 26. Simple Correlation Between Rainfall and Atmospheric Pressure in Duhok Governorate between (2010-2020)

Variable	Station	Correlation	Relationship Sig
Atmospheric Pressure	Zakho	0.016	0.964
	Semel	0.403	0.249
	Duhok	0.292	0.412
	Akre	-0.365	0.299
	Mangesh	-0.460	0.181
	Bamarne	0.232	0.518

Source: Researcher's work depend on (Appendix 4 to 11)

4.2. Statistical Analysis of Rainfall Data in Duhok Governorate Stations

Statistical analysis is defined as a process through which data related to scientific research is prepared and processed. Moreover, these data are analyzed and studied, and then results are extracted from them. The data analysis process is done by following a number of mathematical and logical methods. Statistical analysis is the ideal and appropriate solution for all sciences, including geography with its various branches, especially the human branches, and therefore they are used to analyze their data, and issue results from them. This process was carried out through the following statistical methods: (Descriptive Statistics, Runs Test) which were relied upon in the study. Then, the Kendall-Mann test was used to test the oscillation trends of the rain element

4.2.1. Runs Test

Before conducting the statistical analysis process, it is necessary to conduct the experimentation process and scrutinize the data related to the study in order to know the accuracy of the data used in the analysis and the results can be extracted through the program as a result (Minitab, SPSS 23). In this study, the researcher relied on SPSS 23 to find out the homogeneity of these data at the level 95%. When looking at (Table 27) and Taking the Sig table and field of data for the study into consideration, it was found that the level of homogeneity of data for all stations in the study area was more than (0.05), which indicates that the data of the study area are mostly homogeneous and (95%), this is a sign of the validity and accuracy of the data. But if there are stations with homogeneity of less than (0.05), it is a sign of the heterogeneity and scientific accuracy of the data.

Table 27. Runs Test of Rainfall Data in the Stations of Duhok Governorate (2000-2020)

Station	Test Value[a]	Cases < Test Value	Cases >= Test Value	Total Cases	Number of Runs	Z	Asymp. Sig. (2-tailed)
Duhok	578.2714	12	9	21	9	-0.817	0.414
Zakho	602.7143	10	11	21	10	-0.438	0.661
Amedi	853.3619	11	10	21	10	-0.438	0.661
Zawita	848.1143	12	9	21	10	-0.36	0.719
Semel	473.5	12	9	21	9	-0.817	0.414
Sarsink	1008.3048	11	10	21	12	0.011	0.991
Swaratoka	828.7952	15	6	21	9	-0.04	0.968
Akre	685.9	13	8	21	8	-1.145	0.252
Bateel	485.3238	10	11	21	11	0	1
Mangash	727.5381	12	9	21	9	-0.817	0.414
Darkar	584.1952	9	12	21	11	0	1
Kani masi	884.1524	11	10	21	12	0.011	0.991
Deralok	907.4333	11	10	21	12	0.011	0.991
Qasrok	584.4952	11	10	21	8	-1.336	0.182
Batofa	798.9143	12	9	21	10	-0.36	0.719
Bamarny	843.1857	12	9	21	9	-0.817	0.414
Denarta	1051.819	10	11	21	10	-0.438	0.661
Bardarash	458.1524	11	10	21	9	-0.887	0.375
Chamanke	1003.7571	10	11	21	10	-0.438	0.661
Sheikhan	590	12	9	21	10	-0.36	0.719

Source: From the Researcher's work based on (Appendix 2)

4.2.2. Descriptive Statistics

A descriptive statistic is a brief description of a wide range of data or a set of methods used to make it easier to quantity the main characteristics of data by using tables and charts to make it easier to understand for their users (URL6). Descriptive statistics use several measures that adopt different methods in summarizing and presenting data, graphical measurements, central direction measures, dispersion measures and correlation metrics, and each of these measures has different tools and methods in analyzing and arranging data and the way of anderstanding the different variables and relationships. Descriptive statistics are of great importance that make it easier for data users to analyze, understand and study their variables in order to improve data and develop them in the future and address imbalances (URL7).(Table 28) shows the description of the main characteristics of rainfall data in the stations of studyarea.

Table 28. Descriptive Statistics of Rainfall in the Stations of Duhok Governorate (2000-2020).

Station	N	Mean	Std. Deviation	Min	Max	Percentiles		
						25th	50th (Median)	75th
Duhok	21	578.2714	178.8962	337.9	953	423.1	511.1	697.55
Zakho	21	602.7143	157.43606	344	956	507	613	708
Amedi	21	853.3619	213.45081	544.4	1282	665	803.2	975
Zawita	21	848.1143	258.34731	480.1	1418	623.85	816.4	1057
Semel	21	473.5	153.15218	271.6	841.1	371.75	439.9	584.1
Sarsink	21	1008.3048	300.14756	444	1646.5	801.25	1002.5	1199
Swaratoka	21	828.7952	286.37378	445	1630.9	636.1	773.7	907.15
Akre	21	685.9	195.76155	328.8	1114	547.35	653.8	788.2
Bateel	21	485.3238	144.06576	299.7	797	352.55	499.1	570.65
Mangash	21	727.5381	210.44898	410	1213.2	579.4	707.2	846.6
Darkar	21	584.1952	184.10755	285	957.3	446.4	639.7	703.6
Kani masi	21	884.1524	195.60417	514.5	1292.6	736.2	869.8	992
Deralok	21	907.4333	233.09962	601.5	1435	730.6	818.2	1038.7
Qasrok	21	584.4952	197.33567	287.8	1100	432.65	579.2	704.15
Batofa	21	798.9143	202.86379	495	1313	670.35	751.2	883.45
Bamarny	21	843.1857	226.73648	495.9	1261.4	690.5	813.2	1012.5
Denarta	21	1051.819	286.8375	564.8	1713.3	808.7	1071	1237.1
Bardarash	21	458.1524	147.89767	273.2	821.6	329.3	428.4	509.2
Chamanke	21	1003.7571	274.98912	520.2	1580	802.5	1006.4	1155.5
Sheikhan	21	590	197.28391	320	1061	452.75	566.8	648.5

Source: Researcher’s Work Relying on (Appendix 2)

4.2.3. The Mann-Kendall Trend Test

This method is used in this study to test the flactuation trends of the rainfall element (Yılmaz, 2018), at Duhok stations, a test that is not used to detect the presence or absence of a moral linear direction (oscillation) of the values of the element studied. The method of this test was formulated by scientist Henry Mann (Mann, 1945) to distribute trends of change, and the test was statistically distributed by the scientist Maurice Kendall (Kendall, 1975), and also proposed by WMO to identify statistically significant trends in climate data time series. It was conducted using the application of Makesens 0.1 as part of the Excel lot program applied to rain data for the region's stations.

The number of annual values in the data series analyzed by the n code as shown in Table (29) and Map (24) represents missing values that are allowed and n can be less than the number of years in the time series studied. Mann-Kendall S test statistics are calculated using the following formula.(Özbunar, 2019).

1. The value of S in the test is calculated in the following formula.(Hirsch & Slack, 1984; Coşkun,S . 2020a. Coşkun, et al., 2020)

$$s = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k)$$

2. According to the established H1 hypothesis (k≠j) and in the n ≥ k,j series, it means that the sequentially Xk and Xj data do not show similarity but show an inhomogeneous distribution. It is calculated with the following formula.(Özfidaner, 2007).

$$sgn(x_j - x_k) = \begin{cases} 1 \;\; if \;\; x_j - x_k < 0 \\ 0 \;\; if \;\; x_j - x_k < 0 \\ -1 \; if \;\; x_j - x_k < 0 \end{cases}$$

Where n: number of year.

Xk, Xj: The value of the climate element studied in years j,k where k>j.

If n is 9 or less, the absolute value of S is compared directly to the theoretical distribution of S derived by Mann and Kendall (Gilbert, 1987). In Makesens, the two-tailed test is used for four different significance levels α: 0.1, 0.05, 0.01 and 0.001. At certain probability level H0 is rejected in favor of H1 if the absolute value of S equals or exceeds a specified value Sα/2, where Sα/2 is the smallest S which has the probability less than α/2 to appear in case of no trend. A positive (negative) value of S indicates an upward (downward) trend. The minimum values of n with which these four significance levels can be reached are derived from the probability table for S as follows

Table 29. Minimum Values For n

Significance Level α	Required n
0. 1	≥ 4
0.05	≥ 5
0.01	≥ 6
0.001	≥ 7

The significance level 0.001 means that there is a 0.1% probability that the values xi are from a random distribution, and with that probability we make a mistake when rejecting H0 of no trend. Thus, the significance level 0.001 means that the existence of a monotonic trend is very probable. Respectively, the significance level 0.1 means that there is a 10% probability that we make a mistake when rejecting H0.

If n is at least 10 the normal approximation test is used. However, if there are several tied values (equal values) in the time series, it may reduce the validity of the normal approximation when the number of data values is close to 10. First, the variance of S is computed by the following equation which takes into account that ties may be present.

3. The mean and variance of the homogeneously distributed data were computed in the test statistic S, whose mean was zero, as in the following formula. (Coşkun, Gozalan, Öztekinci, 2022).

$$VAR(s) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right]$$

Where q: Number of equal value

tp: number of data values in group **p**

4. The results obtained in the calculated data sets were compared with the critical variable z by calculating standard normal variables. (Coşkun,S. 2020b).

$$Z = \begin{cases} S > 0 \ \Rightarrow & \dfrac{S-1}{\sqrt{VAR(S)}} \\ S = 0 \ \Rightarrow & 0 \\ S < 0 \ \Rightarrow & \dfrac{S-1}{\sqrt{VAR(S)}} \end{cases}$$

The trend line is tested according to the following:

H0: There is no trend line, when 2⁄a - Z>ZI.

H1: There is an increasing or decreasing linear trend.

The positive + or negative – value of Z indicates the rise or decline of the trend line.

The presence of a statistically significant trend was evaluated using the Z value. A positive (negative) value of Z indicates an upward (downward) trend. The statistic Z has a normal distribution. To test either an upward or downward monotone trend (a two-tailed test) at α level of significance, H0 was rejected if the absolute value of Z was greater than Z1-α/2, where Z1-α/2 was obtained from the standard normal cumulative distribution tables. In Makesens, the tested significance levels α are 0.001, 0.01, 0.05 and 0.1.

Estimating the true trend line that exists each year in sens Slop, the X method is used in cases where the trend can be assumed to be linear. That means f(t) is in the equation.

5. $$f(t) = Qt + B$$

Where Q is oscillation and B is constant. To get the Q slope estimate in the equation, first we calculate the inclination of all the value of the data (Salmi, 2002).

6. $$Q_i = \frac{x_j - x_k}{j - k}$$

Where j>k

In general, the results of the Mann-Kendall test mean that there is an increasing trend if it is positive and a decreasing trend if it is negative. (Gözalan, 2019; Coşkun, 2020c). The value of (Q) means the percentage of volatility, if the result is negative (-) means that the percentage of volatility is trending down, and if positive (+), this means the percentage that is trending up, and if the result appears with signs (**), it means that 95% of the oscillation is present and continuing. and if (*) This means that 95% of the oscillation process is realistic and trending upwards. These results come from the (z) field, if the result is greater than (1.96), This means that the value of (Q) is trending upwards, and if it is less than (1.96) means that the value of (Q) is trending downward. As shown in Table (30) and the statistical equations applied to rain data in all stations of the governorate for the year (2000-2020), the value of (Q) in the majority of stations moving upwards, with a realistic ratio of 95% , and this change is continuous in the station (Sersenk,Swaratoka and Chamank) because the result of (Z) in that stations is more than (1.96) as shown in the pattern (22.23.35), while the rest of the oscillation stations are moving upwards as shown in the remaining figures. (17, 18, 19, 20, 21, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 36).

Table 30. Mann-Kendall Trend Sens Slope Estimate

Time Series	First Year	Last Year	n	Test Z	Signific	Q	Qmin95	Qmax95
Duhok	2000	2020	21	0.88		6.328	-10.033	22.588
Zakho	2000	2020	21	1.54		8.136	-3.871	19.787
Amedi	2000	2020	21	1.12		8.873	-7.806	24.191
Zawita	2000	2020	21	1.3		14.846	-11.329	35.531
Semel	2000	2020	21	0.21		0.889	-8.477	16.351
Sarsink	2000	2020	21	2.45	*	28.512	8.177	50.514
Swaratoka	2000	2020	21	2.39	*	15.988	3.407	38.892
Akre	2000	2020	21	1.12		8.628	-8.779	26.242
Bateel	2000	2020	21	0.57		2.17	-10.21	16.511
Mangash	2000	2020	21	1		8.339	-8.893	23.959
Darkar	2000	2020	21	0.45		3.355	-11.743	22.703
Kani masi	2000	2020	21	0.82		6.548	-10.246	24.091
Deralok	2000	2020	21	1.18		11.848	-6.667	27.833
Qasrok	2000	2020	21	0.51		4.848	-10.775	22.929
Batofa	2000	2020	21	1.06		8.134	-8.137	24.973
Bamarny	2000	2020	21	0.69		7.317	-12.091	30.446
Denarta	2000	2020	21	0.82		8.938	-13.059	34.018
Bardarash	2000	2020	21	0.21		0.822	-10.567	13.223
Chamanke	2000	2020	21	2.02	*	25.556	1.418	45.128
Sheikhan	2000	2020	21	1		3.936	-7742	18.506

Source:Researcher’s Work Relying on (Appendix 2)

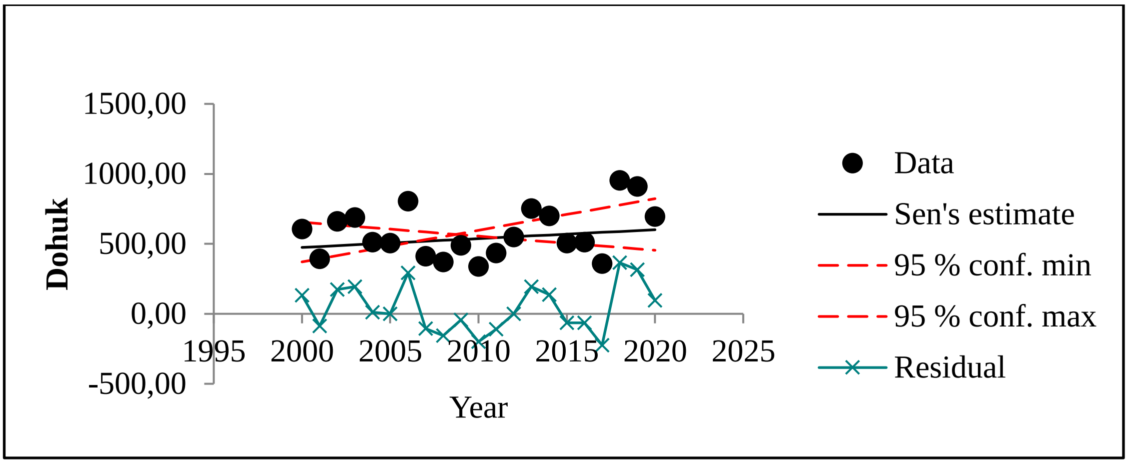


Figure 17. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Duhok Station

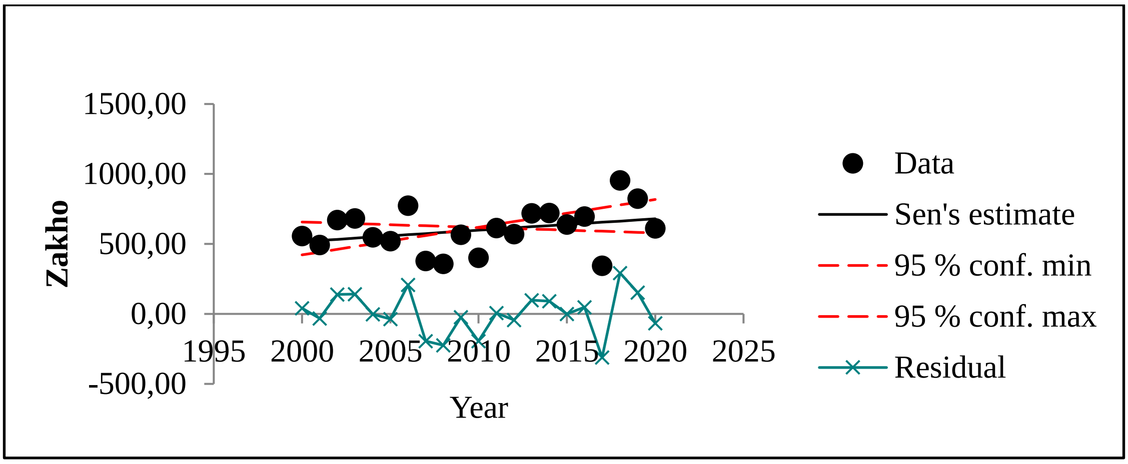


Figure 18. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Zakho Station

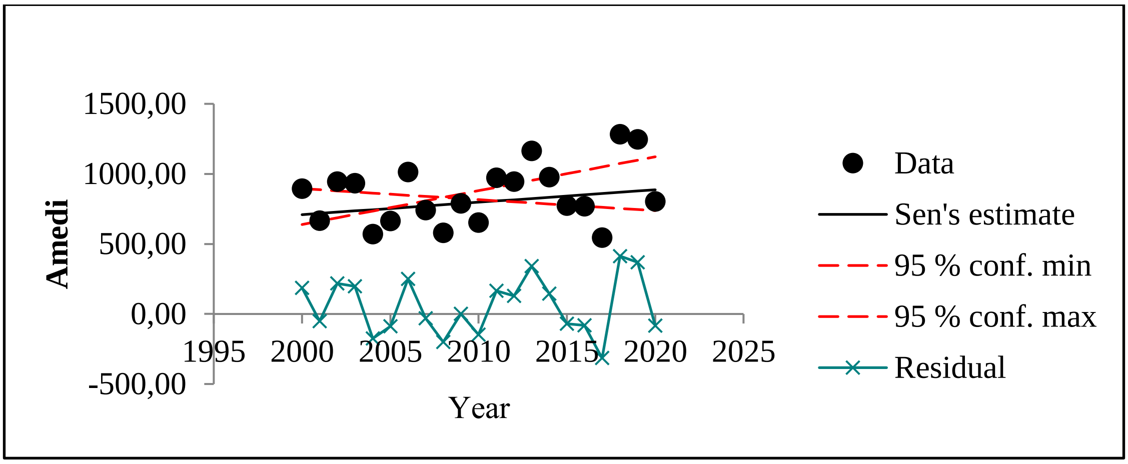


Figure 19. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Amedi Station

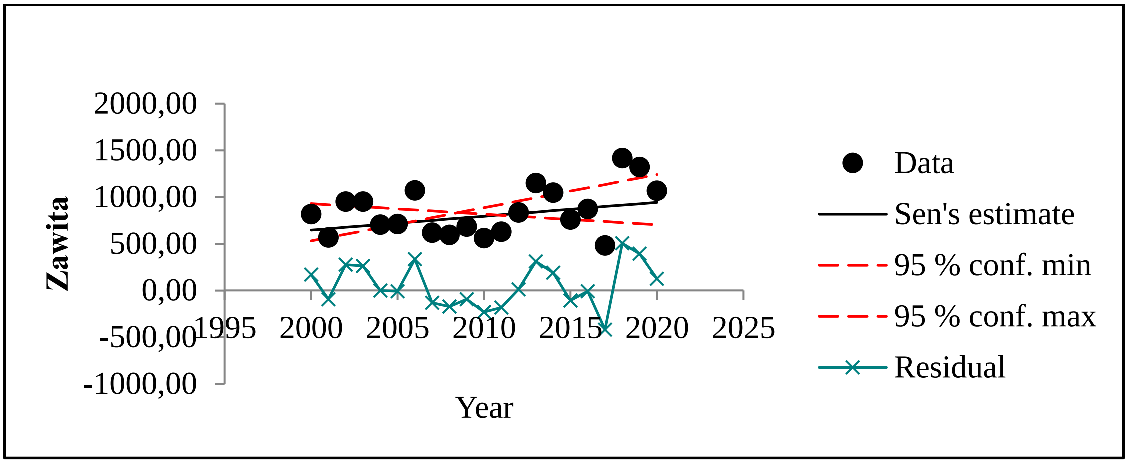


Figure 20. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Zawita Station

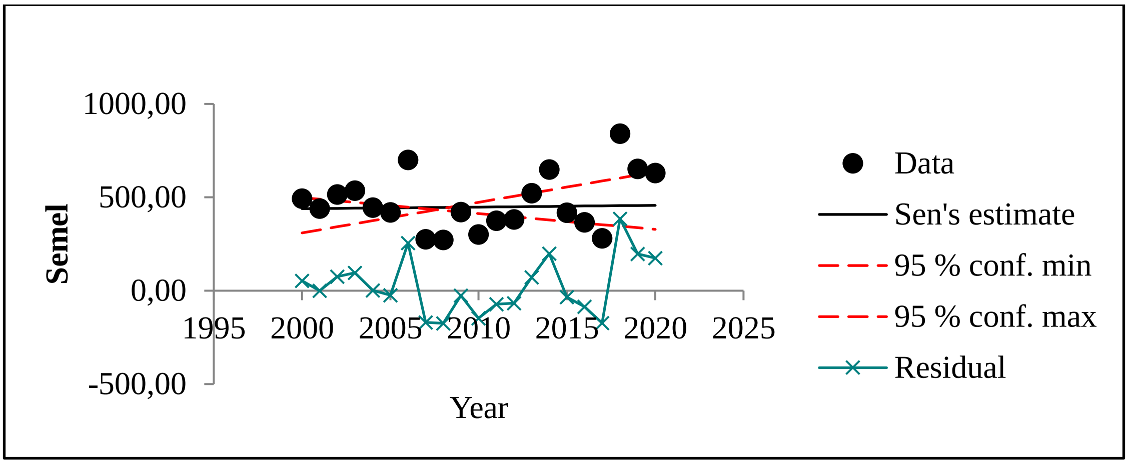


Figure 21. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Semel Station

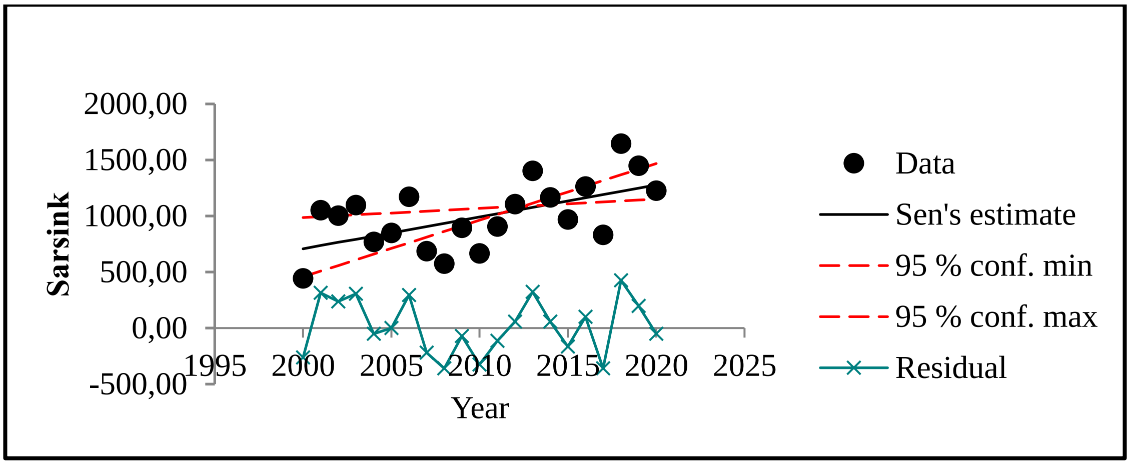


Figure 22. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Sarsink Station

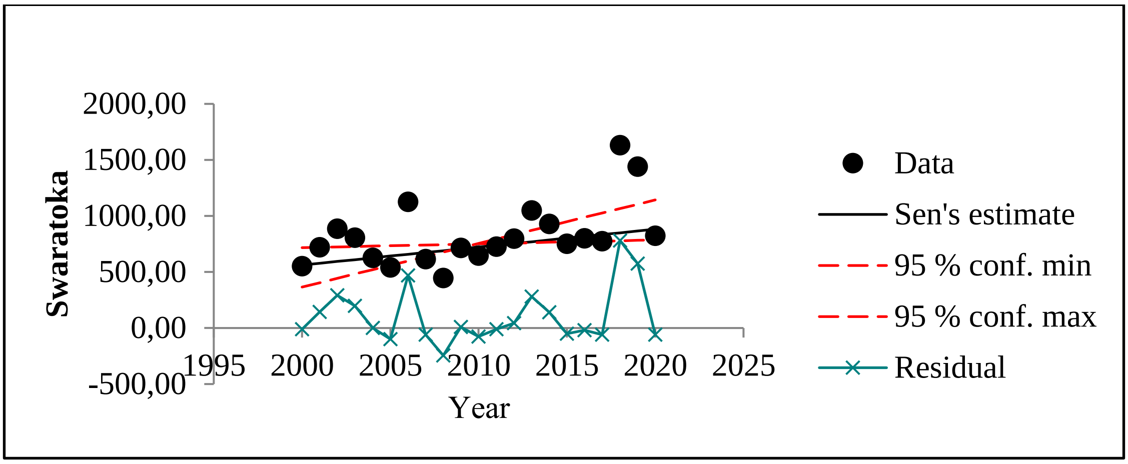


Figure 23. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Swaratica Station

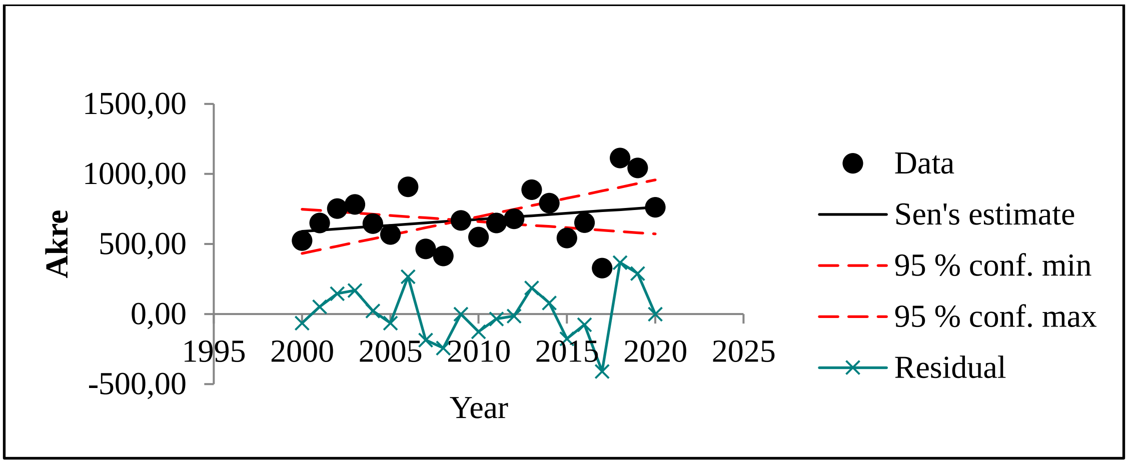


Figure 24. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Akre Station

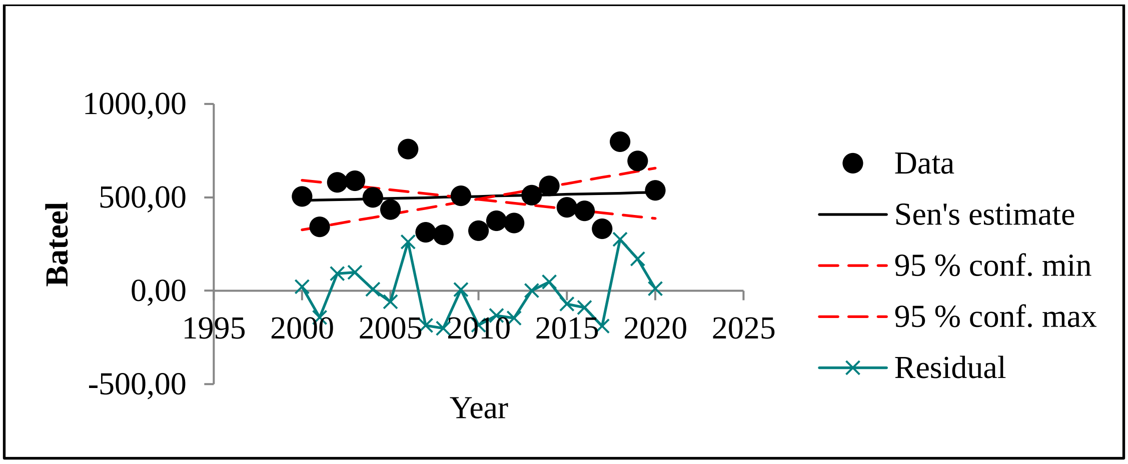


Figure 25. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Bateel Station

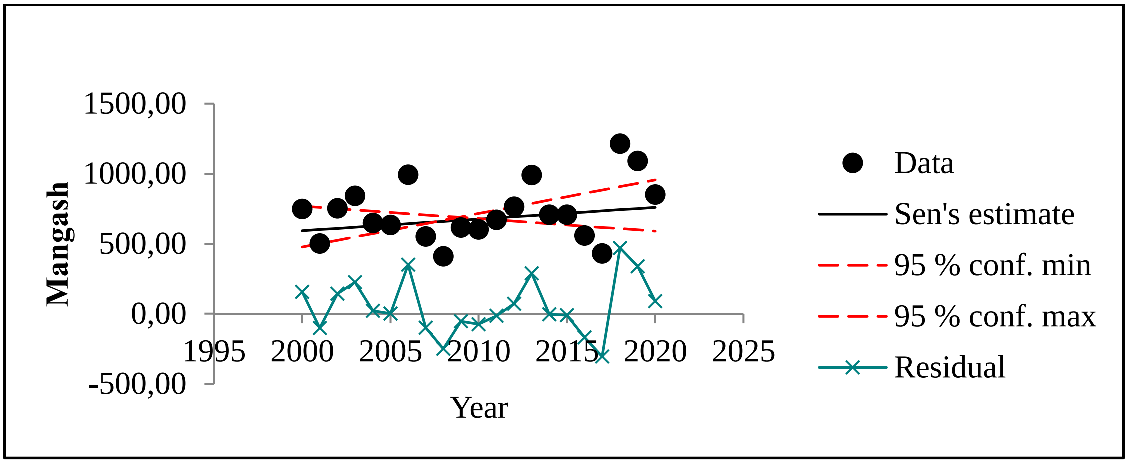


Figure 26. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Mangish Station

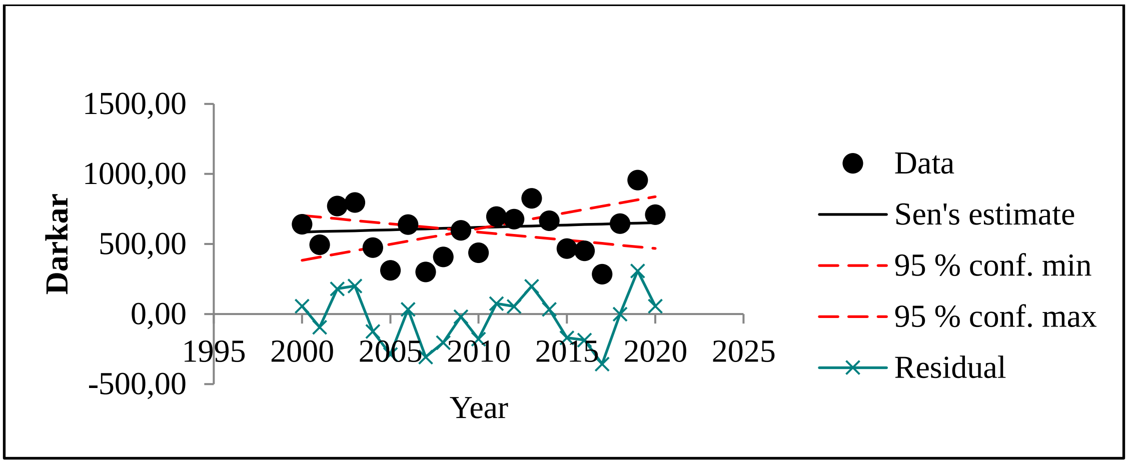


Figure 27. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Darkar Station

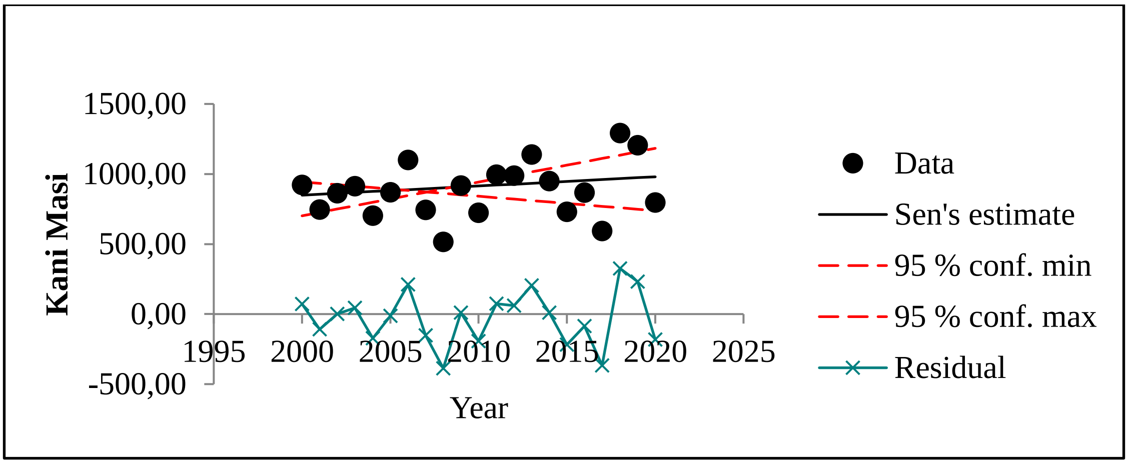


Figure 28. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Kani Masi Station

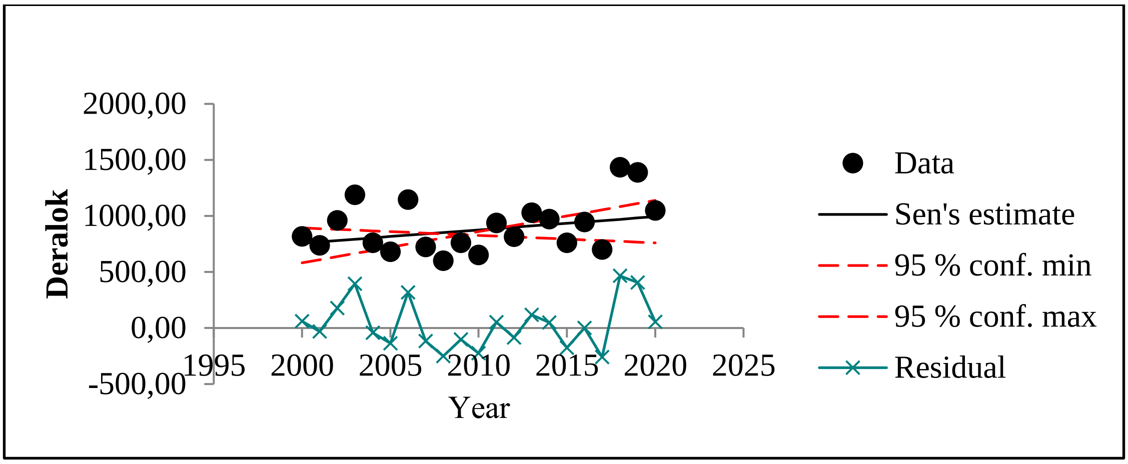


Figure 29. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Deralok Station

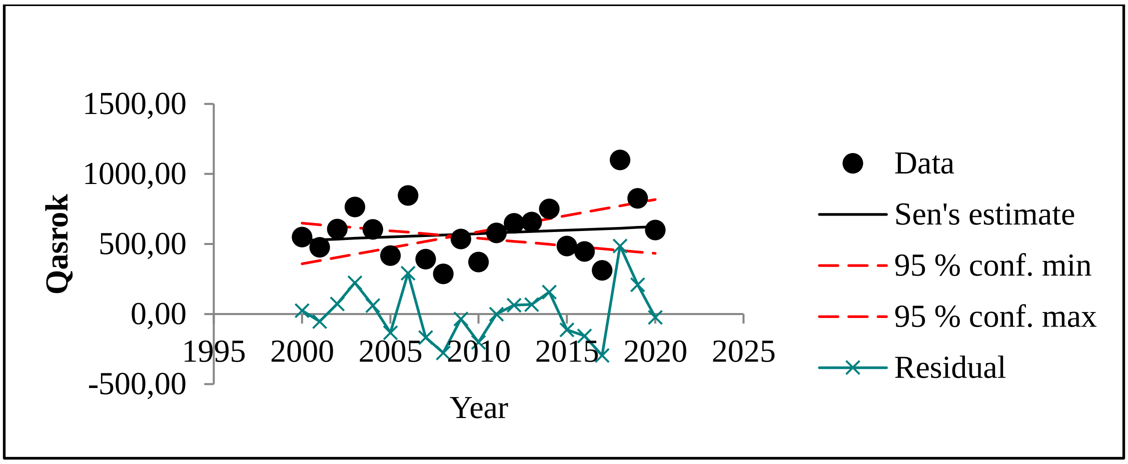


Figure 30. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Qasrok Station

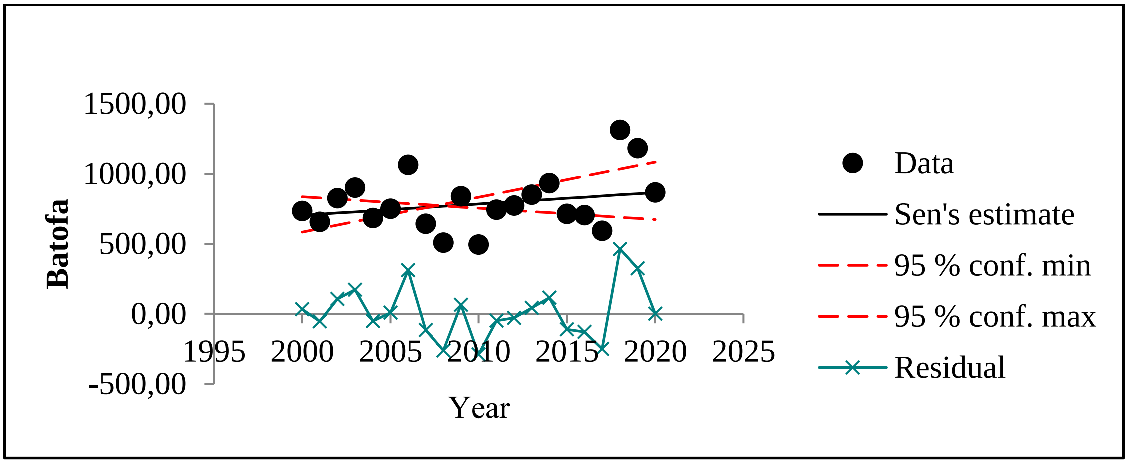


Figure 31. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Batofa Station

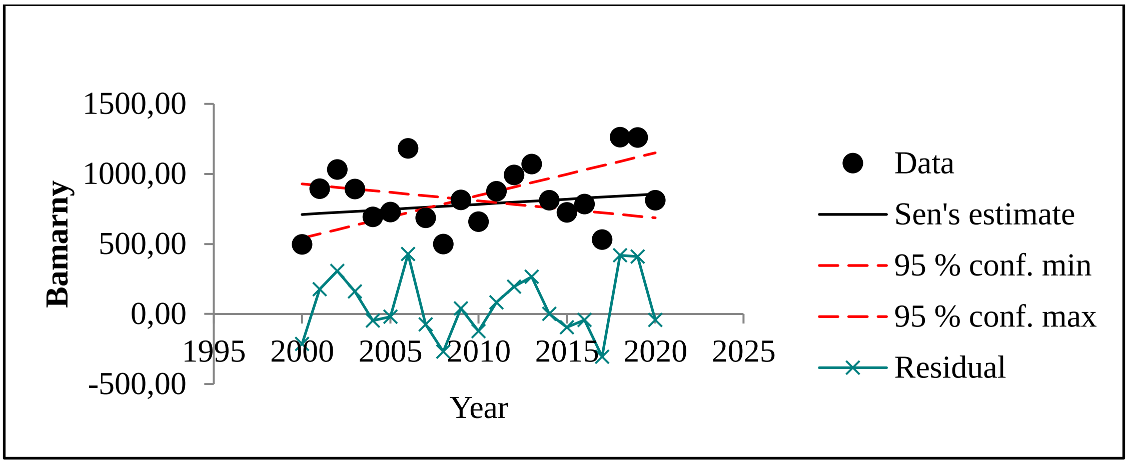


Figure 32. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Bamarne Station

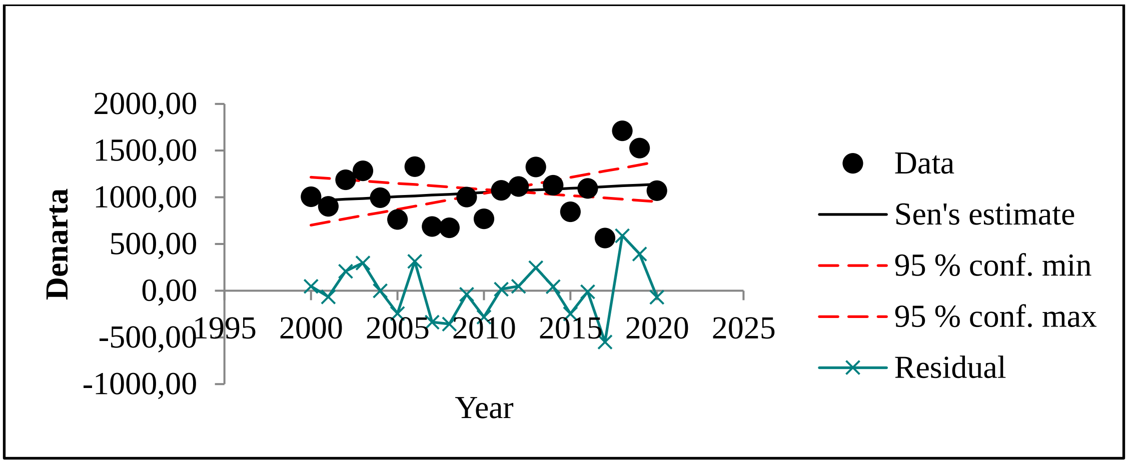


Figure 33. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Dinarta Station

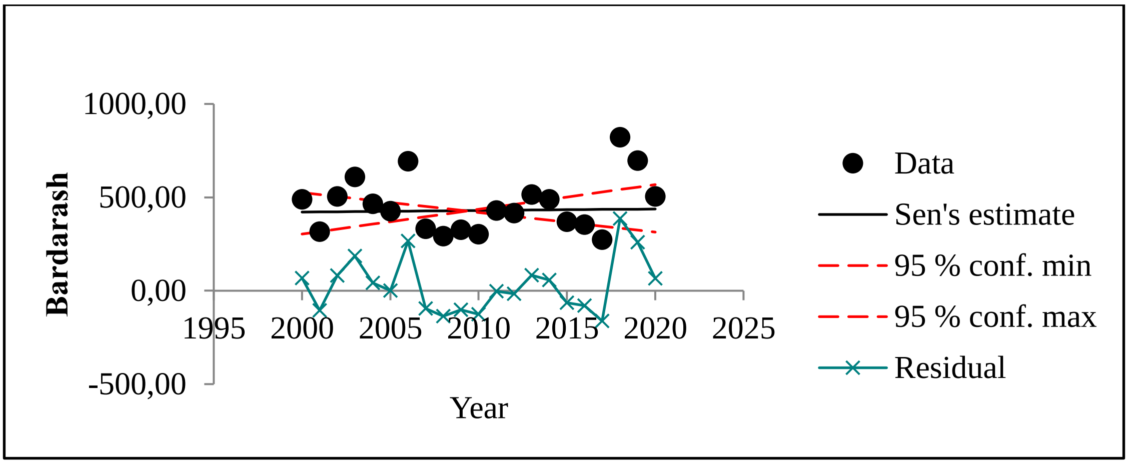


Figure 34. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Baedarash Station

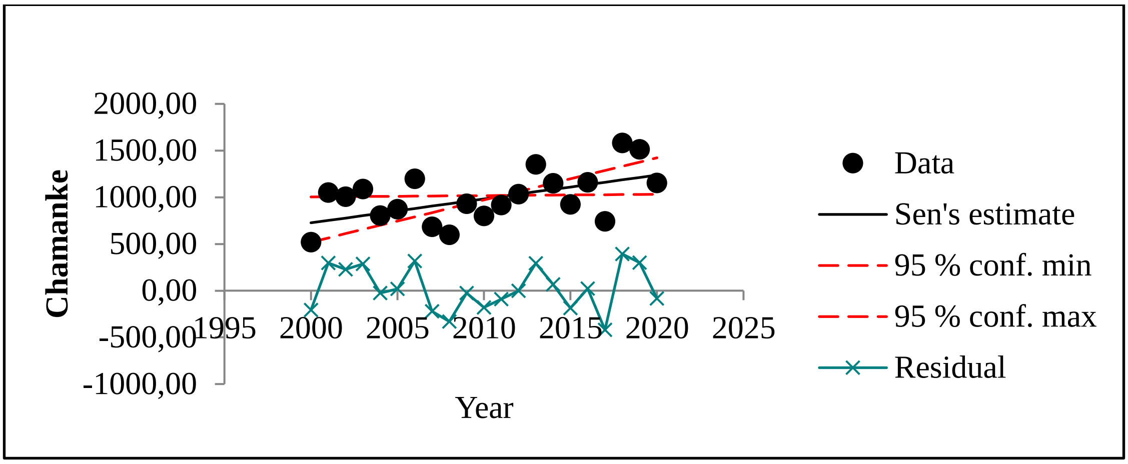
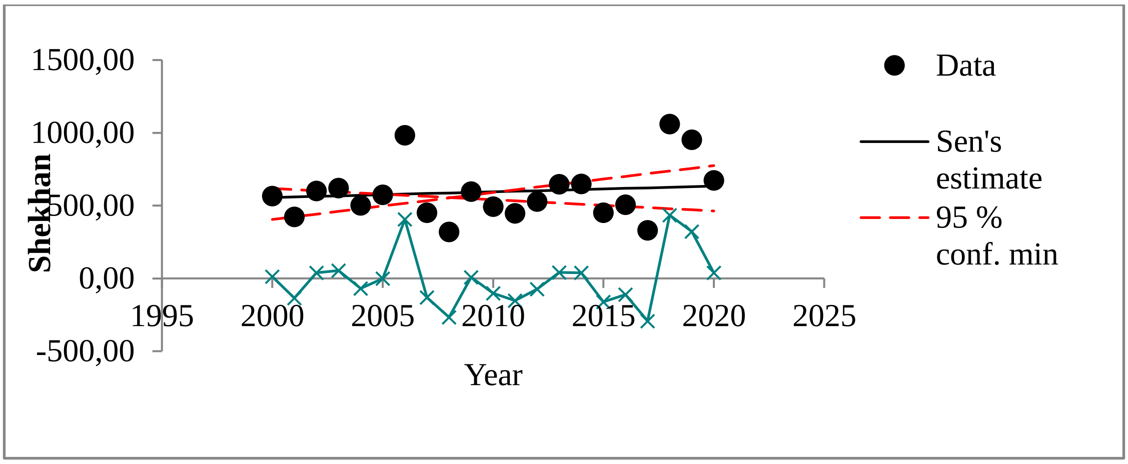
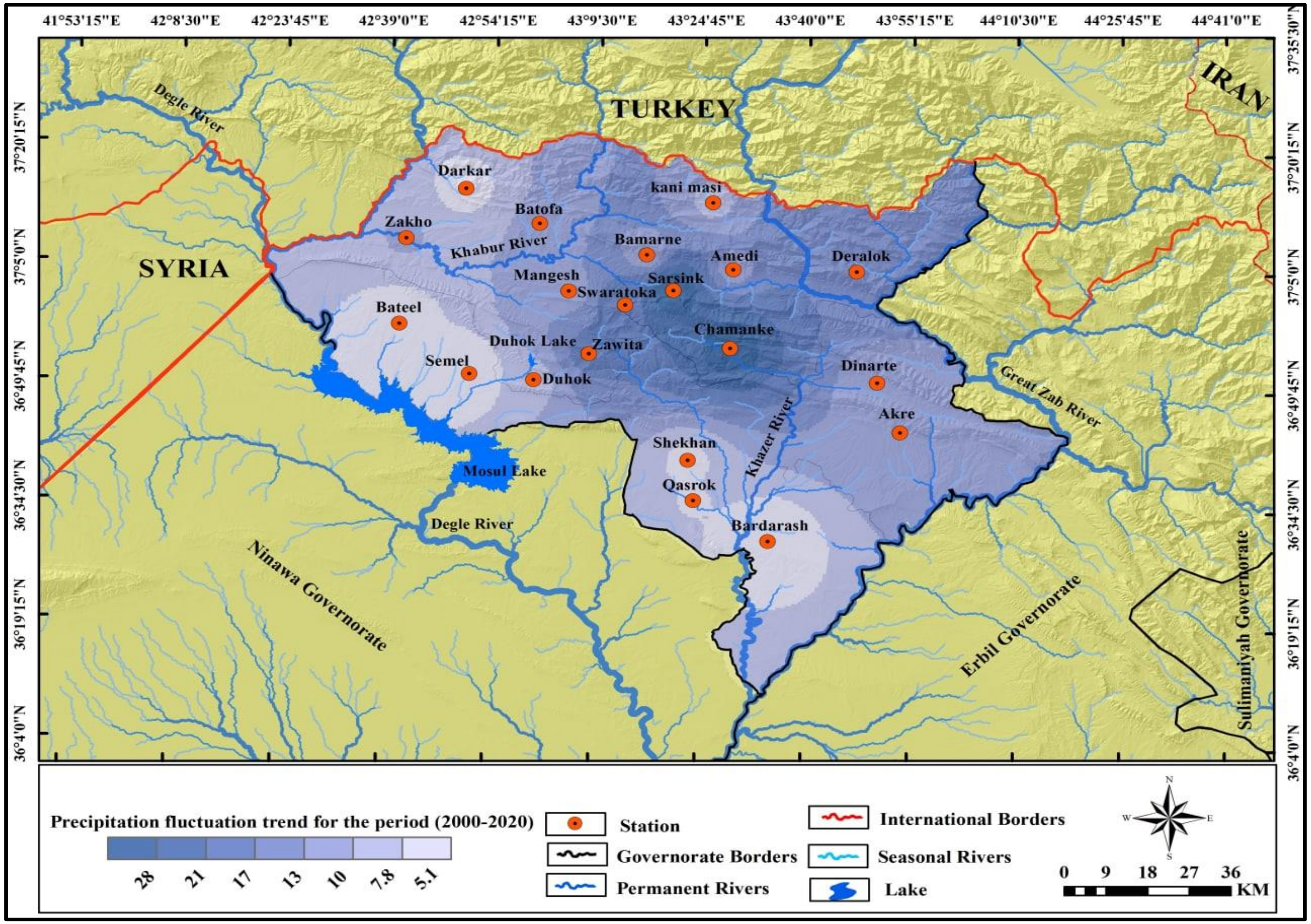


Figure 35. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Chamanke Station



Source : From (Figure 17) to (Figure 36) of the Researcher's Work Based on (Table 30)

Figure 36. Annual Time Series and Slope Direction Statistics for the Rainfall Element at Shekhan Station



Source: From the Researcher's Work Based on (Table 30)

Map 24. Direction of Rainfall Fluctuation in Duhok Stations by Mann Kendall Test for the Period (2000-2020)

4.3. Future Predictions of Rainfall for the Stations of Duhok Governorate

The third research about the Future forecasts of the rains of the stations in Duhok province is the basis for all scientific planning processes, as a feature of the modern era in all different areas of life. The study of rainfall amounts is an important topic in most countries of the world, including the study area, because of its direct relationship with the economic and social activities of the population, and in the fields of planning for the management of water resources, particularly in the planning process for agricultural development. Predicting future rainfall is, therefore, an active element in helping humans to develop future plans for various aspects of human, plant and animal life (Almaliki, 2009). So this research aims to build a simulation of future rainfall forecasting in the study area for a period of time from (2022) to (2030). Future rainfall data at Duhok governorate stations have been predicted by Holt-Winters Forecasting Method:

- **Prediction by Holt-Winters Forecasting Method**

The time series is defined as a random process of historical data collected over time, while predicting that is the process of predicting the future based on time series data. It is an important activity that comes after the planning process and can be dispensed with, especially in the decision-making process because of its future vision of what phenomena and variables will be in the future. Hence, it is important to find an appropriate model suitable for the data available for the study area (Awad Allah, 2016).

Exponential boot is one of the familiar techniques for predicting time series, as it is considered an important statistical and inference procedure that deals with noise or random errors. The boot is defined as the process of refinement of data that have confusion, and a type of successful estimation which was proved by studying cases that change over time. The exponential boot gives highly efficient results as it reduces the lost values compared to predicting the use of traditional methods such as: Surface forecasting method and fixed moving averages. (Mahmoud, 2010). Many temporal series of social, economic and natural phenomena have Seasonal behavior, where there are repeated increases and decreases in the values of these phenomena, which repeat themselves within a ceiling called the season, and do not lose sight of the models that were built to represent those chains the seasonal behavior and processing. Despite the complexities that the models were limited to them as seasonal features were prominent in addition to the usual features, which has made it difficult to estimate them, especially in non-linear cases, so Pegels classified the methods of the exponential in a way that method was classified to be suitable for certain chains (Hyndman R. J, Koehler A .B, Snyder R. D, & Grose, S. 2002). Recently, this classification consist of added trend, So, the classification includes: an unseasonal series, an added seasonal series or a double seasonal series.

Generally, there are several methods of exponential boot, each method corresponds to a particular type of time series data (stable and unstable). When the series is stable, a simple single exponential boot method is used, but if the series shows a linear pattern it can rely upon the Holt linear method or the exponential trend method. When the seasonal pattern appears in the data, these methods give the wrong results for prediction. To avoid this problem, another method of exponential preface is used which is called triple exponential boot or holt winters seasonal method that relies on two data analysis models (Abdel Ahad, M. Younis & Nadwa. 2012).

1- Multiplicative Seasonality Model $Y_t = M \times T \times C \times S \times I \pm E$

2- Additive Seasonality Model $Y_t = M + T + C + S + I \pm E$

- **Applied Side**

Future values were predicted based on the first model called multiplicative Seasonality Model only because this method is used when seasonal changes are increasing along the time chain. This means that seasonal changes are proportional to the chain level, depending on several MAPE, MAD, MSE criteria. Where:

MAPE: mean Absolute percentage error $\frac{1}{n}\sum \left[\frac{Z_{t-\hat{z}_t}}{Z_{\ t}}\right] \times 10_0$

MAD: mean Absolute deviation $\frac{\sum_I^n = |\mathrm{e}_t|}{n}$

MSD: mean Square Deviation $\frac{\sum_{i=1}^n (\mathrm{e}_i)2}{n} = \frac{\sum_{i=1}^n \left(z_{t-\hat{z}_t}\right)2}{n}$

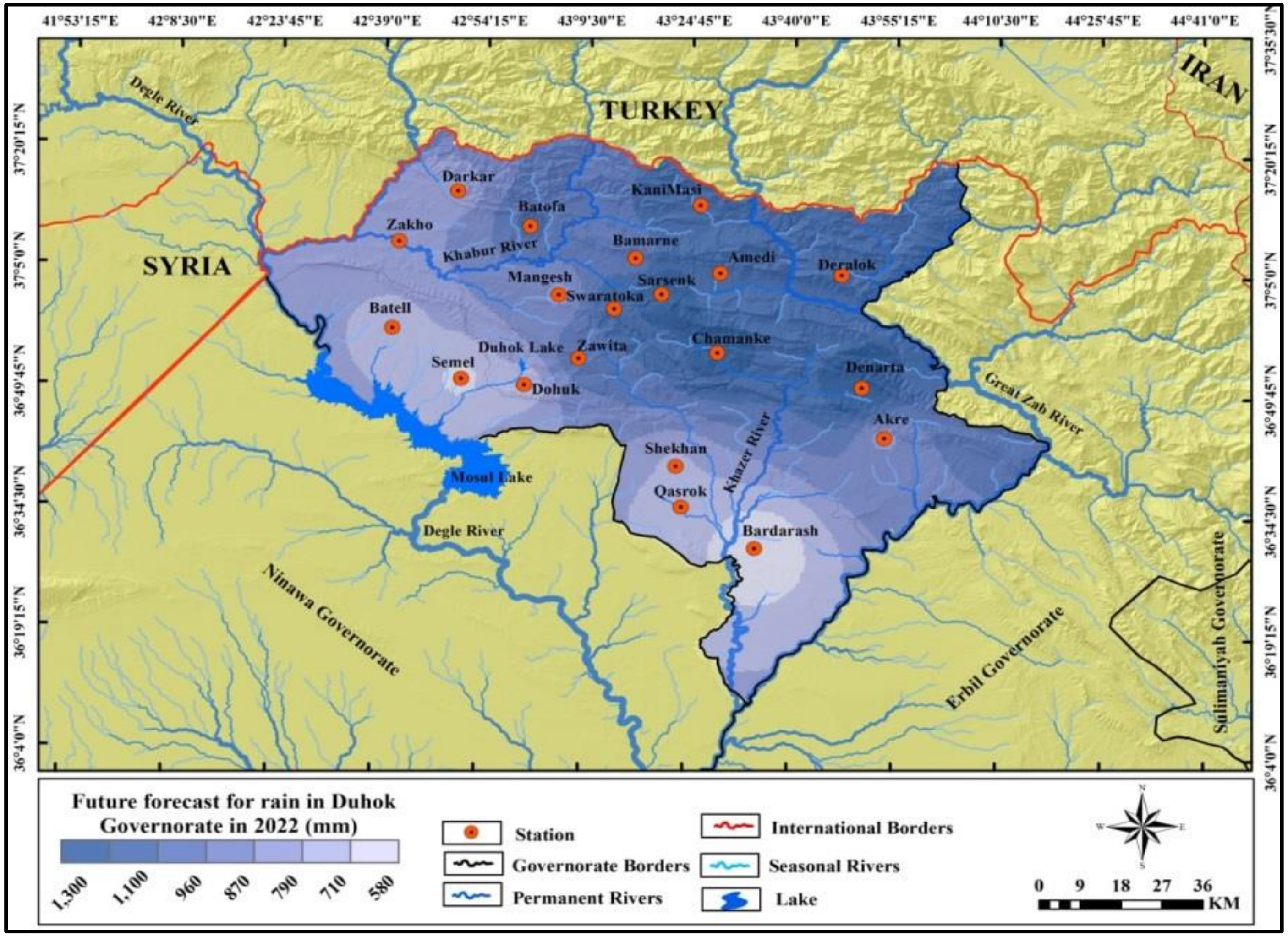
To apply this method, it is needed to choose three values for α, γ, δ as follows:

Level = $\underline{X} = \alpha(\underline{X}_{t-1} + T_{t-1}) + (1 - \alpha)\left(\frac{X_t}{F_{t-s}}\right)$

Trend= $T_t = \gamma T_{t-1} + (1 - \gamma)(X_t - \underline{X}_{t-1})$

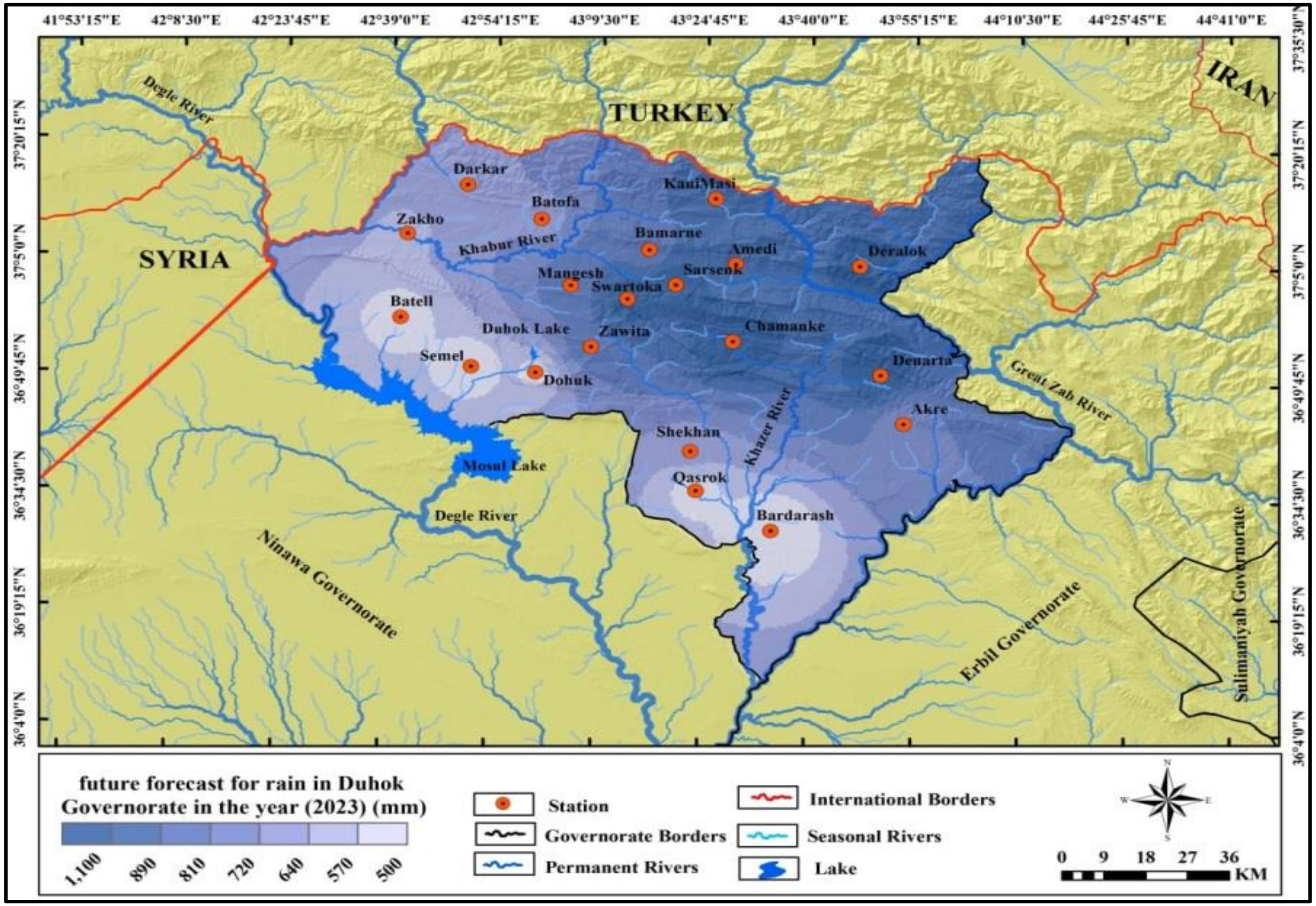
Seasonal = $\boldsymbol{F_t = \delta F_{t-s} + (1 - \delta)\left(\frac{X_t}{\underline{X}_t}\right)}$

The first step in analyzing the data and the model used is to draw the resedues (errors) to determine the nature of the data and reveal whether the resedues (errors) follow the natural distribution or not. The resedues (errors) are the differences between the original values and the values estimated using regression. It shows a future forecast of the amount of rainfall in all stations of the governorate from the year (2022 to 2030) in (Maps 25 to 33).



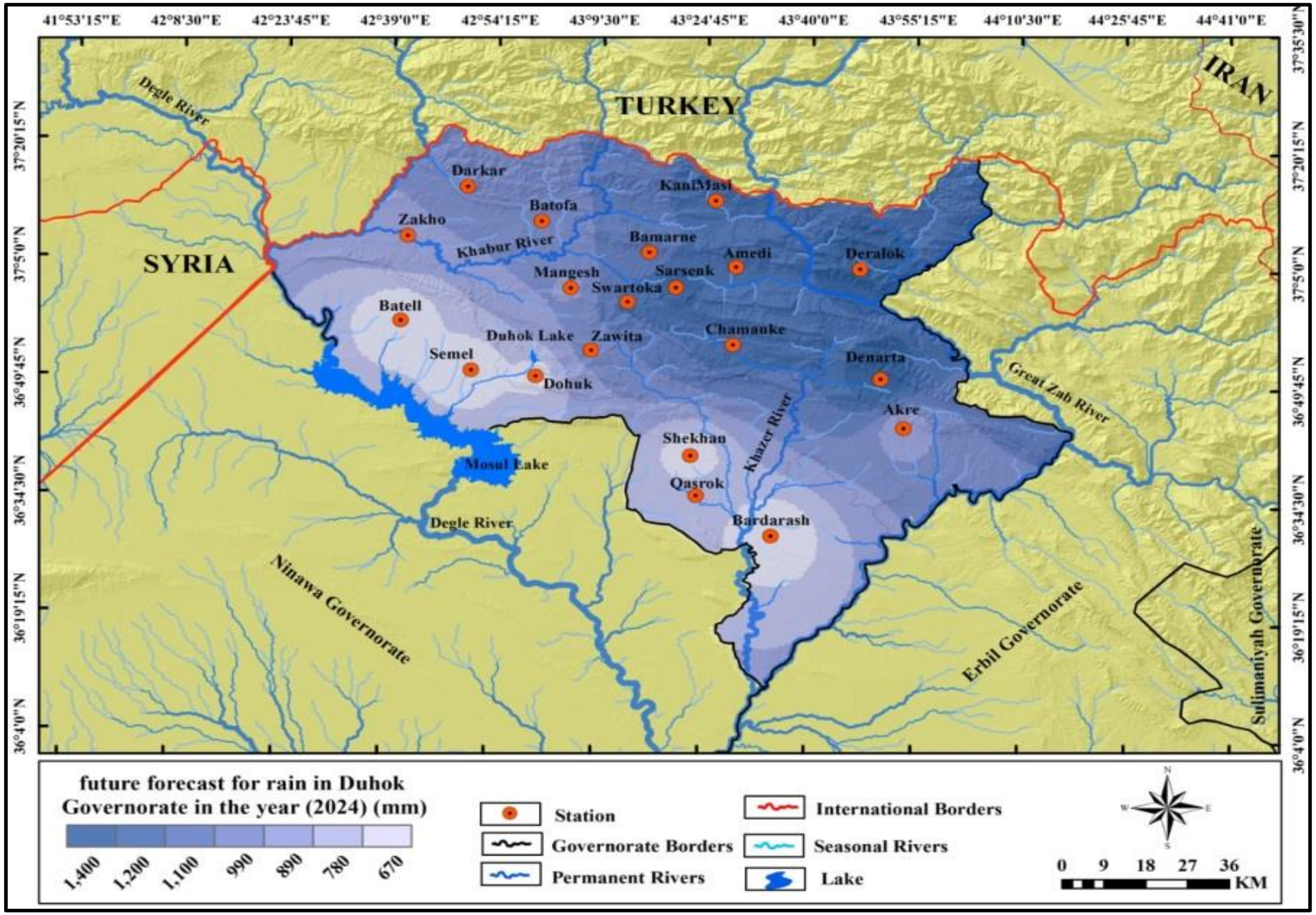
Source: From the Researcher's work based on (Appendix 12)

Map 25. The Future Forecasting of Rainfall in Duhok Governorate Stations in (2022)



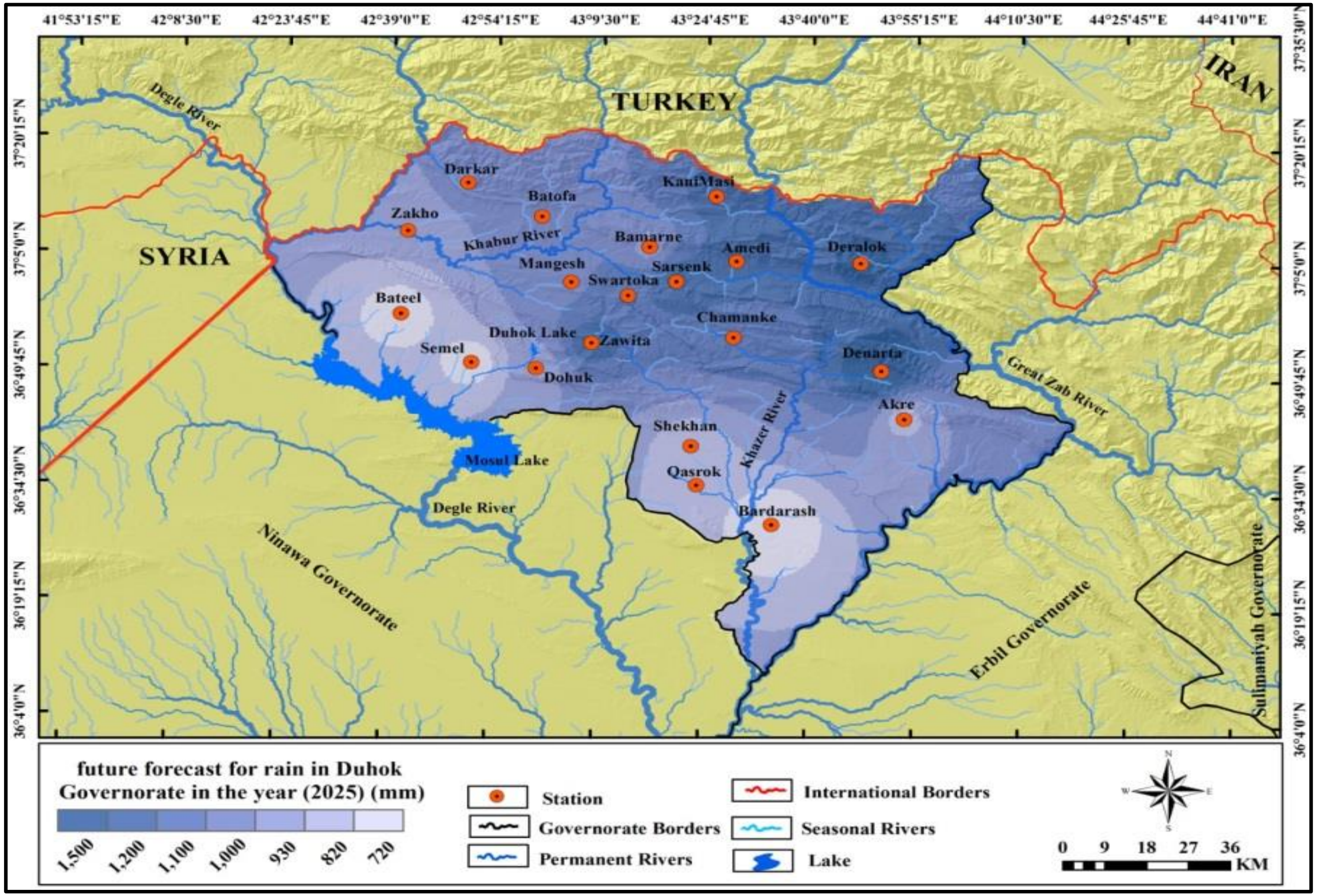
Source: From the Researcher's work based on (Appendix 12)

Map 26. The Future Forecasting of Rainfall in Duhok Governorate Stations in (2023)



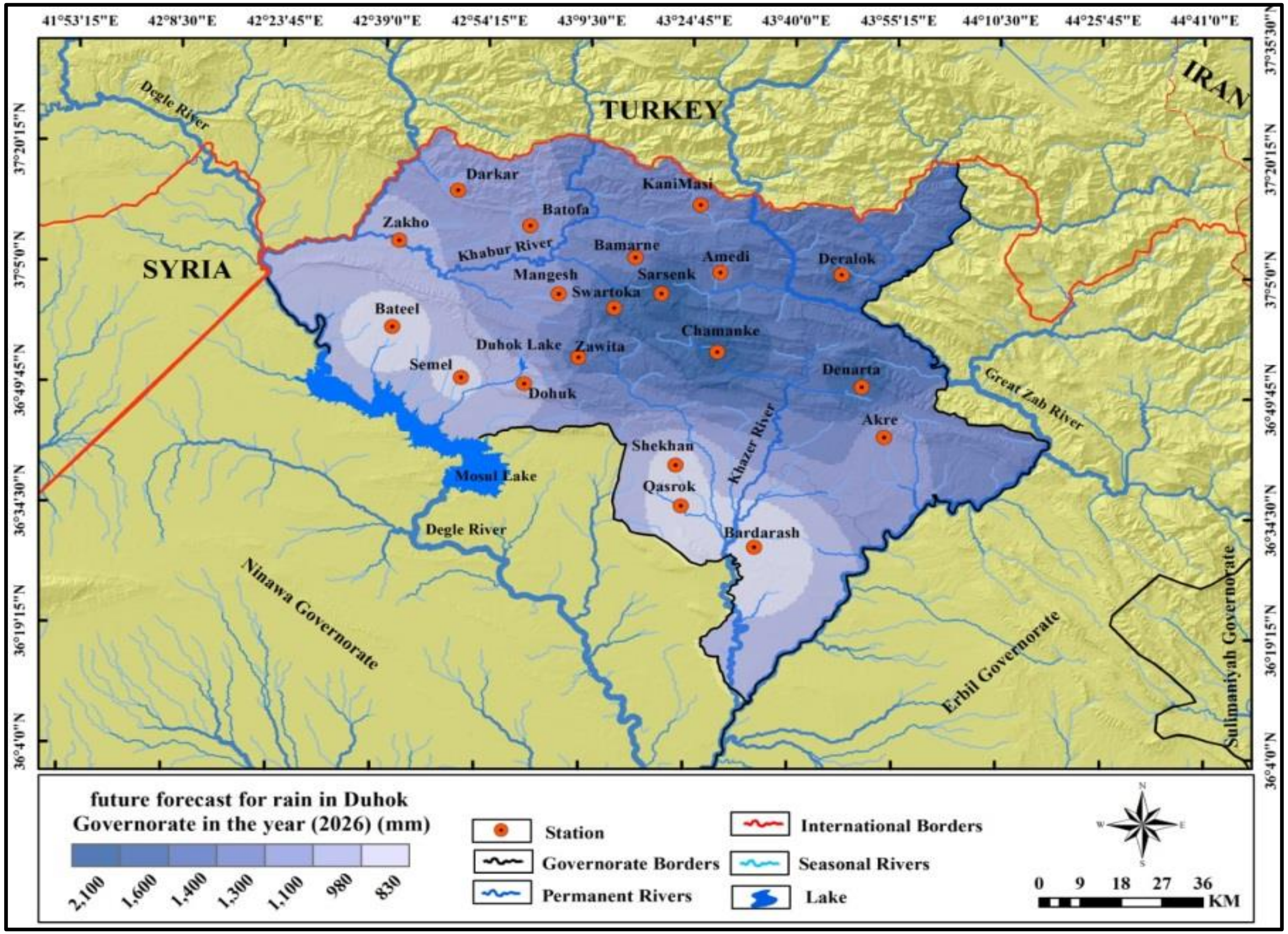
Source: From the Researcher’s work based on (Appendix 12)

Map 27. The Future Forecasting of Rainfall in Duhok Governorate Stations in (2024)



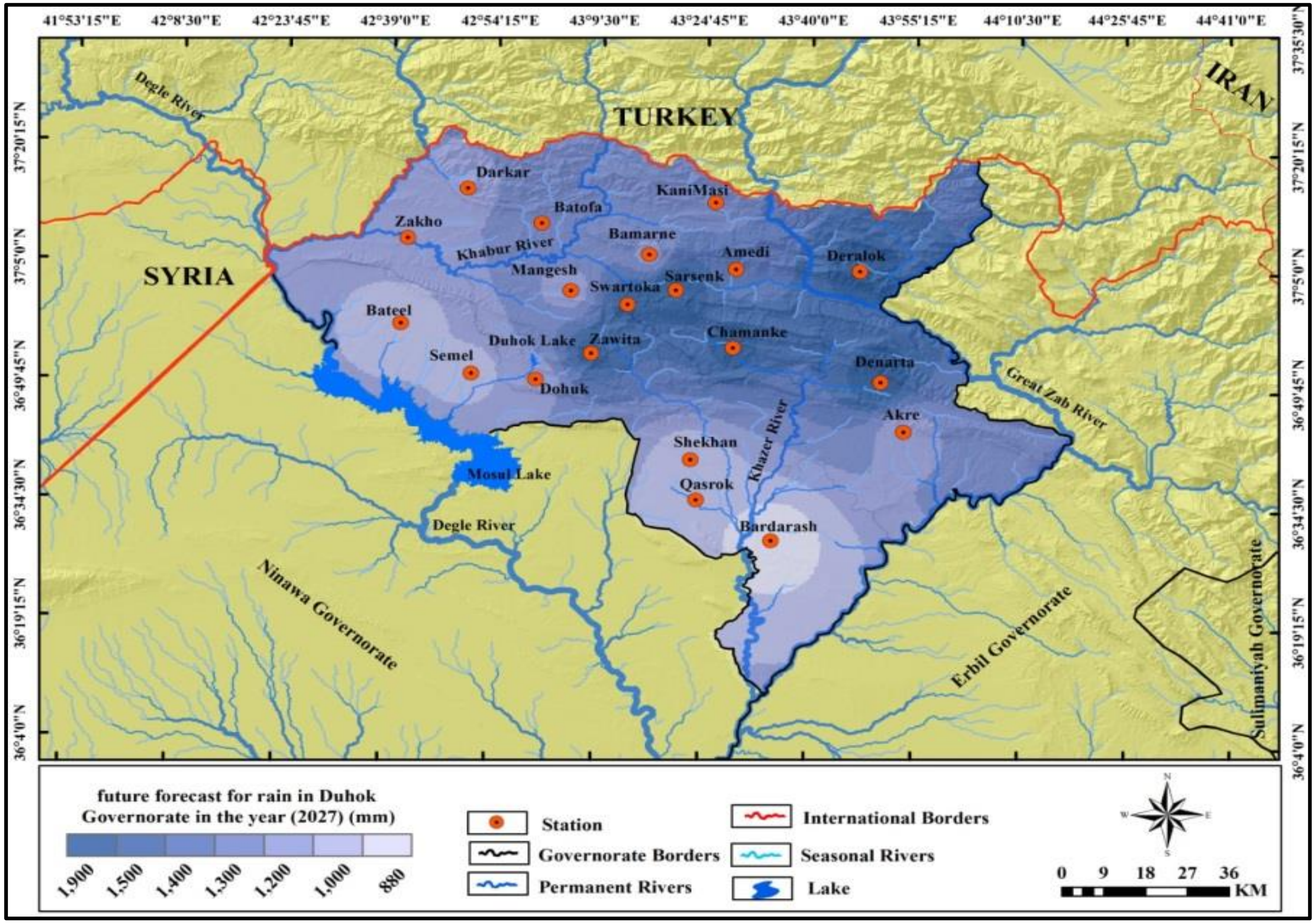
Source: From the Researcher's work based on (Appendix 12)

Map 28. The Future Forecasting of Rainfall in Duhok Governorate Stations in (2025)



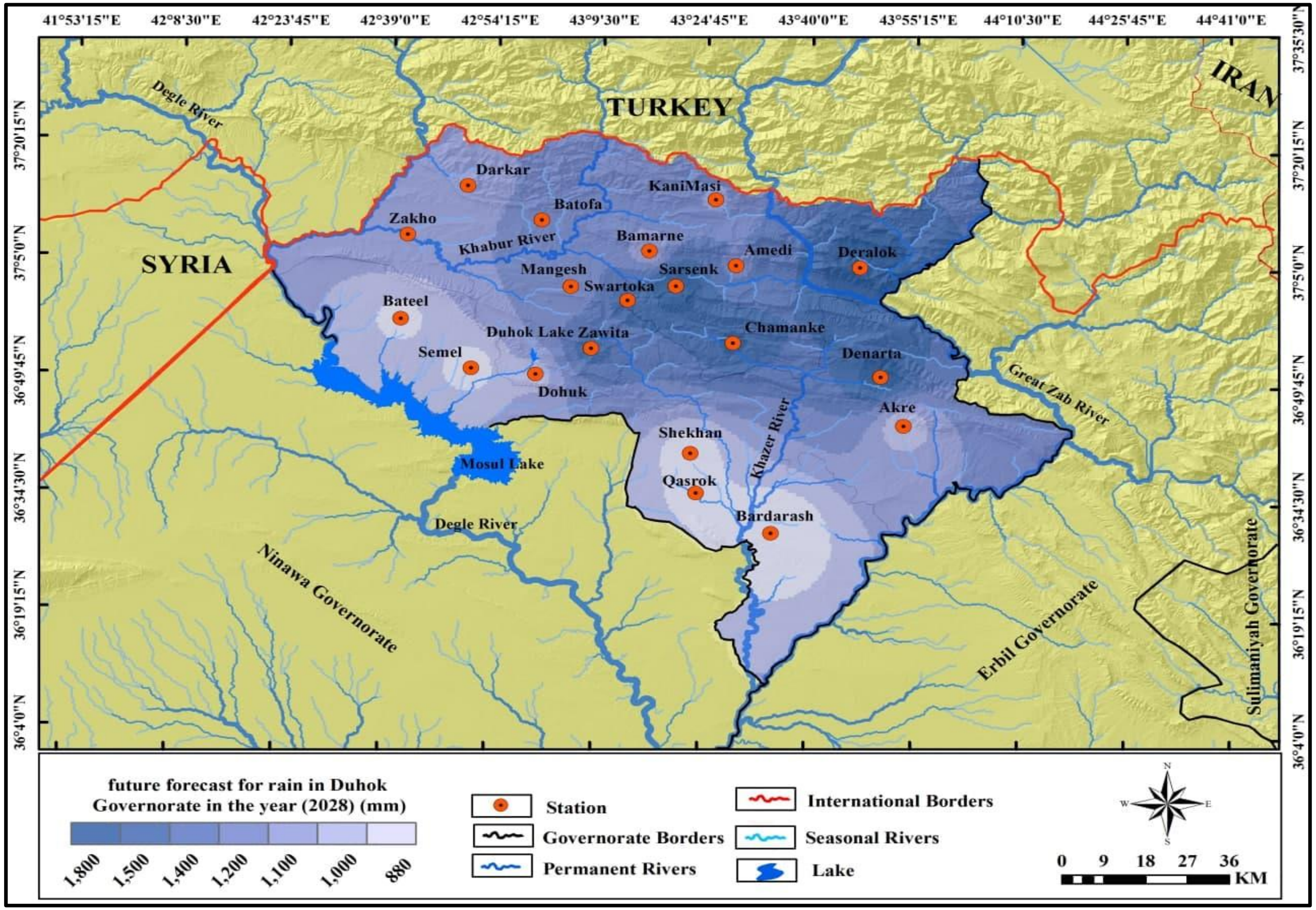
Source: From the Researcher's work based on (Appendix 12)

Map 29. The Future Forecasting of Rainfall in Duhok Governorate Stations in (2026)



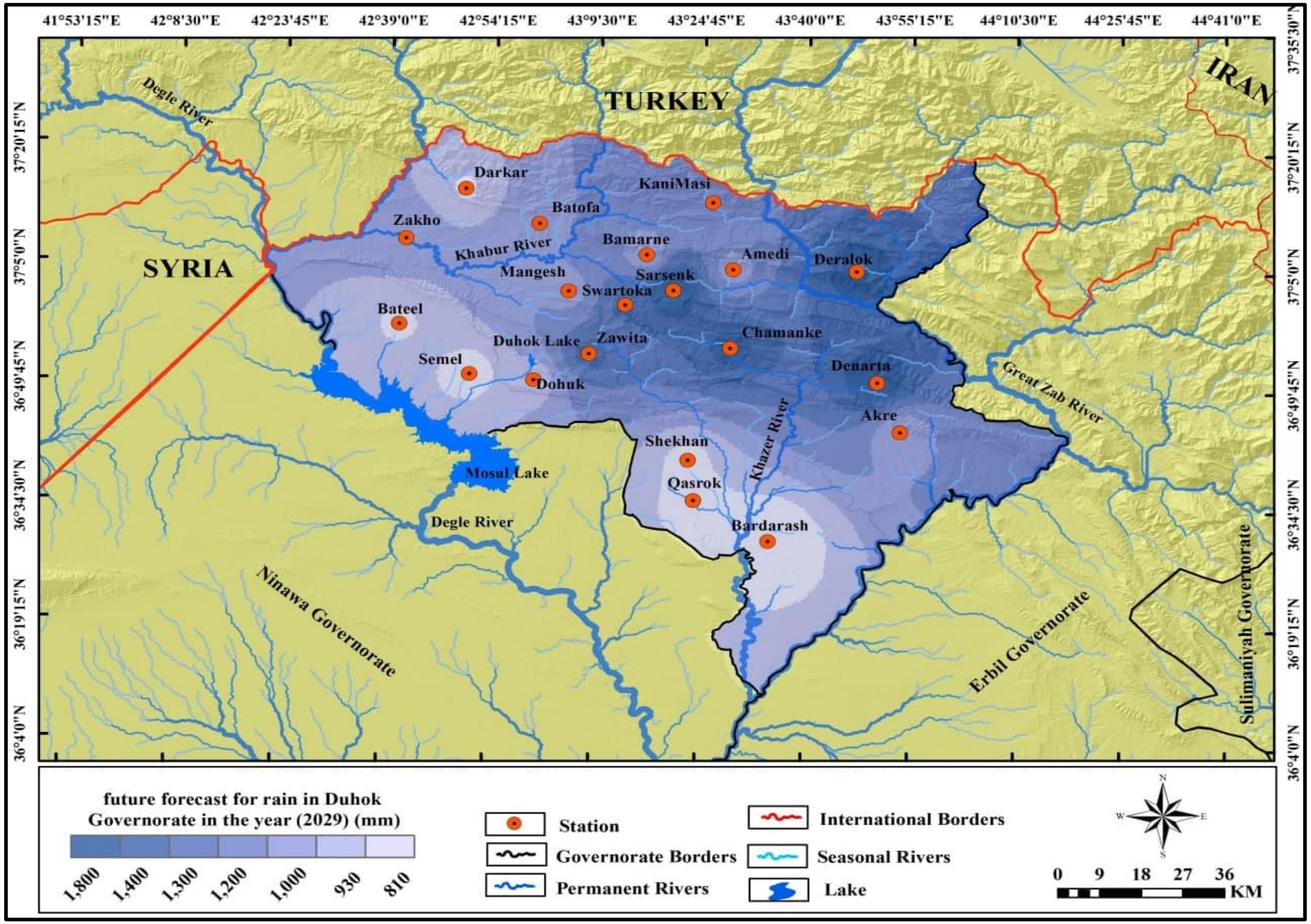
Source: From the Researcher's work based on (Appendix 12)

Map 30. The Future Forecasting of Rainfall in Duhok Governorate Stations in (2027)



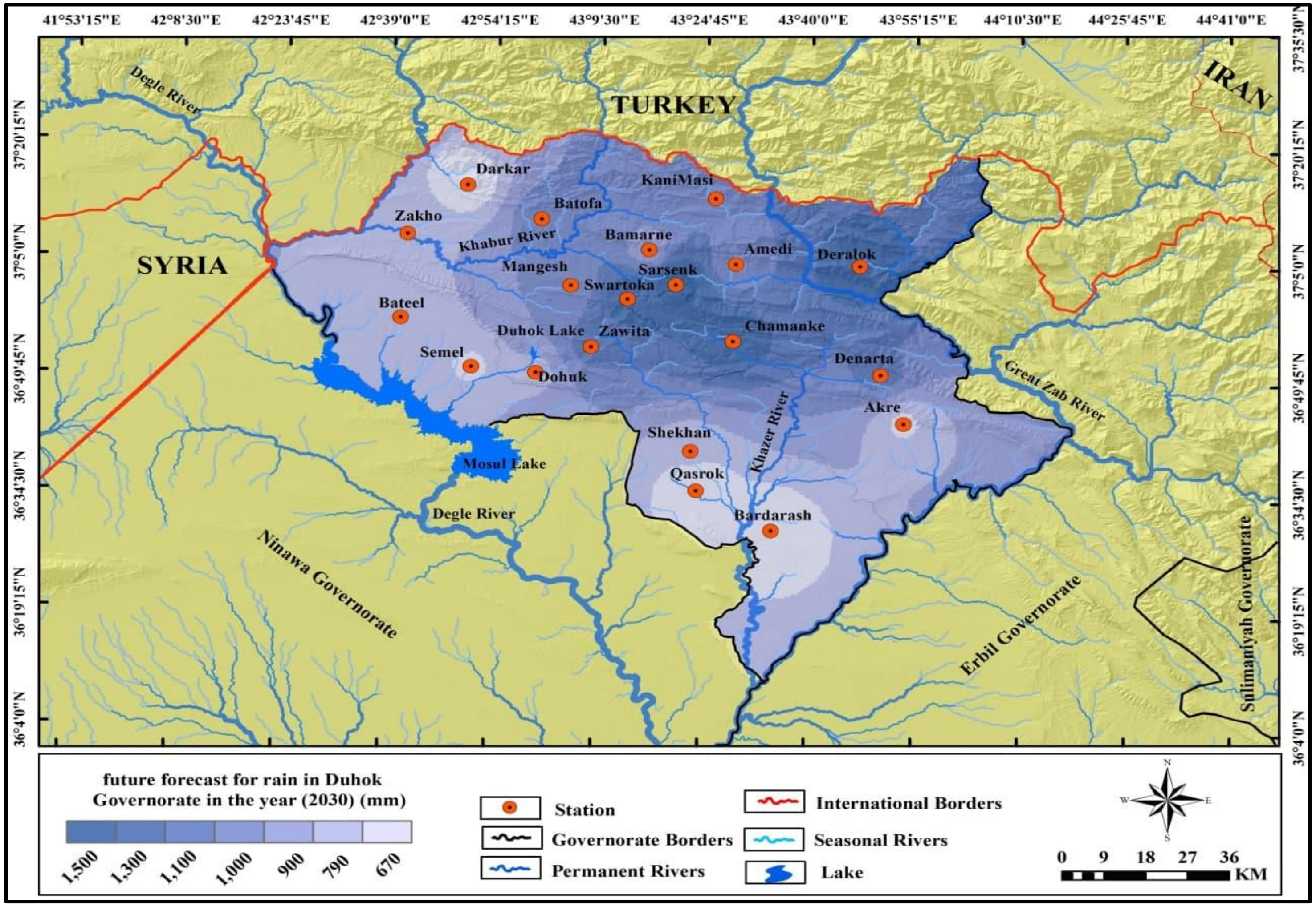
Source: From the Researcher’s work based on(Appendix 12)

Map 31. The Future Forecasting of Rainfall in Duhok Governorate Stations in (2028)



Source: From the Researcher’s work based on (Appendix 12)

Map 32. The Future Forecasting of Rainfall in Duhok Governorate Stations in (2029)



Source: From the Researcher's work based on (Appendix 12)

Map 33. The Future Forecasting of Rainfall in Duhok Governorate Stations in (2030)

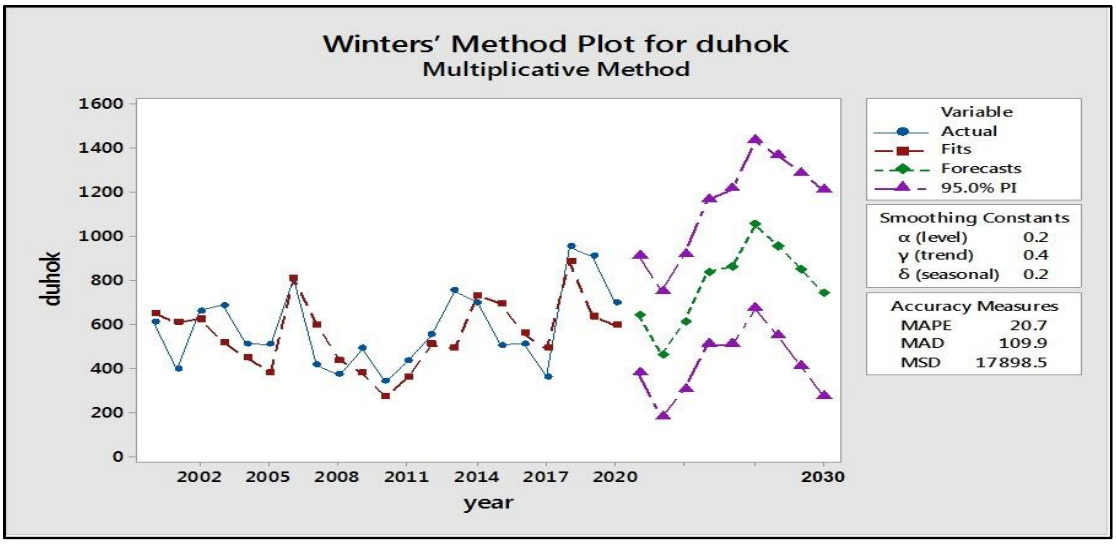
The Residual Figure Showing The Amount Of Rainfall For All Stations:

1. Duhok Station: Table (31) shows the predicted values of rainfall using the seasonal multiplicative model for the next 9 years at Duhok station, predicting that the lowest rainfall during this period will be recorded in (2023) by (46 1.04mm) and the largest amount will be in (2027) by (1051.42mm), Figure (37) shows the graph of the original, graded and predicted values with the values of the three criteria.

Table 31. Future Forecast of Rainfall at Duhok Station for 2030

Period	Forecast	Lower	Upper
2022	642.67	373.476	911.87
2023	461.04	174.461	747.62
2024	610.97	303.779	918.16
2025	835.68	505.253	1166.11
2026	861.07	505.301	1216.85
2027	1051.42	668.607	1434.22
2028	954.88	543.674	1366.08
2029	848.44	407.751	1289.13
2030	739.54	268.469	1210.61

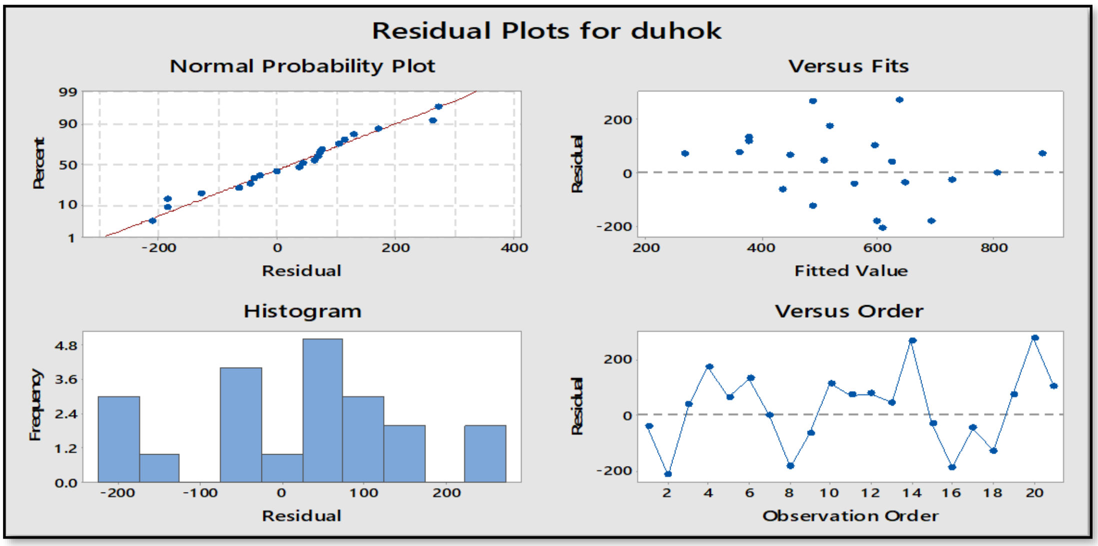
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 31)

Figure 37. Predicted Values of the Amount of Rainfall by the Multiplication Model at the Duhok Station

As mentioned above, one of the steps governing the audit of the model used is the graph, which shows through (Figure 38) that the data follows the normal distribution at Duhok station, that the shape of the spread of the resedues (errors) with directional values takes a random form around zero, and that "a specific pattern or shape of these resedues can not be monitored (they fluctuate randomly around zero). So, we can judge here the stability of the contrast. It is clear from the form that most observations within are the boundaries of the period of the resedue (error) confidence, and that's a good indication that mistakes represent purely random changes.



Source: From the Researcher's work based on the (Table 31)

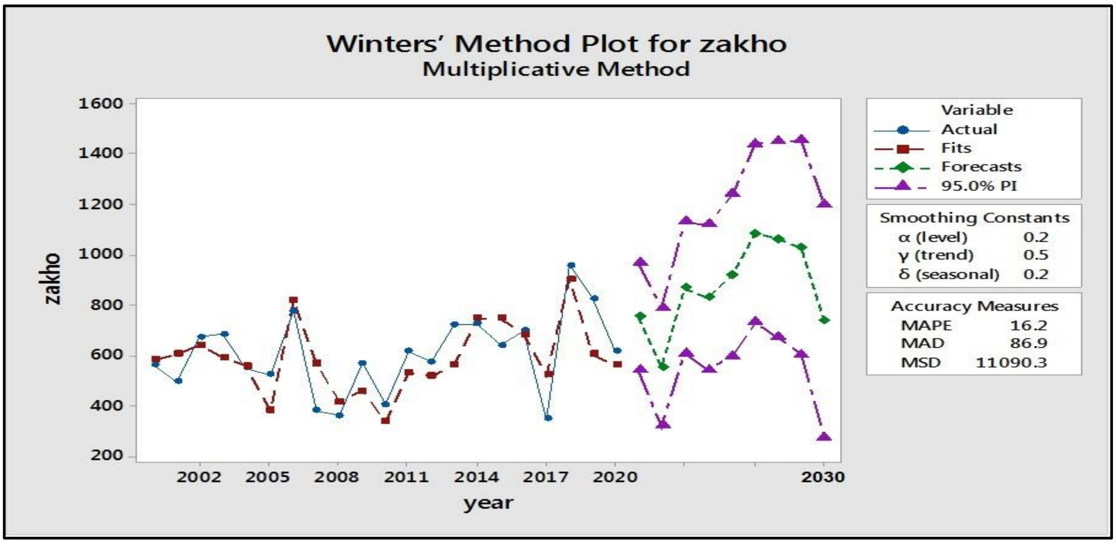
Figure 38. Residues for the Amount of Rainfall at Duhok Station

2. Zakho Station: Table 32 and Figure 39, predict that zakho station in the next 9 years will record the lowest rainfall in (2023) by (551.90mm) and the largest amount in (2027) by (1083.44mm).

Table 32. Future Forecast of Rainfall at Zakho Station for 2030

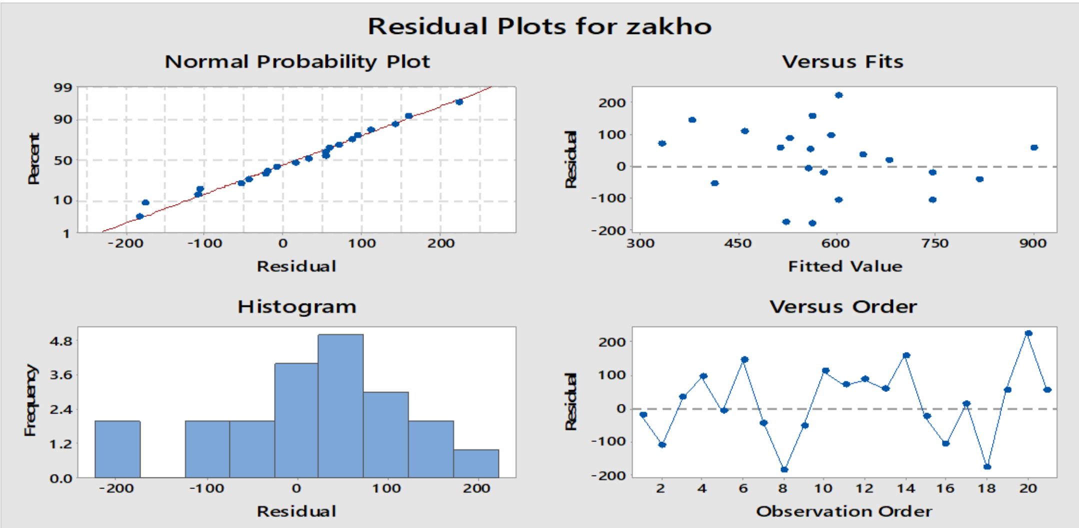
Period	Forecast	Lower	Upper
2022	750.17	537.219	963.13
2023	551.90	317.238	786.57
2024	866.77	605.955	1127.58
2025	828.73	538.518	1118.93
2026	917.59	595.630	1239.54
2027	1083.44	728.009	1438.87
2028	1059.10	668.915	1449.29
2029	1025.57	599.663	1451.48
2030	733.66	271.287	1196.04

Source: From the researcher’s work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 32)

Figure 39. Predicted Values of the Amount of Rainfall by the Multiplication Model at Zakho Station



Source: From the Researcher's work based on the (Table 32)

Figure 40. Residues of the Amount of Rainfall for Zakho Station

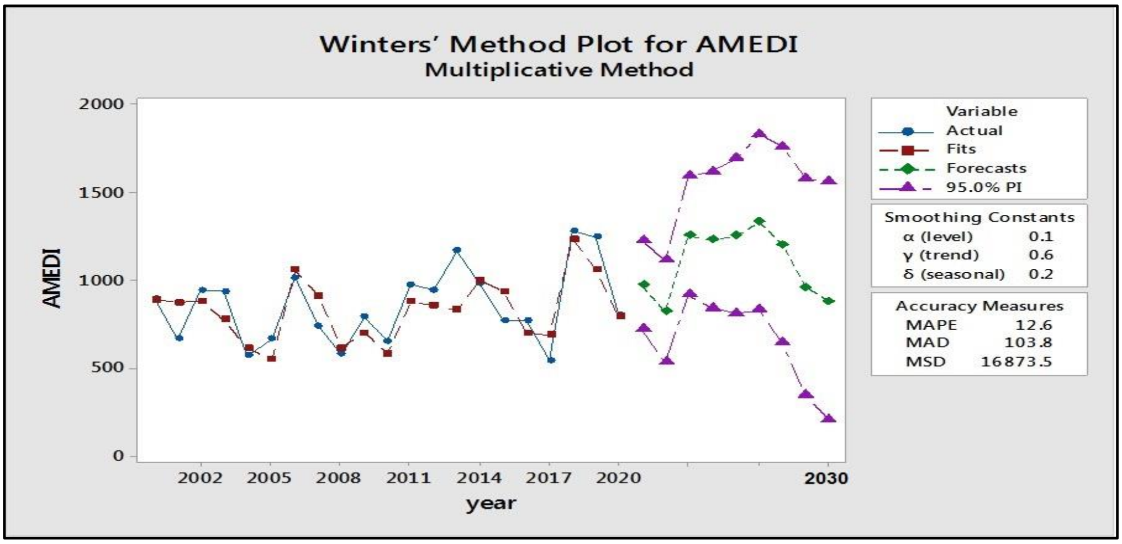
(Figure 40) demonstrates the data normally distributed at Zakho station, and the shape of the spread of the resedues with directional values takes a random form around zero.

3- **Amedi Station:** Table 33 and Figure 41 Predict that amedi station in the next 9 years will record the lowest rainfall in (2023) by (821.04mm) and the largest amount in (2027) by (1330.21mm).

Table 33. Future Forecast of Rainfall at Amedi Station for 2030

Period	Forecast	Lower	Upper
2022	972.11	717.687	1226.53
2023	821.04	528.989	1113.08
2024	1253.34	915.590	1591.09
2025	1230.04	841.339	1618.74
2026	1251.51	808.432	1694.59
2027	1330.21	830.428	1829.99
2028	1200.71	642.622	1758.80
2029	959.87	342.313	1577.42
2030	880.98	203.108	1558.84

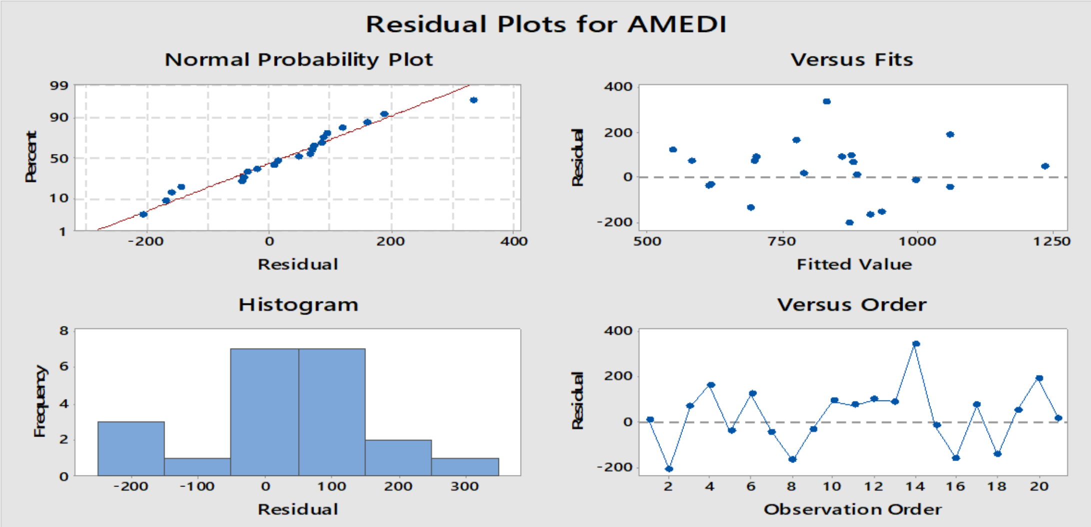
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 33)

Figure 41. Predicted Values of the Amount of Rainfall by the Multiplication Model at Amedi Station

Figure 42 Shows that the data distributed normally at Amedi station, and that the shape of the spread of the resedues swith directional values takes a random form around zero.



Source: From the Researcher's work based on the (Table 33)

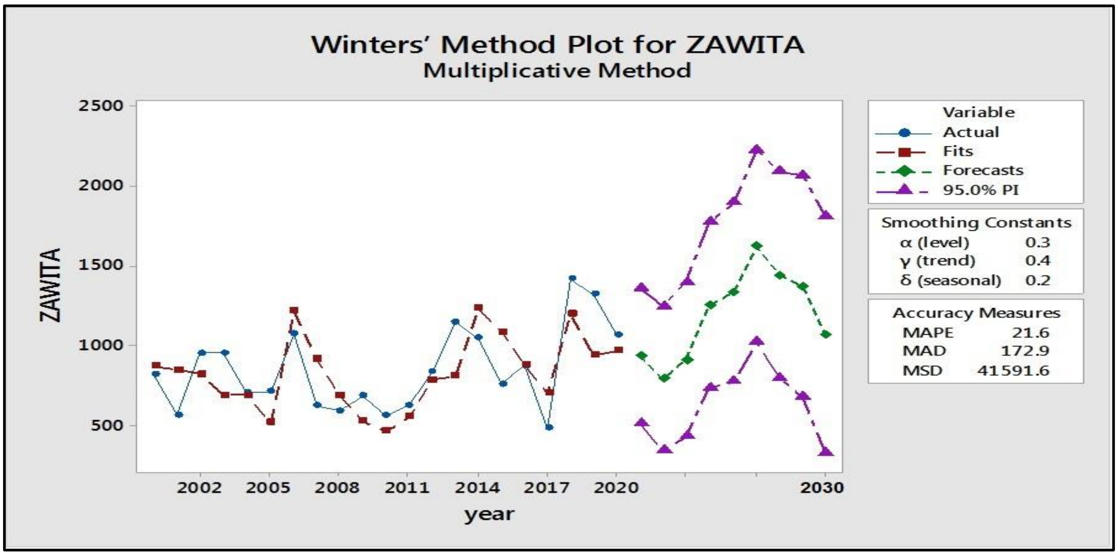
Figure 42. Residues for the Amount of Rainfall for Amedi Station

4. Zawita Station: It can be seen through Table 34. That forecast of the amount of rainfall over the next 9 years at Zawita Station shows that the lowest amount will be recorded in (2023) by (791.24mm) and the largest amount in (2027) by (1619.70mm), note the (Figure 43).

Table 34. Future Forecast of Rainfall at Zawita Station for 2030

Period	Forecast	Lower	Upper
2022	934.02	510.54	1357.50
2023	791.24	340.41	1242.07
2024	910.37	427.12	1393.62
2025	1250.08	730.28	1769.89
2026	1332.12	772.45	1891.80
2027	1619.70	1017.49	2221.90
2028	1439.75	792.88	2086.62
2029	1369.50	676.23	2062.76
2030	1064.84	323.79	1805.89

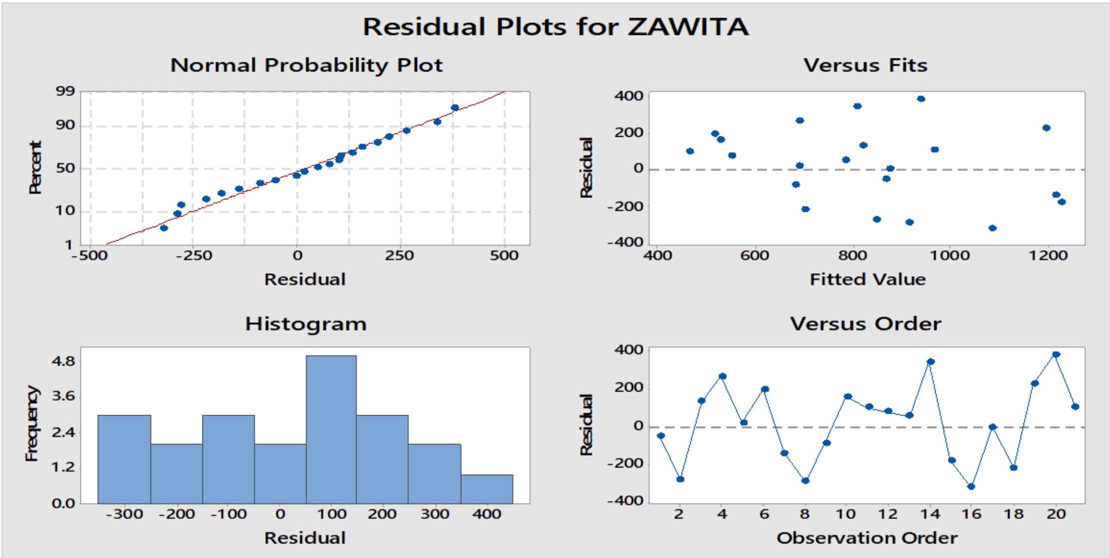
Source: From the researcher’s work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 34)

Figure 43. Predicted Values of the Amount Of Rainfall by the Multiplication Model at Zawita Station

The data follow the normal distribution at Zawita, and the shape of the spread of the resedues with directional values takes a random form around zero. Note (Figure 44).



Source: From the Researcher's work based on the (Table 34)

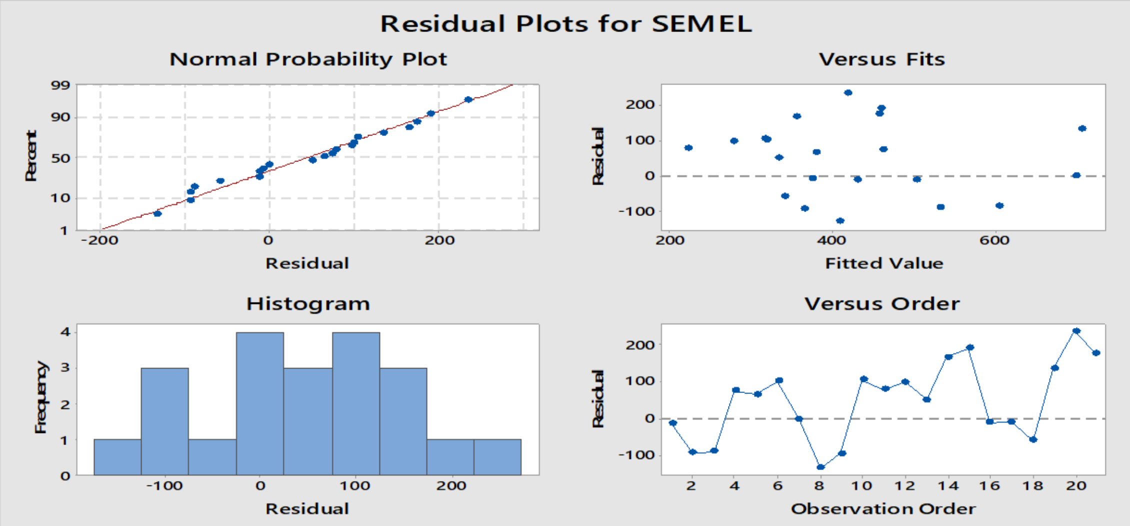
Figure 44. Residues for the Amount of Rainfall for Zawita Station

5. Semel Station: It can be seen through Table 35 that predicted values of rainfall for the next (9) years at Semel station are predicted to be (405.420mm) and the largest amount in (2027) by (956.411mm), note the (Figure 45).

Table 35. Future Forecast of Rainfall at Semel Station for 2030

Period	Forecast	Lower	Upper
2022	533.230	303.515	762.95
2023	405.420	152.286	658.55
2024	535.203	253.861	816.55
2025	642.006	328.958	955.06
2026	755.713	408.417	1103.01
2027	956.411	573.006	1339.82
2028	807.141	386.245	1228.04
2029	717.915	258.485	1177.34
2030	643.052	144.286	1141.82

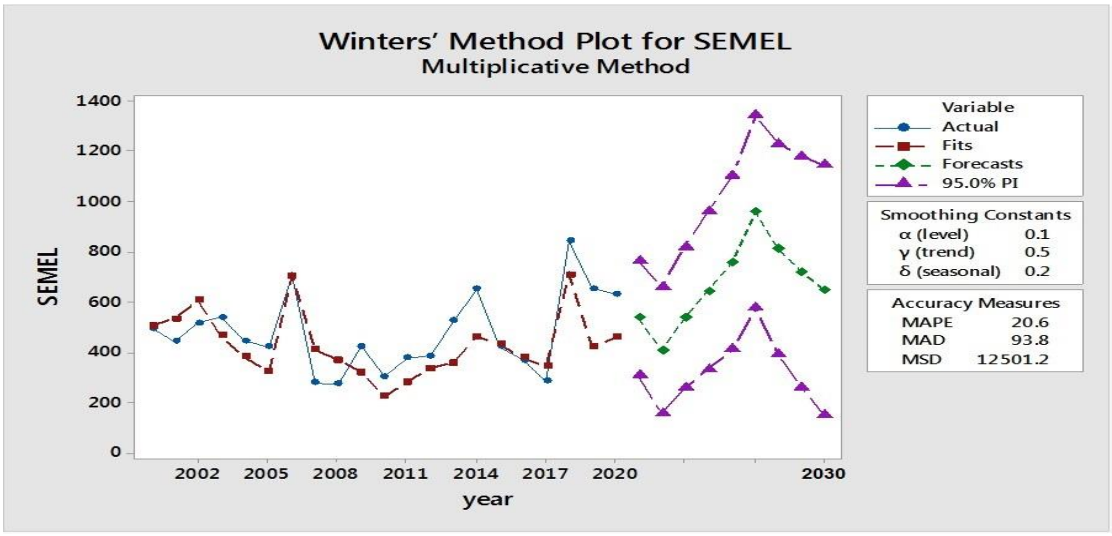
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 35)

Figure 45. Predicted Values of the Amount of Rainfall by the Multiplication Model at Semel Station

At Semel station, the data have a natural distribution, and the shape of the spread of the resedues with directional values takes a random form around zero. as shown in Figure (46).



Source: From the Researcher's work based on the(Table 35)

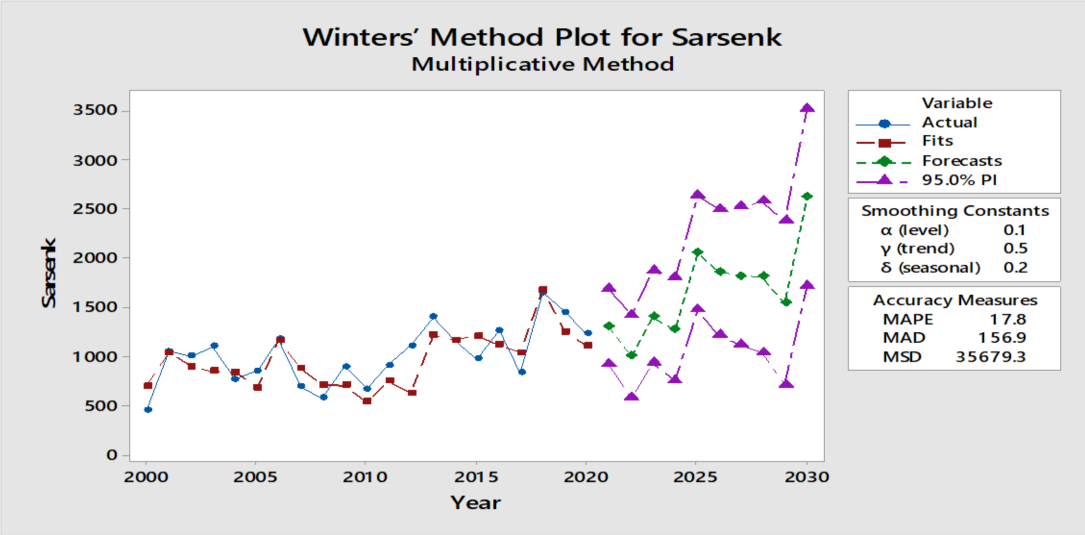
Figure 46. Residues for the Amount of Rainfall for Semel Station

6. Sarsink Station: In the next (9) years, Sarsink predicts the lowest rainfall in (2023) of (1,000.22mm), and the largest amount in (2026) which will be (2055.17mm), as illustrated in Table 36 and Figure 47).

Table 36. Future Forecast of Rainfall at Sarsink Station for 2030

Period	Forecast	Lower	Upper
2022	1299.38	915.12	1683.64
2023	1000.22	576.78	1423.65
2024	1398.12	927.50	1868.74
2025	1274.19	750.53	1797.85
2026	2055.17	1474.22	2636.11
2027	1858.13	1216.78	2499.47
2028	1818.48	1114.42	2522.54
2029	1808.80	1040.28	2577.32
2030	1543.03	708.71	2377.35

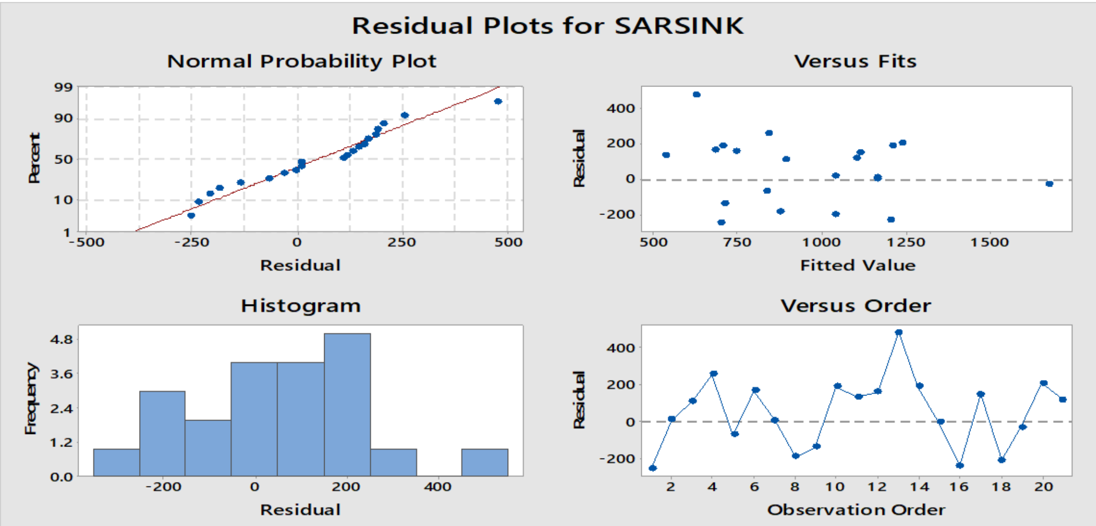
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 36)

Figure 47. Predicted Values of the Amount of Rainfall by the Multiplication Model at Sarsink Station

Figure 48 shows that the data follow a normal distribution at Sarsink station, and that the shape of the spread residues with trend values takes a random shape around zero.



Source: From the Researcher's work based on the (Table 36)

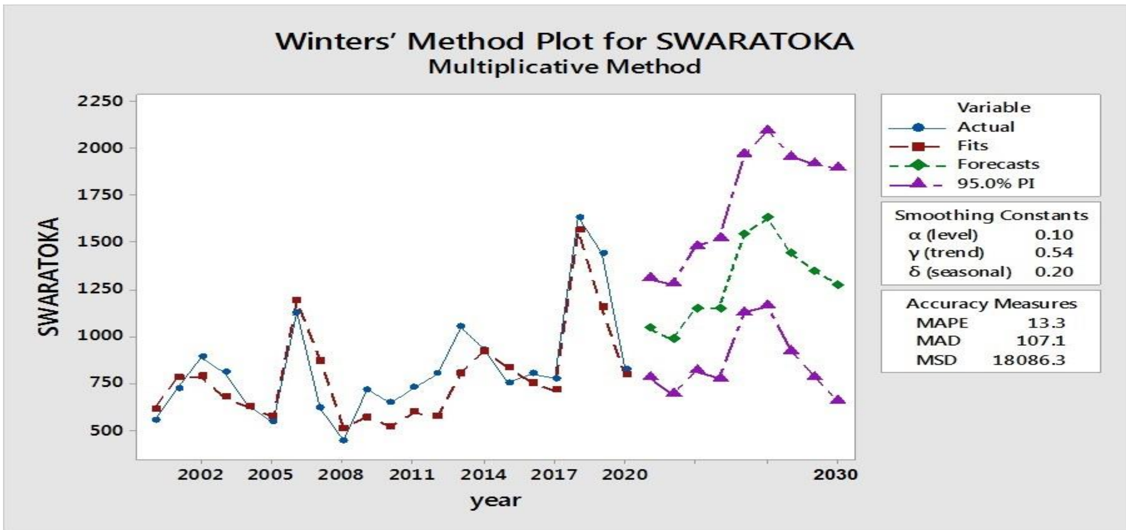
Figure 48. Residues for the Amount of Rainfall for Sarsink station

7. Swaratoka Station: It can be noticed through both Table 37 and Figure 49 that predicted rainfall values for the next (9) years at Swaratoka station would be the lowest amount of rainfall will be recorded in (2023) at (981.13m m) and the largest amount in (2027) by (1627.05mm).

Table 37. Future Forecast of Rainfall at Swaratoka Station for 2030

Period	Forecast	Lower	Upper
2022	1041.38	779.11	1303.66
2023	981.13	687.57	1274.69
2024	1146.64	815.24	1478.05
2025	1146.04	772.21	1519.86
2026	1544.48	1125.05	1963.90
2027	1627.05	1159.77	2094.33
2028	1436.92	920.16	1953.69
2029	1347.50	780.05	1914.96
2030	1271.47	652.42	1890.52

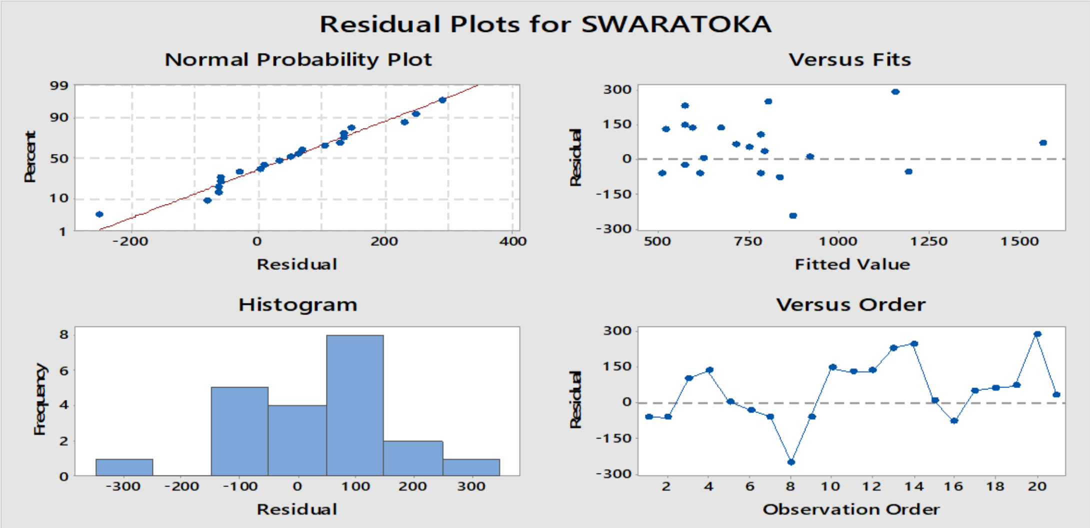
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 37)

Figure 49. Predicted Values of the Amount of Rainfall by the Multiplication Model at Swaratoka Station

The Figure (50) indicates that the data follow normal distribution at Swaratoka, and that the shape of the spread of the resedues with directional values takes a random form around zero.



Source: From the Researcher's work based on the (Table 37)

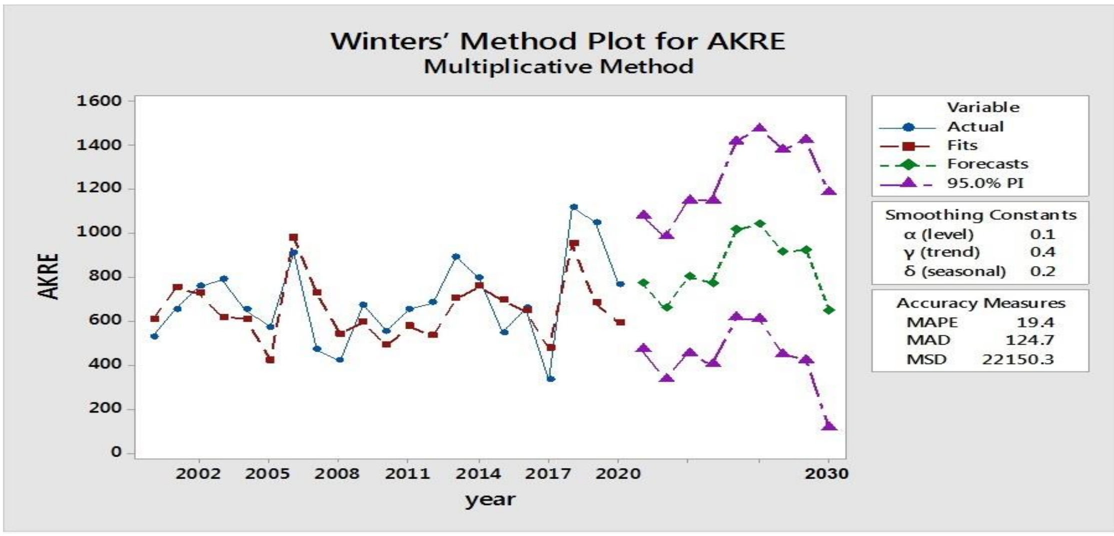
Figure 50. Residues for the Amount of Rainfall for Swaratoka Station

8. Akre Station: Table 38 and Figure 51 show the forecast of the amount of rainfall over the next (9) years at Akre station, where the lowest amount will be recorded in (2023) by (655.34mm) and the largest amount in (2027) by (1038.81 m).

Table 38. Future Forecast of Rainfall at Akre Station for 2030

Period	Forecast	Lower	Upper
2022	770.99	465.506	1076.47
2023	655.34	330.127	980.54
2024	797.84	449.240	1146.44
2025	771.79	396.829	1146.76
2026	1012.59	608.862	1416.32
2027	1038.81	604.403	1473.22
2028	911.81	445.178	1378.43
2029	919.59	419.497	1419.68
2030	644.98	110.413	1179.54

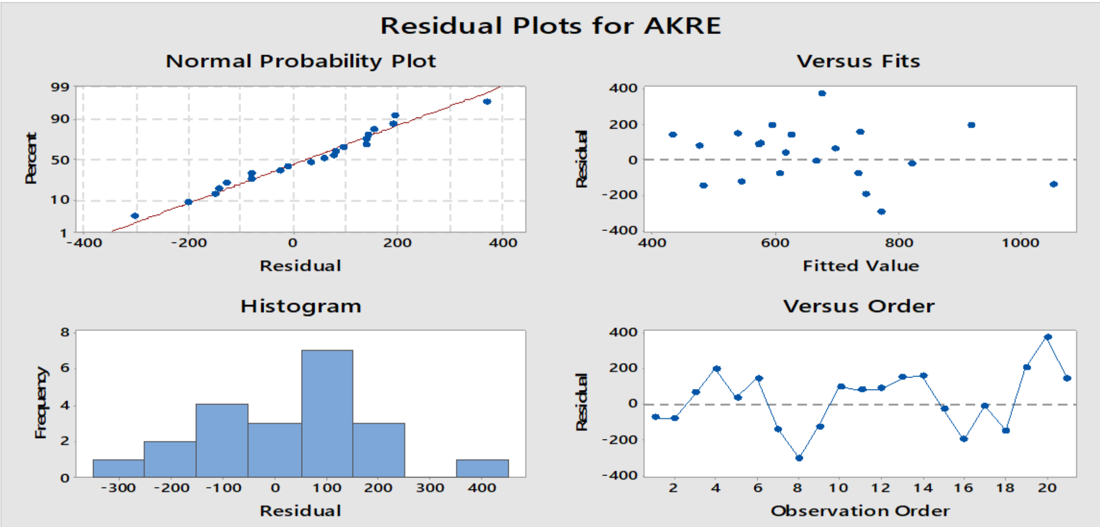
Source: From the researcher’s work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 38)

Figure 51. Predicted Values of the Amount of Rainfall by the Multiplication Model at Akre Station

The data of Akre station show natural distribution, and the shape of the spread of the residues with directional values takes a random form around zero. as seen from in Figure (52).



Source: From the Researcher's work based on the (Table 38)

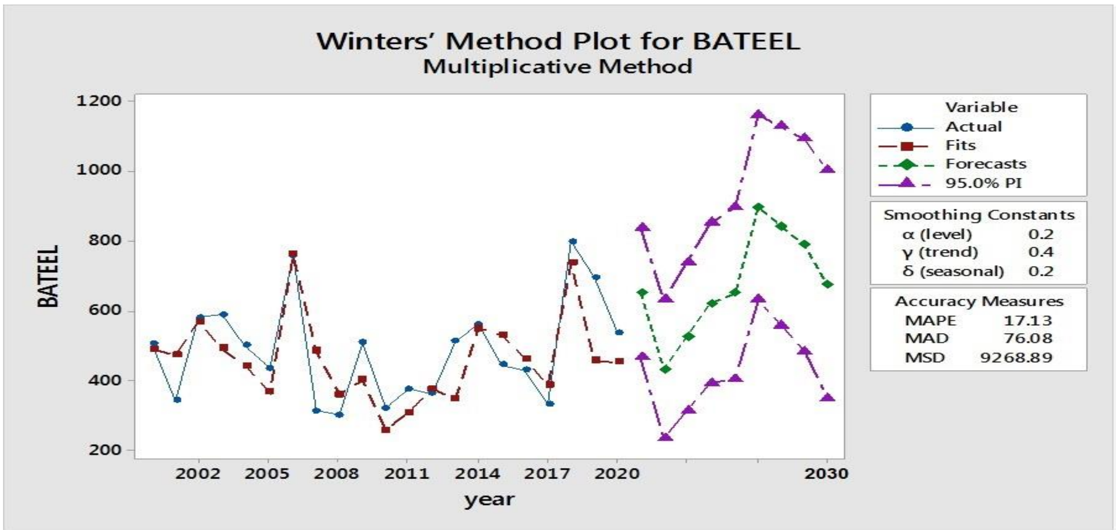
Figure 52. Residues for the Amount of Rainfall for Akre Station

9. Bateel Station: It is clear through Table (39) and Figure (53) that predicted values of rainfall for the next (9) years at Bateel station, will be the lowest in (2023) by (431,422 m) and the largest amount in (2027) by (895.280mm).

Table 39. Future Forecast of Rainfall at Bateel Station for 2030

Period	Forecast	Lower	Upper
2022	650.860	464.472	837.25
2023	431.422	232.997	629.85
2024	525.780	313.084	738.48
2025	621.049	392.265	849.83
2026	650.288	403.955	896.62
2027	895.280	630.227	1160.33
2028	841.323	556.611	1126.04
2029	786.946	481.816	1092.08
2030	673.703	347.538	999.87

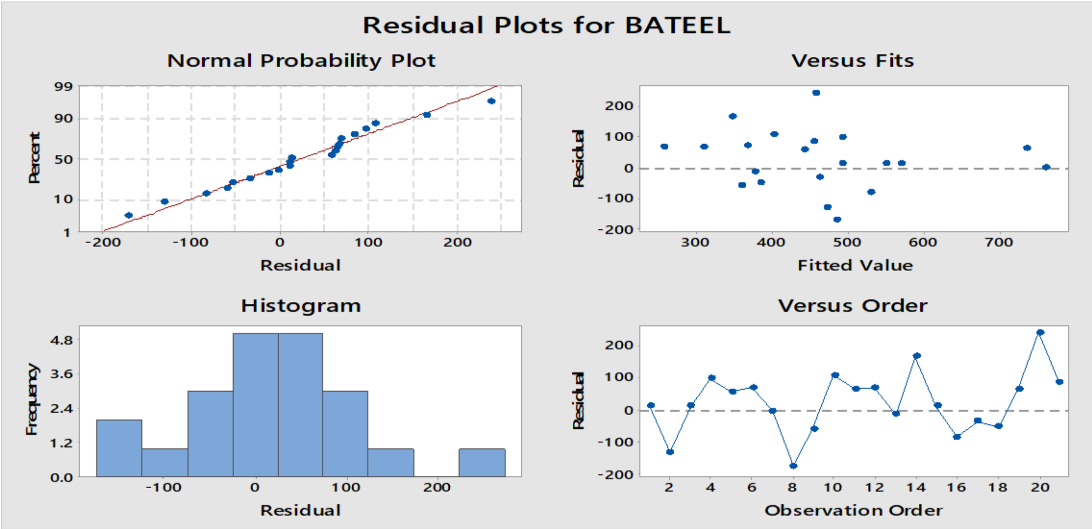
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 39)

Figure 53. Predicted Values of the Amount of Rainfall by the Multiplication Model at Bateel Station

Figure (54) illustrates that the data follow normal distribution at Bateel station and that the shape of the spread of the residues with directional values takes a random form around zero.



Source: From the Researcher's work based on the (Table 39)

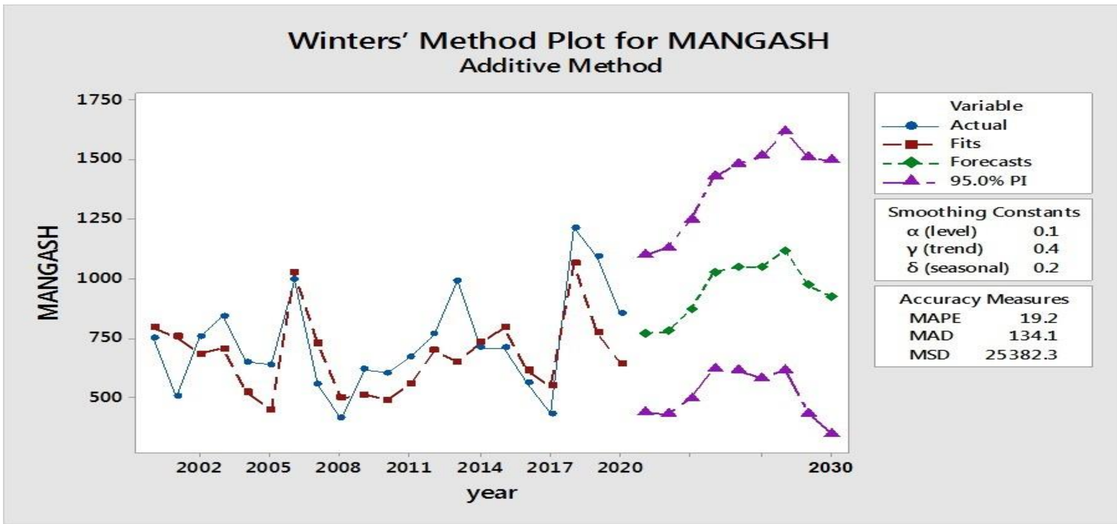
Figure 54. Residues for the Amount of Rainfall for Bateel Station

10. Mangish Station: It is noticed through Table (40) and Figure (55) the predicted values of rainfall for the next (9) years at Mangish station, will be lowest rainfall will be recorded in (2022) by (765.70mm) and the largest amount in (2028) by (1114.56mm).

Table 40. Future Forecast of Rainfall at Mangish Station for 2030

Period	Forecast	Lower	Upper
2022	765.70	437.264	1094.13
2023	775.90	426.258	1125.54
2024	868.14	493.355	1242.93
2025	1022.72	619.579	1425.85
2026	1045.23	611.173	1479.29
2027	1045.29	578.246	1512.34
2028	1114.56	612.870	1616.24
2029	968.31	430.649	1505.98
2030	920.15	345.426	1494.88

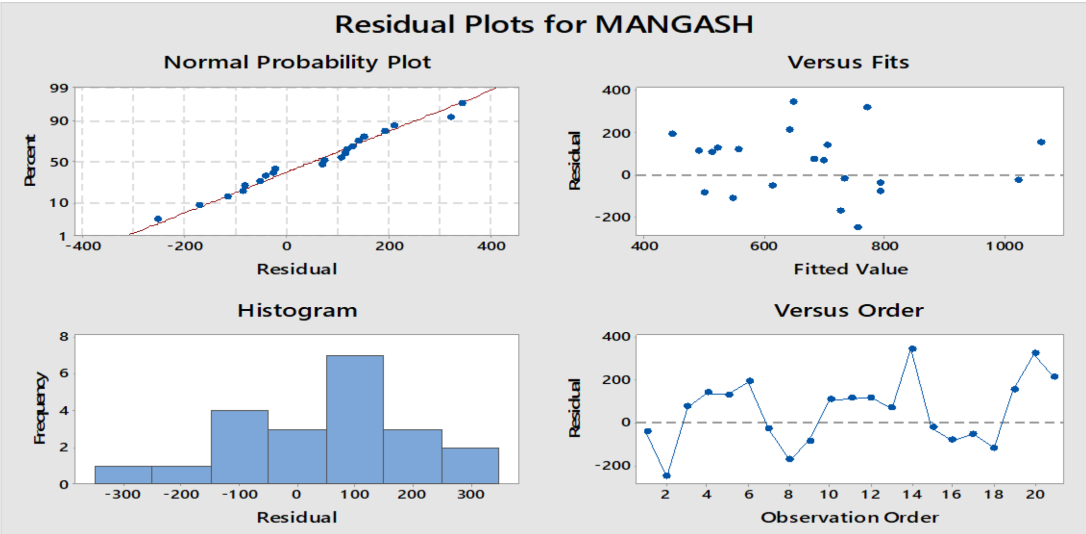
Source: From the researcher’s work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 40)

Figure 55. Predicted Values of the Amount of Rainfall by the Multiplication Model at Mangish Station

The data of Mangish station show that there is a natural distribution, and the shape of the spread of the residues with directional values takes a random form around zero. as shown in the Figure (56).



Source: From the Researcher's work based on the (Table 40)

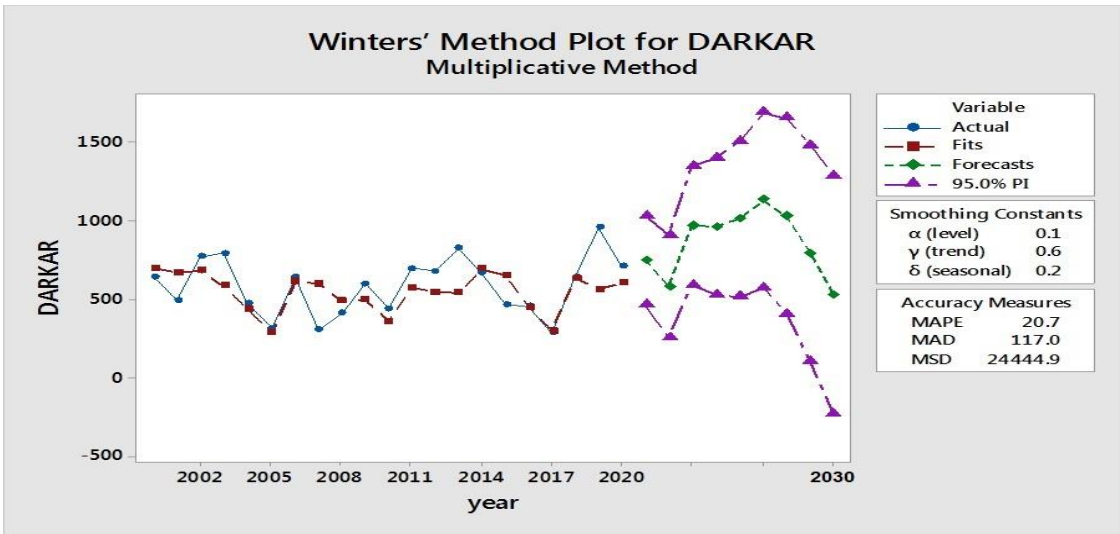
Figure 56. Residues for the Amount of Rainfall for Mangish Station

11. Darkar Station: Through Table (41) and Figure (57), it can be seen that the forecast of the amount of rainfall over the next (9) years at Darkar station shows that the lowest amount will be recorded in (2030) by (530.49mm) and the largest amount in (2027) by (1134.57mm).

Table 41. Future Forecast of Rainfall at Darkar Station for 2030

Period	Forecast	Lower	Upper
2022	749.82	463.264	1036.37
2023	583.27	254.338	912.20
2024	973.34	592.925	1353.75
2025	965.14	527.350	1402.93
2026	1016.24	517.199	1515.29
2027	1134.57	571.662	1697.47
2028	1031.02	402.442	1659.60
2029	793.53	97.976	1489.08
2030	530.49	-232.991	1293.98

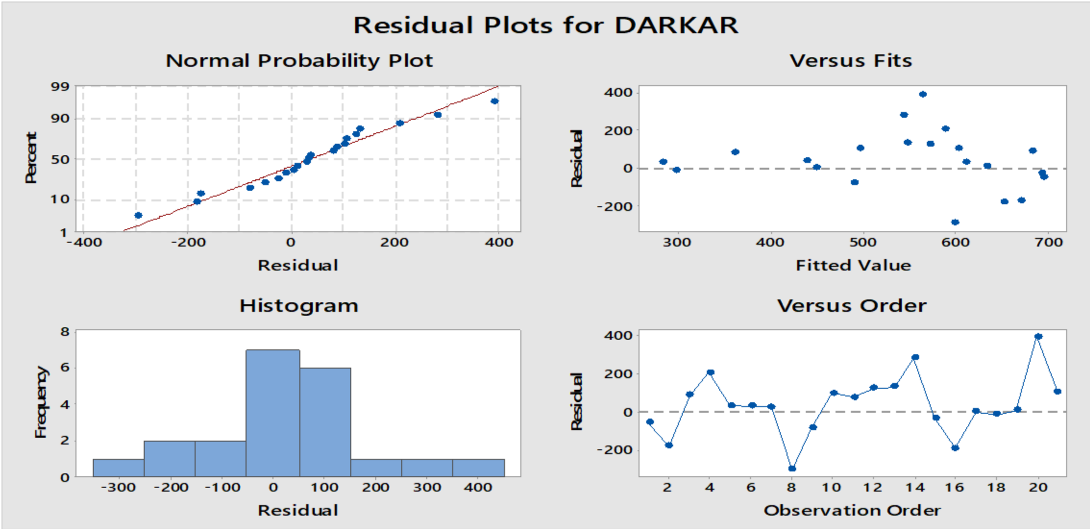
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 41)

Figure 57. Predicted Values of the Amount of Rainfall by the Multiplication Model at Darkar Station

Through Figure (58). It is found that the data follow normal distribution at Darkar station and that the shape of the spread of the residues with directional values takes a random form around zero.



Source: From the Researcher's work based on the (Table 41)

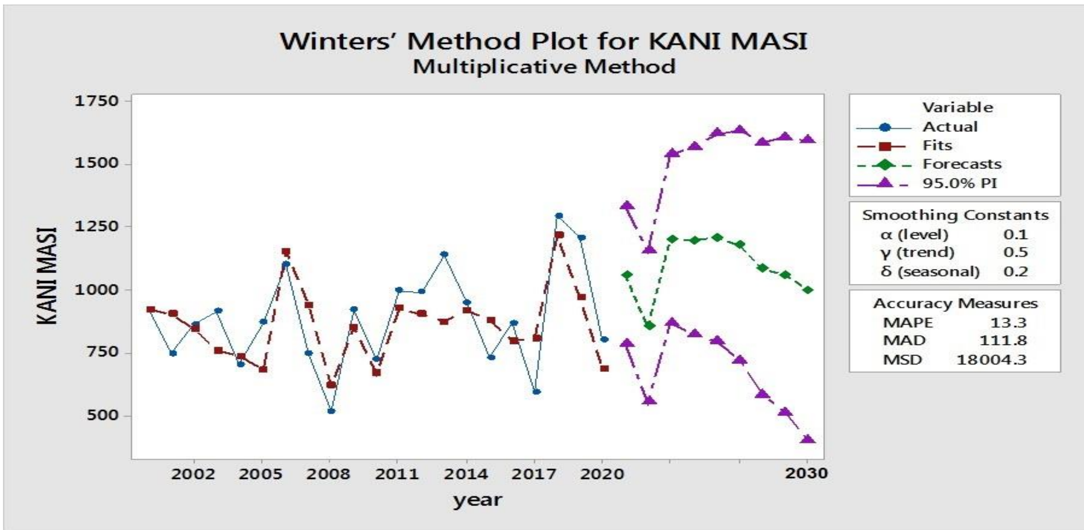
Figure 58. Residues for the Amount of Rainfall for Darkar Station

12. Kani Masi Station: Table (42) and Figure (59) show the predicted values of rainfall for the next (9) years at Kani Masi station, where the lowest rainfall will be recorded in (2023) at (852.48mm) and the largest amount in (2026) by (1206.17mm).

Table 42. Future Forecast of Rainfall at Kani Masi Station for 2030

Period	Forecast	Lower	Upper
2022	1058.90	784.907	1332.90
2023	852.48	550.552	1154.41
2024	1201.74	866.162	1537.31
2025	1195.31	821.920	1568.71
2026	1206.17	791.928	1620.41
2027	1176.24	718.926	1633.55
2028	1082.78	580.756	1584.81
2029	1057.07	509.083	1605.06
2030	997.02	402.112	1591.93

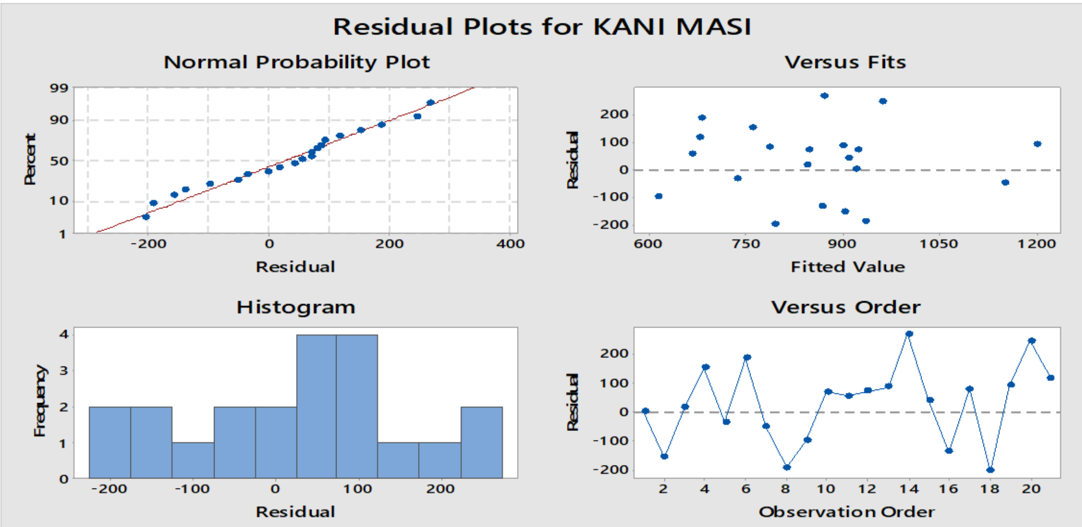
Source: From the researcher’s work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 42)

Figure 59. Predicted Values of the Amount of Rainfall by the Multiplication Model at Kani Masi Station

Figure (60) Confirms that the data show normal distribution at Kani Masi station and that the shape of the spread of the residues with directional values takes a random form around zero.



Source: From the Researcher's work based on the (Table 42)

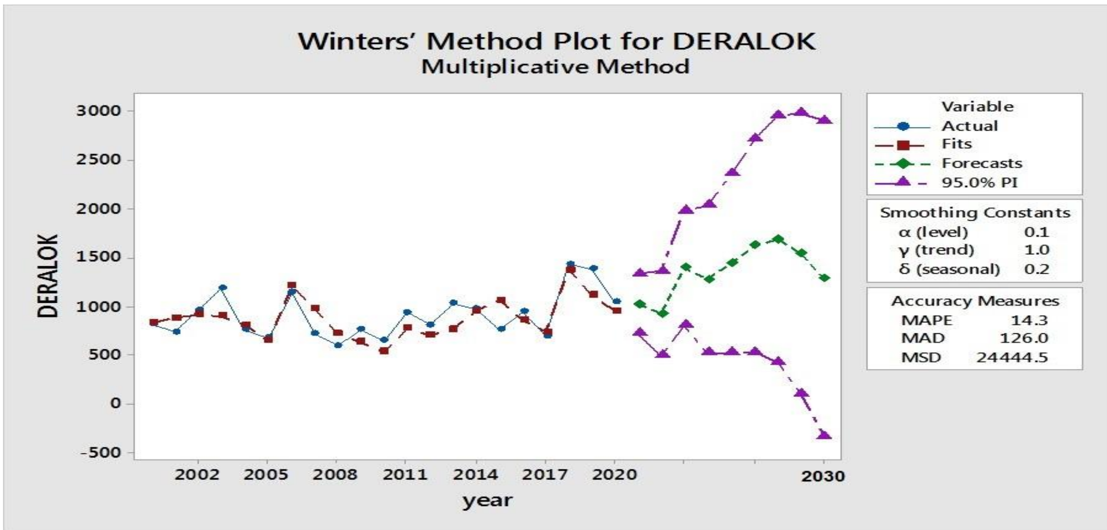
Figure 60. Residues for the Amount of Rainfall for Kani Masi Station

13. Deralok Station: It is noticed in the next (9) years that Derlok station predicts the lowest rainfall in (2023) at (926.23mm), and the largest amount in (2028) at (1693.35 mm) as illustrated in Table (43) and Figure (61).

Table 43. Future Forecast of Rainfall at Deralok Station for 2030

Period	Forecast	Lower	Upper
2022	1025.43	716.759	1334.10
2023	926.23	489.706	1362.76
2024	1397.24	806.175	1988.30
2025	1280.64	524.555	2036.73
2026	1448.35	522.334	2374.36
2027	1628.22	529.655	2726.79
2028	1693.35	420.670	2966.04
2029	1542.46	94.661	2990.26
2030	1285.07	-338.511	2908.66

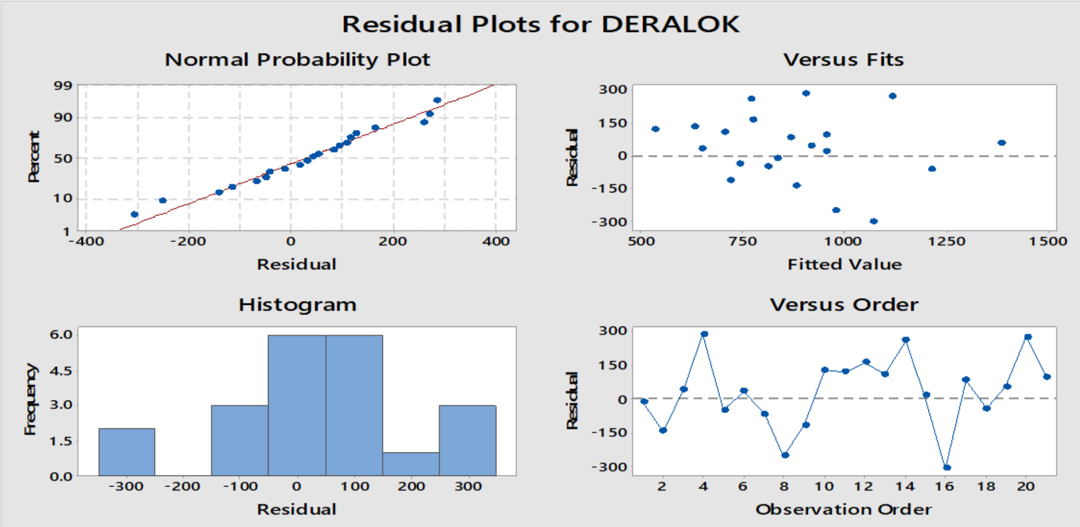
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 43)

Figure 61. Predicted Values of the Amount of Rainfall by the Multiplication Model at Deralok Station

The data show the natural distribution at Deralok station, and the shape of the spread of the residues with directional values takes a random form around zero. as shown in Figure (62).



Source: From the Researcher's work based on the (Table 43)

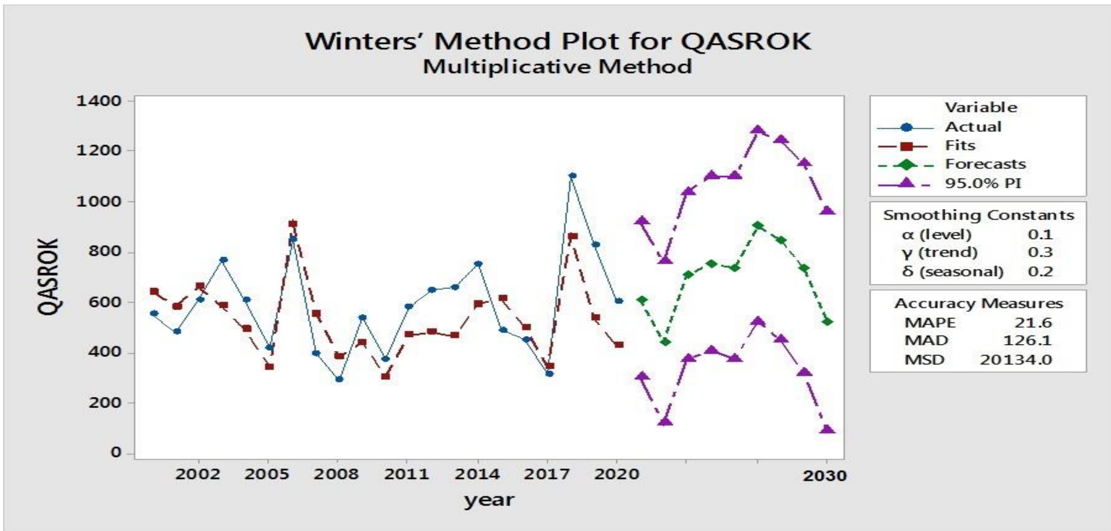
Figure 62. Residues for the Amount of Rainfall of Deralok Station

14. Qasrok Station: Through Table (44) and Figure (63) it is shown that the forecast of the amount of rainfall over the next (9) years at Qasrok station shows that the lowest in (2023) by (437.684 mm) and the largest amount in (2027) by (901.274 mm)**.**

Table 44. Future Forecast of Rainfall at Qasrok Station for 2030

Period	Forecast	Lower	Upper
2022	608.525	299.551	917.50
2023	437.684	117.635	757.73
2024	702.761	369.908	1035.61
2025	751.933	404.739	1099.13
2026	734.912	372.021	1097.80
2027	901.274	521.498	1281.05
2028	843.266	445.570	1240.96
2029	732.410	315.891	1148.93
2030	521.547	85.419	957.67

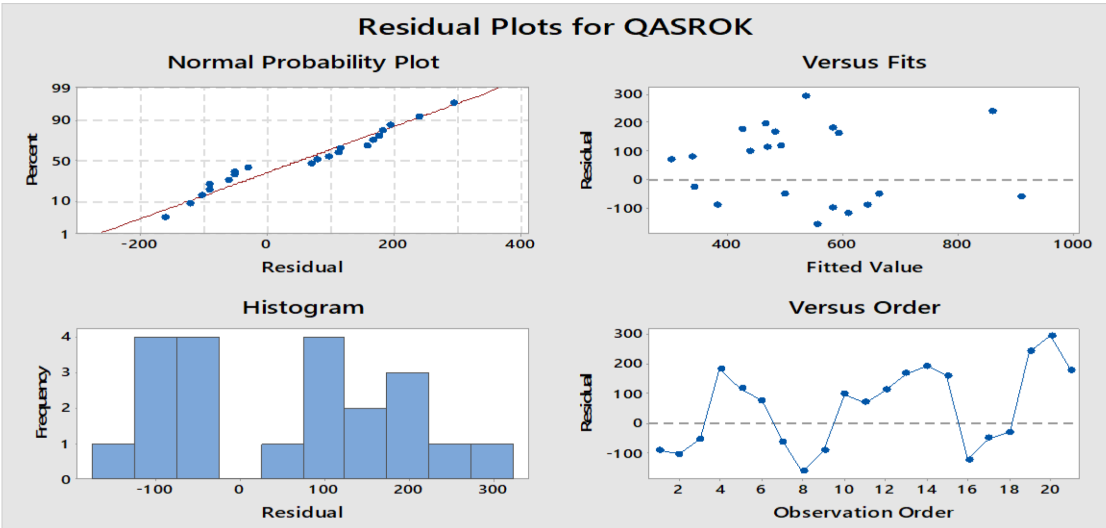
Source: From the researcher’s work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 44)

Figure 63. Predicted Values of the Amount of Rainfall by the Multiplication Model at Qasrok Station

Figure (64) illustrates that the data track is of normal distribution at Qasrok station and that the shape of the spread of the trumpets with directional values takes a random form around zero.



Source: From the Researcher's work based on the Table 44)

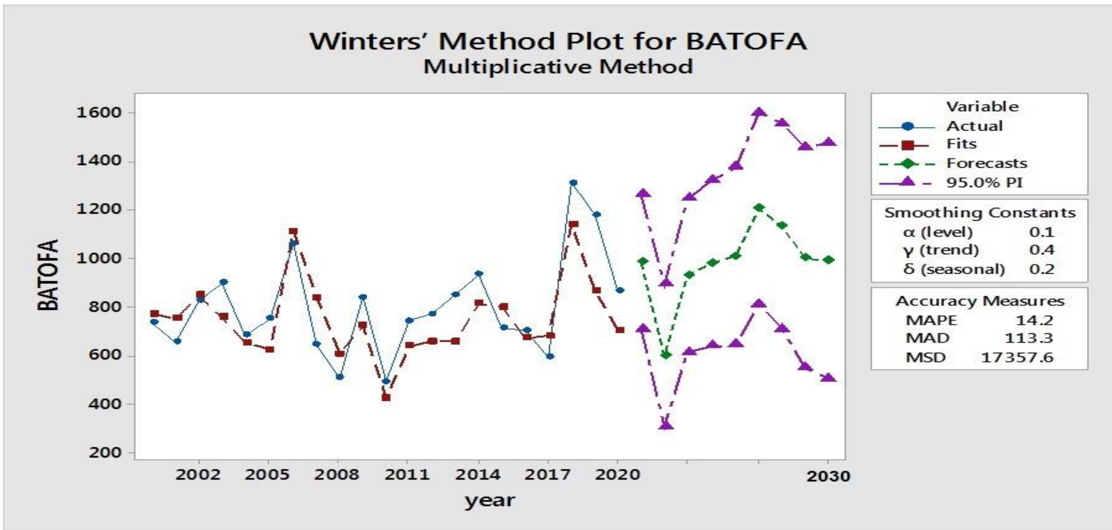
Figure 64. (Residues for the Amount of Rainfall for Qasrok Station

15. Batofa Station: In the next (9) years, Batofa predicts the lowest rainfall in (2023) of (600.35mm), and the largest amount in (2027) at (1207.77 mm), as illustrated in Table (45) and Figure (65).

Table 45. Future Forecast of Rainfall at Batofa Station for 2030

Period	Forecast	Lower	Upper
2022	986.23	708.727	1263.72
2023	600.35	304.926	895.77
2024	930.26	613.597	1246.93
2025	980.10	639.485	1320.72
2026	1011.74	644.995	1378.49
2027	1207.77	813.155	1602.39
2028	1132.61	708.728	1556.50
2029	1002.39	548.107	1456.68
2030	990.43	504.828	1476.03

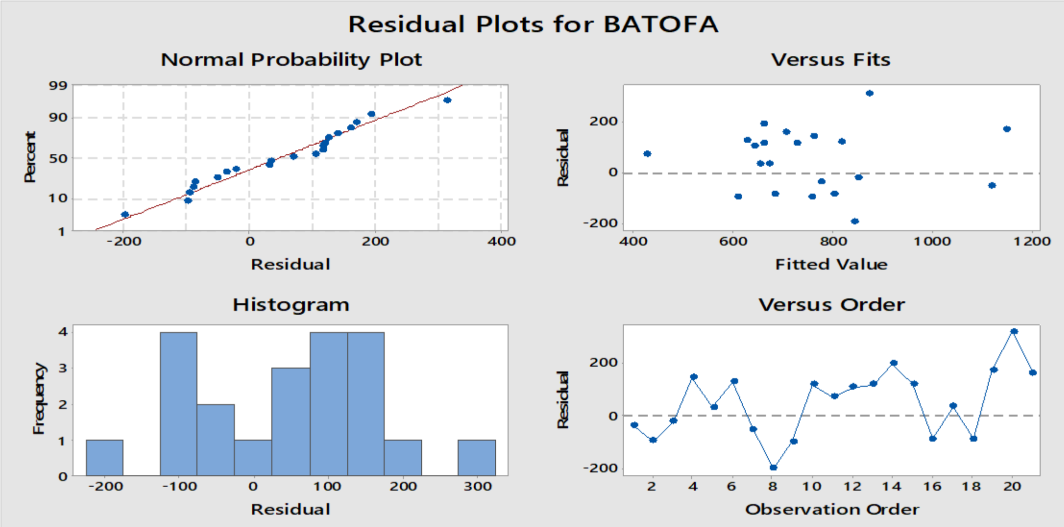
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 45)

Figure 65. Predicted Values of the Amount of Rainfall by the Multiplication Model at Batofa Station

It can be seen through Figure (66) that data follow the normal distribution in Batofa station and that the shape of the spread of the trumpets with directional values takes a random form around zero.



Source: From the Researcher's work based on the (Table 45)

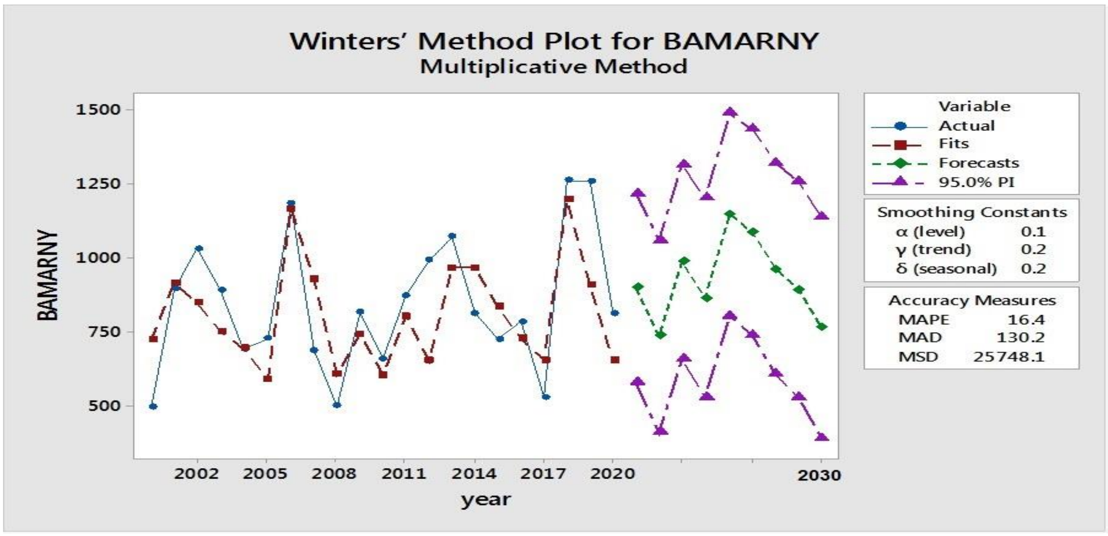
Figure 66. Residues for the amount of Rainfall for Batofa station

16. Bamarny Station: Table (46) and Figure (67) show the forecast of the amount of rainfall over the next (9) years at Bamarny station to be the lowest amount will be recorded in (2023)by (735.82mm) and the largest amount in (2026) by (1147.59mm).

Table 46. Future Forecast of Rainfall at Bamarny Station for 2030

Period	Forecast	Lower	Upper
2022	898.36	579.301	1217.42
2023	735.82	411.764	1059.88
2024	986.76	657.128	1316.39
2025	865.36	529.609	1201.11
2026	1147.59	805.205	1489.98
2027	1085.60	736.087	1435.11
2028	962.97	605.876	1320.06
2029	892.19	527.084	1257.30
2030	763.75	390.226	1137.27

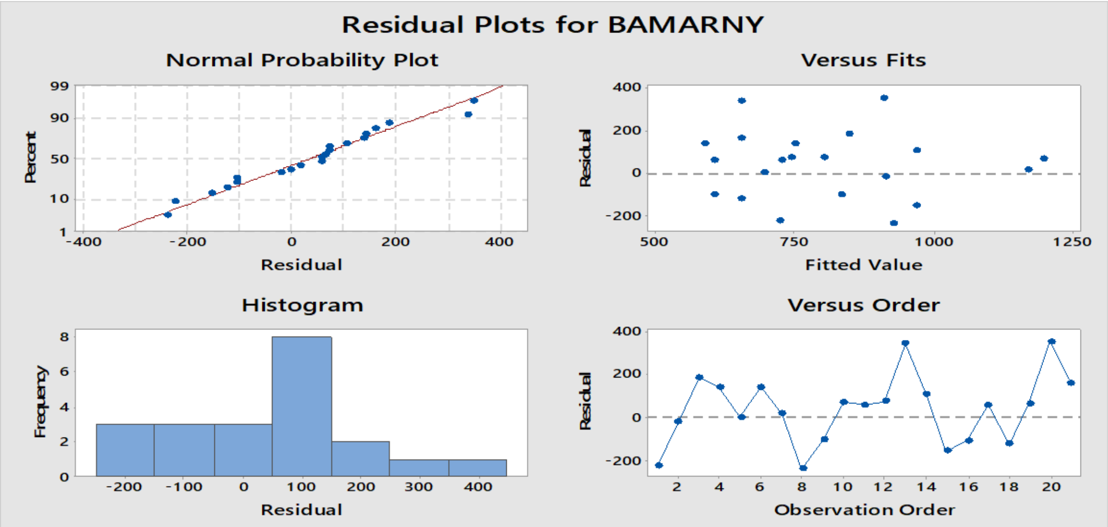
Source: From the researcher’s work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 46)

Figure 67. Predicted Values of the Amount of Rainfall by the Multiplication Model at Bamarny Station

At Bamarny station, the data track shows the natural distribution, and the shape of the spread of the trumpets with directional values takes a random form around zero as can be seen in Figure (68).



Source: From the Researcher's work based on the (Table 46)

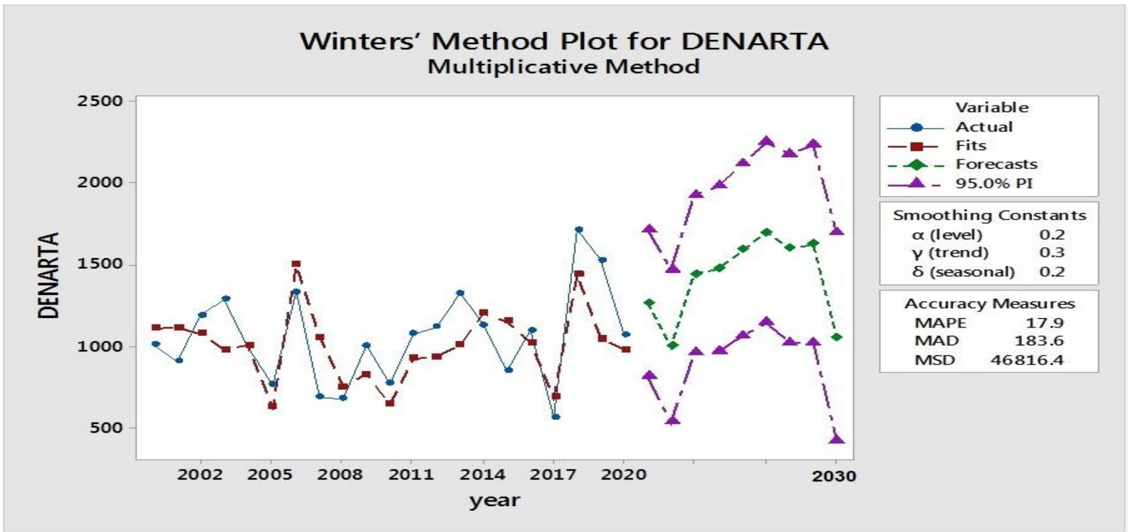
Figure 68. Residues for the Amount of Rainfall for Bamarny Station

17. Denarta Station: The Table (47) and Figure (69) indicate that the forecast of the amount of rainfall over the next (9) years at Denarta station shows the lowest amount in (2023) by (1000.13mm) and the largest amount in (2027) by (1695.60mm).

Table 47. Future Forecast of Rainfall at Denarta Station for 2030

Period	Forecast	Lower	Upper
2022	1263.05	813.31	1712.78
2023	1000.13	534.27	1465.98
2024	1440.26	955.76	1924.75
2025	1471.47	966.10	1976.84
2026	1590.63	1062.41	2118.84
2027	1695.60	1142.81	2248.39
2028	1599.12	1020.24	2177.99
2029	1624.68	1018.41	2230.96
2030	1053.91	419.09	1688.72

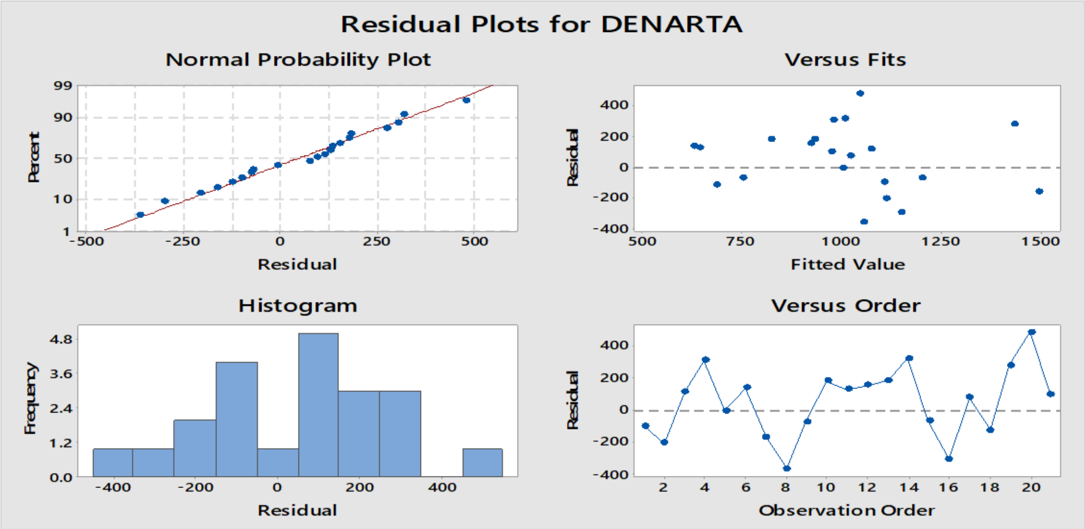
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 47)

Figure 69. Predicted Values of the Amount of Rainfall by the Multiplication Model at Denarta Station

Figure (70) indicates that the data track is of normal distribution in Denarta, and that the shape of the propagation of the trumpet with directional values takes a random form around zero.



Source: From the Researcher's work based on the (Table 47)

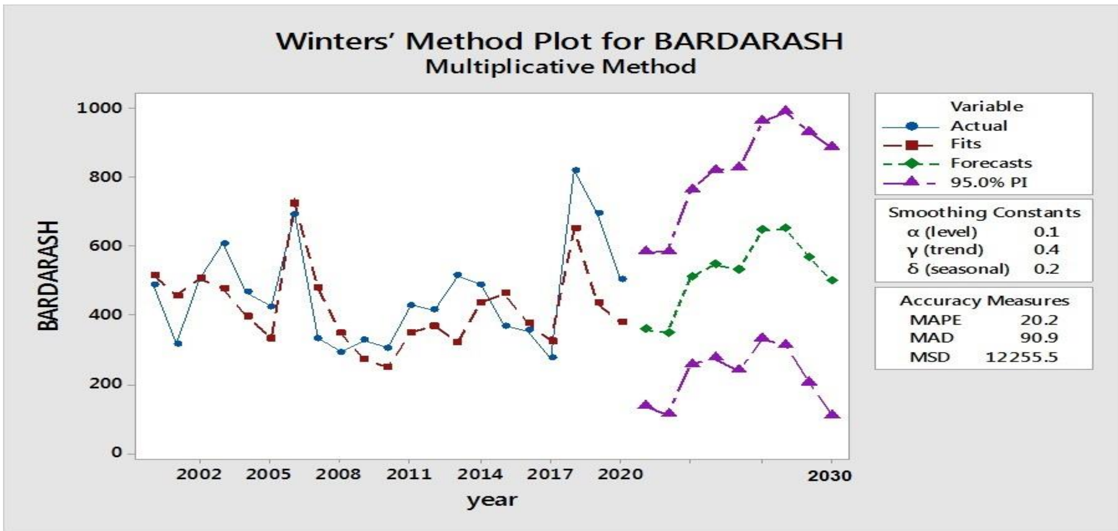
Figure 70. Residues for the Amount of Rainfall for Denarta Station

18. Bardarash Station: Both Table (48) and Figure (71) illustrate that the forecast of the amount of rainfall over the next (9) years at Bardarash station will be the lowest amount in (2023) by (347.728mm) and the largest amount in (2028) by (651.779mm).

Table 48. Future Forecast of Rainfall at Bardarsh Station for 2030

Period	Forecast	Lower	Upper
2022	359.148	136.325	581.970
2023	347.728	110.515	584.940
2024	510.092	255.819	764.366
2025	547.764	274.258	821.270
2026	532.867	238.382	827.353
2027	647.700	330.836	964.565
2028	651.779	311.412	992.146
2029	569.177	204.401	933.953
2030	498.320	108.399	888.242

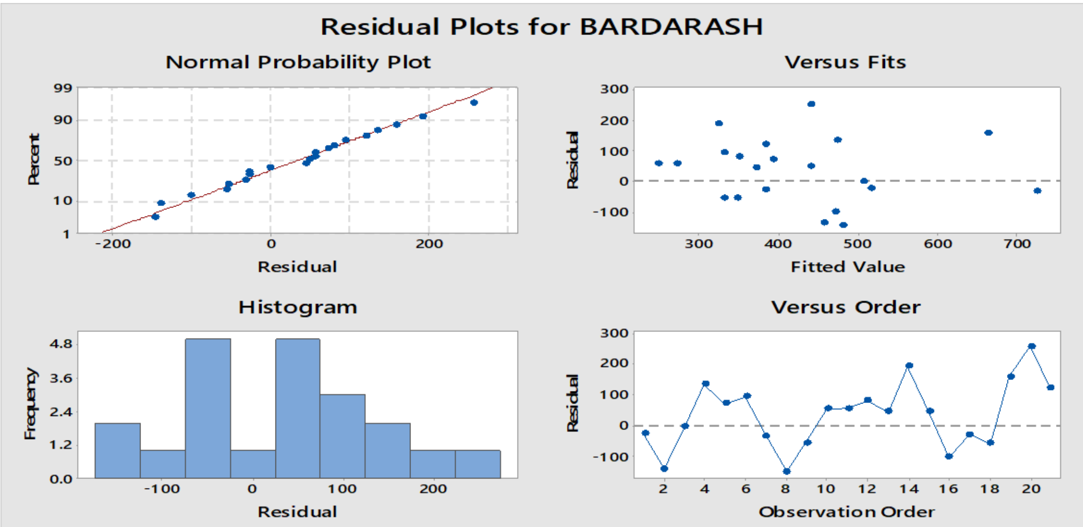
Source: From the researcher’s work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 48)

Figure 71. Predicted Values of the Amount of Rainfall by the Multiplication Model at Bardarsh Station

At Bardarsh station, data track is normally distributed, as well as the shape of the spread of the trumpets with directional values takes a random form around zero as shown in the Figure (72).



Source: From the Researcher's work based on the (Table 48)

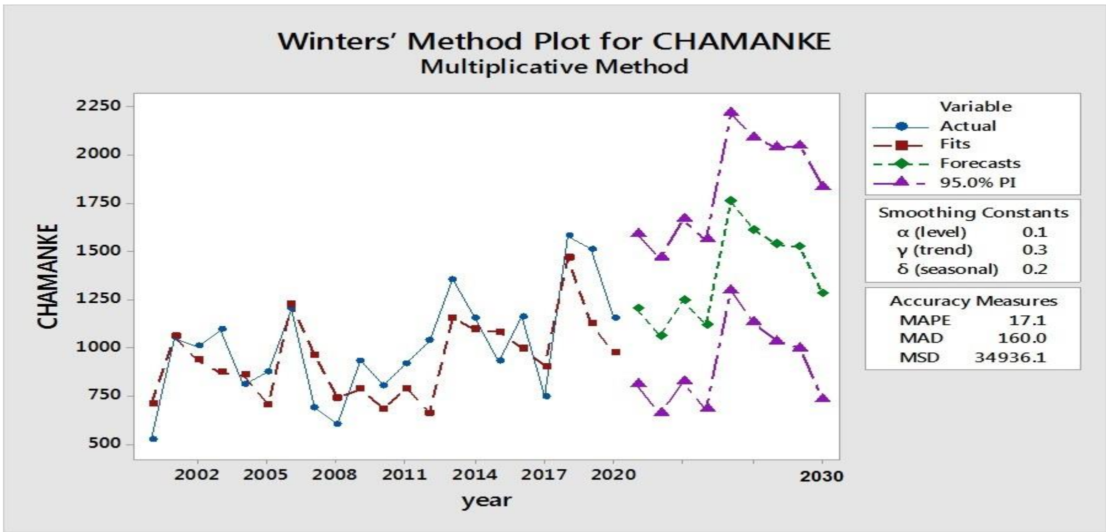
Figure 72. Residues for the Amount of Rainfall for Bardarash Station

19. Chamanke Station: In the next (9) years, Chamanke station predicts the lowest rainfall in (2023) at (1058.88mm), and the largest amount in (2026) will be (1756.95mm), as shown in Table (49) and Figure (73).

Table 49. Future Forecast of Rainfall at Chamanke Station for 2030

Period	Forecast	Lower	Upper
2022	1197.83	805.73	1589.93
2023	1058.88	652.72	1465.03
2024	1241.14	818.74	1663.54
2025	1116.66	676.06	1557.27
2026	1756.95	1296.43	2217.48
2027	1609.27	1127.32	2091.22
2028	1534.70	1030.01	2039.39
2029	1520.86	992.28	2049.44
2030	1278.58	725.12	1832.05

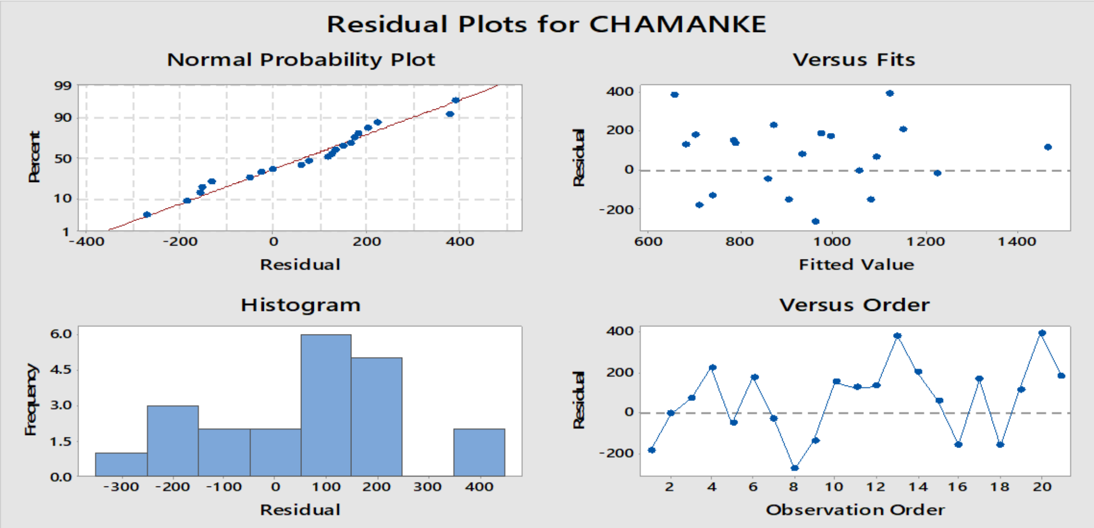
Source: From the researcher's work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 49)

Figure 73. Predicted Values of the Amount of Rainfall by the Multiplication Model at Chamanke Station

Through Figure (74), it can be seen that data track is of normal distribution at Chamanke station and that the shape of the spread of the trumpets with directional values takes a random form around zero.



Source: From the Researcher's work based on the (Table 49)

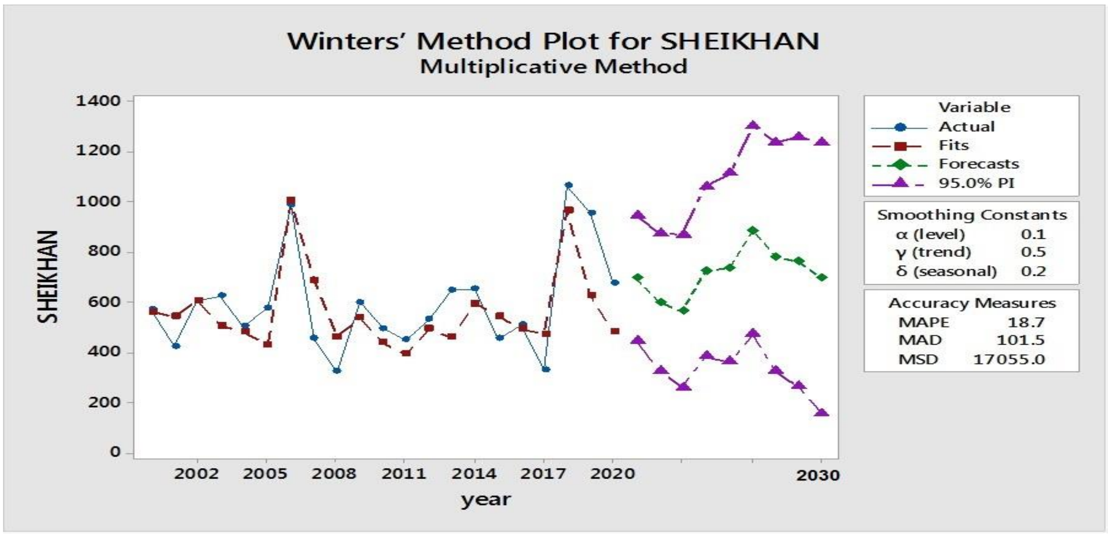
Figure 74. Residues for the Amount of Rainfall for Chamanke Station

20. Sheikhan Station: The Table (50) and Figure (75) show that Sheikhan station predicts that in the next (9) years will record the lowest amount of fall will be in (2024) by (561.693mm) and the largest amount in (2027) by (882.268mm).

Table 50. Future Forecast of Rainfall at Sheikhan Station for 2030

Period	Forecast	Lower	Upper
2022	692.430	443.800	941.06
2023	596.253	322.276	870.23
2024	561.693	257.184	866.20
2025	719.240	380.414	1058.07
2026	734.765	358.872	1110.66
2027	882.268	467.292	1297.24
2028	776.915	321.362	1232.47
2029	757.557	260.296	1254.82
2030	692.699	152.863	1232.54

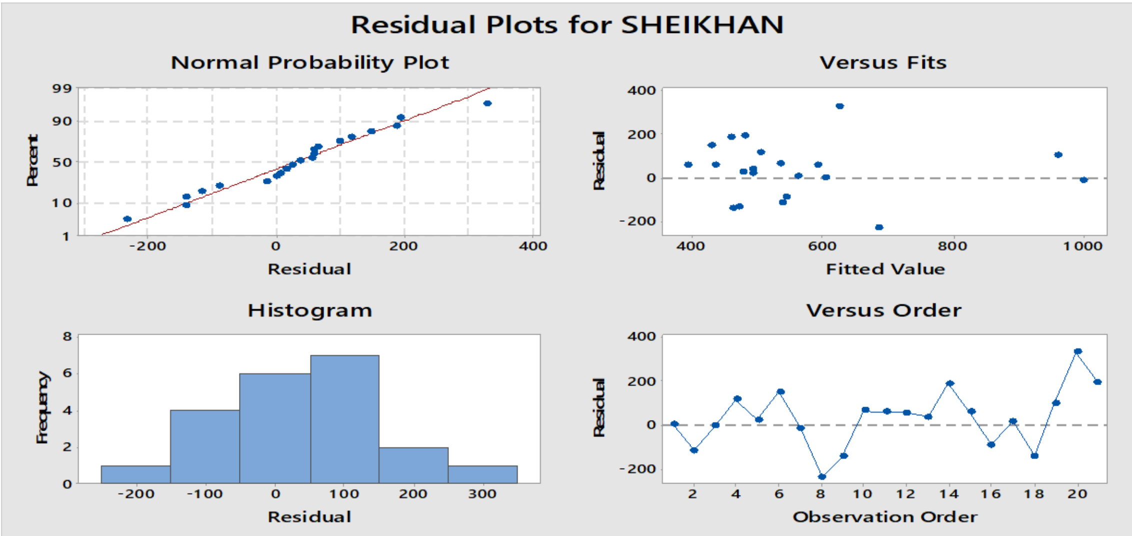
Source: From the researcher’s work based on (Appendix 12)



Source: From the Researcher's work based on the (Table 50)

Figure 75. Predicted Values of the Amount of Rainfall by the Multiplication Model at Sheikhan Station

The data track from Sheikhan station shows there is a natural distribution, and the shape of the spread of the trumpets with directional values takes a random form around zero. as described in the Figure (76).



Source : From the Researcher's Work Based on the (Table 50)

Figure 76. Residues for the Amount of Rainfall for Sheikhan Station

5. RESULTS, DISCUSSION AND RECOMMENDATIONS

5.1. Result and Discussion

Depending on 20 stations in Duhok Governorate, the data of the annual and seasonal average precipitation for a specified period covering the years 2000-2020 were examined and the results were given as follows:

The geographical and astronomical location of the study area made it vulnerable to marine influences coming primarily from the Mediterranean Sea and second ally from the Arabian Gulf (Ismael, 1994), through the frontal Mediterranean low pressures coming from the west within the Mediterranean and the Atlantic Ocean as they are the main source of precipitation in the study area. There is a strong direct relationship between the variable of location and distance from the sea with the variable of rainfall in the study area, where the value of their correlation coefficient reached (0.514 *) and (0.527 *), both of which are statistically significant at a level of less than (0.05).

During this study, it was found that the topography of the study area had a clear effect on the amount of rainfall at the monthly and seasonal levels, as it was confirmed that the high amount of rain was falling on the mountainous stations of the study area, but the lower southern stations dis not receive the same amount of rainfall. It was found that there is a strong directive correlation between the altitude variable and the rainfall variable (Daler Aziz Taha (2013), where the value of the correlation coefficient was (0.573**), which is statistically significant at a level of less than (0.05). Therefore, topography plays an important role in increasing the amount of rainfall as well it is considered one of the most positively related variables at the seasonal and monthly levels (Işik, Bahadir & Cağlak, 2018).

The study area had witnessed a clear temporal fluctuation of the amount of rainfall from year to another between increase and decrease around the general average, where the temporal fluctuation in the rainfall average recorded a high rate for some years and a law rate for others (Ibrahim, 2012). This negatively affected the various life activities, as the annual average of the amount of rain falling in Duhok

Governorate was approximately (739.8 mm) for the time period (2000-2020) with an upward trend reached (11.102x).

It is evident through the use of the coefficient of change that drought conditions prevailed during (12) rainy seasons out of the total (21) rainy seasons, i.e. (57%) during the study period. This affected human activity and negatively affected groundwater in general and the agricultural sector in particular, especially in the study area, as it depends on rain-fed agriculture. This led to the displacement of the population from the agricultural potential to other places to live. The positive change coefficient reached its highest rate during the rainy season (2018), where this season was characterized by the amount of rain that exceeded the general average by (62.69%). Whereas the negative change coefficient reached its highest rate during the rainy season (2008), as this season was characterized by a decreased amount of rain than the general average by (-38.99%).

It is clear from the study of the triple and five moving averages that there were periods of increasing and decreasing amounts of rain, which were irregular periods, that the direction of the rain regression line for the monthly averages of rainfall in Duhok governorate during the study period (2000-2020) was heading towards the rise except for the month (January- February) where the gradient line of rainfall in them was heading downward.

The total average of the spatial variation of the amount of rainfall in Duhok governorate ranged around (739.88 mm) during the study period which was (21) years. Due to its height above sea level,the study area was exposed to the air masses accompanying moisture-rich low pressures. On the other hand, we found that the stations located in the plain areas witnesed a noticeable decrease in the monthly averages of rainfall.

The result of the relationship between the rainfall variable and other climatic elements (temperature, humidity, and atmospheric pressure) showed that there was an mid-direct correlation between the rainfall variable and the temperature variable, as the correlation value was (0.228), which was not statistically significant due to the effect of the distance factor between the study area and the neighboring water bodies. There was a strong direct correlation between the rainfall variable and the humidity variable, whose correlation value reached (**0.790) with statistical significance at a level of less than (0.01). There was a weak direct correlation between the rainfall variable and the atmospheric pressure variable, where it reached (0.403) due to the terrain factor, in which the atmospheric pressure decreases as we rise to the top.

By applying the statistical Mann kendall equation to rainfall data in all stations of the governorate for the period (2000-2020), a fluctuation value appeared in most stations that tend to rise. In addition, there were three stations that had a fluctuation of realistic and continuous rate of 95%, they were (Sersink, Swaratoka and Chamanke), while the rest of the stations of the fluctuation process tended to rise.

The general trend of time series for future rainfall prediction in the study area is using the Holt Winters seasonal method based on the multiplication seasonal model. This model indicates a continuous increase in the amount of rainfall during the period (2022-2030) and during this period the year (2027) will be more rainy, and the year (2023) less rainy according to the amount of rainfall.

5.2. Recommendations

1. Founding several meteorological stations in all parts of the governorate to facilitate the search process.

2. Using modern instruments and methods in as well as to providing advanced tools to read all climatic elements continuously and correctly, and updating the equipment of constantly in order to obtain accurate and correct readings to give correct results.

3. Building a climatic database including all governorate stations for the longest possible period, in addition to updating it contentiously , considering that rainfall is the most important climatic element and has the most impact on man and his various activities.

4. Paying attention to water harvesting projects in the governorate, since the results of the study indicated that there was a trend towards an increase in the amount of rain, in order to get benefit from the rain falling on the governorate.

5. Creating integration and cooperation between the Meteorological in northern Iraq and the meteorological authorities in all the governorates of Iraq in order to serve

projects and research that study the region, particularly in the stations that are close and complementary to one another.

REFERENCES

Abdel Ahad, M. Younis and Nadwa…. (2012), Predicting the Quantity of Sales for a Medical Product Using Triple Exponential Smoothing Method, (in Arabic), *Journal of Education and Science*, Iraq, Volume 25, Issue 4.

Abdelbaqi, F. Kh. (2001), *Phenomenology of the Upper Atmospheric Layers and Their Impact on Forming and Drafting the Climate of Iraq*, (Ph.D. thesis unpublished, in Arabic), College of Arts, University of Baghdad, p. 61.

Abed, H. F. (2015), A Geographical Analysis of the Weather Conditions in Iraq, (in Arabic), *Journal of Geographical Research*, University of Karbala, Volume 5, Issue One, p. 2.

Aboud, M. N. (2005), *A Geographical Analysis of Climate Variation Between Al-Hayy, Al-Najaf and Al-Nukhayb Stations*, (MSc research Unpublished, in Arabic), College of Arts, University of Al-Qadisiyah, p. 39.

Abu radi, F. A. (2004), *Foundations of Climatological and Plant Geography*, (in Arabic), The Renaissance, Dar Al-Arabiya, Beirut, Lebanon, 1,155.

Abdulrahman, M.A. (2016), The cold polar air mass affecting the weather and climate of Iraq, Al-Mustansiriya University, College of Education, *Journal of Arts*, No. 118, pg. 462.

Alalusy, D. S. I. (2009). *Elements and Phenomena of Iraq's Climate, Their Modern Characteristics and Trends*, (MSc research Unpublished, in Arabic), University of Baghdad, p. 27-131.

Alani, H. T, and Wali M. S. (1984), *Weather Maps and Weather Forecasting*, (in Arabic), Basra,p. 11.

Alasadi, K. A-W. (1991), *The Recurrence of Atmospheric Depressions and Their Impact on Iraq's Weather*, (MSc research Unpublished, in Arabic), University of Basra, College of Arts,p. 9-12.

Aldowri, Q. Y. J. (2002), *Climate Change in the Semi-Mountainous Region in Iraq and its Impact on the Productivity of Wheat and Barley*, (MSc research Unpublished, in Arabic), Department of Geography, College of Education, Tikrit University, p. 27.

Aljawhari, Y. (1978), Climatic Geography, (in Arabic), Alexandria, *University Youth Foundation for Publishing and Distribution*, p. 117.

Aljburi, A. N. M. (2002), *A Geographical Analysis of the Elements of Climate and some Weather Phenomena in Salah Al-din Governorate*, (MSc research Unpublished, in Arabic), Tikrit University, College of Education ,p. 32.

Aljubouri, S. (2019), Geographical Analysis of the Rainfall Characteristics of the City of Kirkuk, *The Researcher Magazine*, College of Education for Human Sciences, University of Karbala, No. Tenth, 4102, p. 17

AlKinani, N. Kh. (2005), *A Temporal and Spatial Analysis of the Characteristics of the Falling Rain and its Time Series in Iraq To Predict Drought Years*, (MSc research, in Arabic), Kufa University, p. 11.

AlLouh, H. K. (2017), *The Temporal and Spatial Fluctuation of Rain in the West Bank and Gaza Strip During the Period (1995- 2014)*, (MSc research, in Arabic), Islamic University - Gaza, College of Education, p. 52-64.

Almaliki, A. N. (2009), A Computerized Prediction of the Amount of Rainfall in Iran for the Period (2004-2033*)*, *Iranian Studies Journal*, p. 33.

Alnajmawi, S. B. (2008), *The Spatial Correlation of Precipitation North of Latitude (35) in Iraq*, (PhD thesis, in Arabic), University of Mosul, p. 15-56.

Al Naqshabandi, A, M. Amin, Muhammad, S,M. (1980), Introduction to Tourist Geography with an Applied Study on Iraq, (in Arabic), University of Baghdad, p. 104.

Alqshtini, B. I. (1998), Temporal and Spatial Distribution of Rain in Iraq, (in Arabic*), Journal of the Geographical Society*, No. 37, 20.

AlRubaie, SH. A. M. (2000), *Air Altitudes in the Climate of Iraq*, (MSc research Unpublished, in Arabic), University of Baghdad, College of Education, p. 71.

Alsamarayi, Q. (2008), *Climate and Climatic Regions*. (in Arabic), Jordan, Amman: Elisori House for Publishing and Distribution, p. 28.

Alsamarayi, Q. M, Ahlam .J, and Huda. A. S. (1995) Cold Waves in Iraq, An Applied Study in the Climate of Iraq, (in Arabic), *Journal of the Iraqi Geographical Society*, Issue of 29, p. 82.

Alsamarayi, Q. M. (2008), *Principles of Weather and Climate*, (in Arabic), Amman, Jordan, Dar Al-Yazuri for Publishing and Distribution, p. 28-147.

Alsamarayi, Q. M. and Jiwan , S. A. (2008), The Effect of the Rise in the Amount of Rain Falling on Northern Iraq, *Research presented at the Ninth Conference of the Iraqi Geographical Society*, (in Arabic), Baghdad. p. 805.

Al-Shalash, A. H. (1988), *Iraq's Climate*, Translated by Majid Al-Sayyid Wali and Abdul-Ilah Razuki Karbel, Basra University Press, College of Arts. p13.

AlShaaeir, J. A. (2005), Climate Geography (Studies in Regional Climate), (in Arabic), Cooperative Society for Printing, *Damascus University Publications*, p. 26.

Alsoul, A-B. A. S. (2007). *Fluctuation and Variation in Rainfall Rates in the Popularity of Misurata and the Possibility of Exploiting It*, (MSc research, in Arabic), Seventh of October University, p. 89.

Alsumidai, A. G. Kh. (2004), *Modeling Winter Rainfall in the Mountainous Region of Iraq Using Remote Sensing Data*, (MSc research, in Arabic), Tikrit University, p. 11-17.

Alsultan, G. J. (1986), *The Atmosphere, Its Elements and Its Volatility*, (in Arabic), Freedom House for Printing, Baghdad, pp. 347-348.

Al-Tahir, M., Chong, Y. and Zhang, Q. (2010). Statistical Properties of the Temperature, Relative Humidity, and Solar Radiation in the Blue Nile-Eastern Sudan Region, Theoretical and Applied Climatology Jornal 101(3):397-409.

Altawil, S. A. Kh, (2018), *Determining and Analyzing the Rain Concentration in Northern Iraq for the Period (1979-2014)*, (MSc research, in Arabic), University of Mosul, 8.

Anthes.A, (1977), *The Atmosphere*, 3rd Edition Merriall Publishing Company Colluminus , p. 187 .

Awad Allah, Kh. J, (2016), ‹*Using SARIMA and Holt-Winters Models to Forecast Seasonal Time Series*, (MSc research, in Arabic), Al-Azhar University – Gaza,p. 39.

Barry, R. G. and Richard J. C, Atmosphere, Weather and Climate, Eight Edition, *Rout ledge. Taylor and Francis Group*, London and New York, pp .103-184.

Bonfils K. (2012). Trend Analysis of the Mean Annual Temperature in Rwanda during the Last Fifty Years, Journal of Environmental Protection, 3(6):538-551.

Bulut, H., Yeşilata, B. and Yeşilnacar, M.İ. (2006). Determining the Effect of Atatürk Dam Lake on the Regional Climate by Trend Analysis. GAP Vol. Engineering Congress, Şanlıurfa, 1,PP. 79 – 86.

Çöleri, M. Yayvan, M. Deniz, A. Turgut, Ü. Eryılmaz, A. Geçer, C. and Güser, A. (2005), *Air Analysis And Forecast Technique*, Ministry of Environment and Forestry, General Directorate of State Meteorology Affairs, Ankara. P. 43.

Coşkun, M. (2003). Concept Misconceptions About Humidity in Geography Teaching and Recommendations for Correction (in Turkish), *Journal of Gazi Education Faculty*, Volume 23, Issue 3, P.151.

Coşkun, M. and Akbaş, V. (2017). From the Black Sea Coast Inland; Climate Parameters of the Kastamonu Environment, (in Turkish). *Journal of Social Sciences*, (11), 46-86.

Coşkun, M. Coşkun, S. and Gözalan, S. (2020). Temperature Inversion Winter Seasonal in Karabuk-Safranbolu Basin: Possible Effects on Natural and Human Environment (Turkey). *Turkish Studies*, 15(1), P. 74.

Coşkun, M. Gözalan, S. Öztekinci, M. and Coşkun, S. (2022). Trends in the Number of Tropical Days - Summer Days in the Susurluk Stream Basin and Modeling Under the RCP 8.5 Scenario, (in Turkish). *Jass Studies- The Journal of Academic Social Science Studies*, 15(89), 343-358.

Coşkun, M. Gözalan, S, Öztekinci. M. and Dündar, Ö. (2020). Trend Analysis of Mean Temperature and Total Precipitation Data for the Susurlok Stream Basin. (in Turkish), *Journal of Academic Social Research*, 0 (49), 24-39.

Coşkun, S. (2020a). Trend Analysis of Average Temperature, Precipitation and Flow Data for the Aras Kura Enclosed Basin (Turkey). (in Turkish), Firat University, *Journal of Social Sciences*, 30 (2), 29-42.

Coşkun, S. (2020b). Trend Analysis Of Painting In Van Lake Closed Basin,(in Turkish). *Journal of Engineering Sciences and Design*, 8(2), 521 – 532.

Coşkun, S. (2020c). Trend Analysis of Evaporation and Flow Data in the Summer Season of the Closed Akarsay Basin. (in Turkish), *Journal of Social Sciences*, 0 (47), 162-177.

Cosun, F. (2008). *Climate in Kahramanmaras Trend Analysis of Chang*, Master's Thesis (in Turkish), Kahramanmaras Sutçü Imam University, Social Sciences Institute, P. 44.

Danielson, E. W, Levin. J.and Abrams. E, *Meteorology*, McGraw Hill, U.S.A , p. 226.

Gabler, R. E., Robert. J. S, Daniel. L and Wise, *Physical Geography*, Fifth Edition, Saunders Golden Sunburst Series, U.S.A, p. 174.

Ghanem, A (2001). Analysis of Rainfall Probabilities in Arid and Semi-Arid Areas in Jordan . *Damascus University Journal of Arts and Humanities*. 17(2). P. 214-215

Gilbert, R. O. (1987). Statistical Methods for Environmental Pollution Monitoring, Wiley, NY.

Gözalan, S. (2019). *Comparative Trend Analysis of Temperature and Humidity Parameters at Surface Pressure Levels of 850, 700 and 500 hPa: The Case of Turkey*, (Unpublished MA Thesis, in Turkish), Karabuk University Institute of Social Sciences Department.

Hadi, A. S, (2011), *Climate Fluctuation and Its Impact on the Variation of the Boundaries of Climate Regions in Iraq*, (PhD Thesis, in Arabic), University of Baghdad, College of Education for Girls, p. 107.

Hadid, A. S, and Al-Husseini. F. B. (1984), *Climatology*, (in Arabic), Baghdad University Press, Baghdad, p. 75-152.

Hendricks, A. D., (2015).Spatial Precipitation Trends and Effects of Climate Change on Hawaiian Aquifer, Colorado State University,(MSc researchUnpublished), Department of Ecosystem Science and Sustainability.

Hirsch, R. M. and Slack, J. R. (1984). Nonparametric Trend test for Seasonal Data by Sequential Accreditation (in Turkish). *Water Resources Research*, 20(6), 727-732.

Hyndman RJ, Koehler AB, Snyder RD, andGrose, S. (2002). “A State Space Framework for Automatic Forecasting Using Exponential Smoothing Methods” *International Journal of Forecasting*, 18(3), pp. 439–454.

Ibrahim, M. A (2012). *Climate Changes to the Rains of the Egyptian Coasts, a Study in Climatic Geography*, (MSc research Unpublished, in Arabic), Mansoura University. p.5-6

Ibrahim, R, Kh. (2008). *Geographical Analysis of the Climatic Variation Between the Stations of Al-Qaim, Samarra and Khanaqin.* (MSc research Unpublished, in Arabic), Tikrit University, College of Education, p. 16

Işık, F. Bahadır, M and Çağlak, S. (2018), *Essay on the Spatial Distribution of Precipitation in Artvin, Schreiber's formula. (in Turkish), Ondokuz Mayıs University Faculty of Arts and Sciences Department of Geography Ondokuz Mayıs University Institute of Social Sciences.* P. 391.

Ismail, S. Kh. (1994), *Geographical Analysis of Rain Characteristics in Northern Iraq*, (MSc research Unpublished, in Arabic), Salah al-Din University, College of Arts, p. 28-131.

Issa, S. (2006), *Climate Geography*, (in Arabic), 1st Edition, Arab Society Library for Publishing and Distribution, p. 59-60.

Karbel, A. R. and Wali, M. S. (1986). *Weathe and Climatology* (in Arabic), first edition, University of Basra, p. 172-173.

Karbil, I. R, and Wali, M. S. (1988), *Iraq's Climate*, (in Arabic), second edition, University of Basra, p. 187.

Kendall, M.G. (1975). Rank Correlation Methods, 4th edition, Charles Griffin, London.

Khair, S. (2000), *Geography: Its Subject, Curricula, and Objectives*, (in Arabic), House of thought Contemporary, Damascus, p. 59.

Khomsi, K., Mahe G., Tramblay, Y., Sinan, M. and Snoussi M. (2016). Regional Impacts of Global Change: Seasonal Trends in Extreme Rainfall, Run-Off, and Temperature in Two Contrasting Regions of Morocco, Natural Hazard and Earth System Sciences, 16, 1079–1090.

Mahmoud, G. (2010), Improving the Simple Exponential Smoothing Method for Predicting Time Series, (in Arabic), *Iraqi Journal of Statistical Sciences*, No. 18, pp 259-272.

Mahmoud, H. N, (2003), *A Geographical Analysis of the Elements of Climate and some Weather Phenomena in Salah al-Din Governorate*, (MSc research Unpublished, in Arabic), Tikrit University, College of Education, p. 22.

Mann, H. B. (1945). Non-parametric Tests Against Trend, *Econometrica 13*, p. 163-171.

Masoud, B. T. (2015), The General Trend of Rainfall in the Al-Hafara Plain Region. (in Arabic), *The University Journal 2(7)* , p. 224.

Moussa, S. (2005), *The Natural Climate*. (in Arabic), Modern University Office, Alexandria, p. 17.

Murad, B. A. (2020), *Physical Geography of Duhok District*, (in Turkish), Master's Thesis, Van Yüzüncü Yil University, Social Sciences Institute, p. 31.

Mushtahi, A. (2013), The Trend of Change in Rainfall Amounts in the West Bank Between 1997-2008, (in Arabic), *Al-Azhar University Journal*, Human Sciences Series, p. 385.

Özbunar, P. (2019). *Trend analysis of Temperature Parameters of Florya, Sarıyer, Kumköy and Şile (Istanbul) Stations*, (MSc research Unpublished, in Turkish), Karabük University, Department of Geography.

Öztürk, K. (1997*), İstanbul'da Migrenli Bir Grup Hastanın Atakları ile Mevsimler, Meteorolojik Koşullar, Yersel ve Yerötesi Faktörlerin İlişkileri*, (in Turkish), Uzmanlık Tezi, Istanbul Üniversitesi Istanbul Tip Fakültesi. P. 6.

Özvedaner, M, (2007). *Analysis of Turkey's rainfall data trends and their impact on river flows*, (unpublished MA thesis, in Turkish), (Advisor: Associate Professor Dr. Fatih Topaloğlu), Adana: Cukurova University Institute of Science and Technology.

Palani, N. M. R. (2020), The Impact Of El Nino And La Nina On Some Climate Elements At Sulaymaniyah Station In The Kurdistan Region Of Iraq During The Period (2008-2018), *Plant Archives Vol. 20, Supplement 2*, 3922.

Park, C.)2003(, The Environment Principles and Application, Second Edition, *Routle Taylor and France Group*, London and New York, p. 299.

Pielke, R. A., Stohlgren, SR T., Schell, L., Parton W., Doesken, N., Redmond, K. and McKee, T. (2002). Evaluating regional and local trends in temperature: an example from eastern Colorado, USA, International Journal of Climatology, 10.1.002.

Robert E. Gable. James F. Petersen and L. Michael Trapasso,)2004(, *Physical Geography*, seventh Edition, Thomson, Brooks Cole Inc. Canada, pp. 183 – 184.

Salami, A.W., Ikpee, O.D., Ibitoye, A.B. and Oritola, S.F., (2016). Trend Analysis of Hydro-meteorological variables in the Coastal Area of Lagos "using Mann-Kendall's test and Standard Anomaly Index Methods", Journal of Applied Sciences and Environmental Management, Vol. 20, No: 3, 797 -808.

Salmi, T, (2002), Detecting Trends of Annual Values Atmospheric Pollutants Bythe Mann- Kendall Test and Sen's Slope Estimates the Excel Template Application Makesens, *Meteorological Instituted Finnish Meteorological Institute Helsinki*, p. 8-11.

Sharif, A, J. (1998) *Climate of the Erbil Region,* (PhD thesis, in Arabic), Salahaddin University, P. 1.

Sharaf, A. (1985), *Climatological and Plant Geography*, (in Arabic), Egypt, Arab Universities House, Alexandria Book Center, p. 50-78.

Sharaf, M. I. (2006), *Applied Climate Geography,* (in Arabic), University Knowledge House, Faculty of Arts, Alexandria University, p. 157.

Shehadeh, N,)1996(, *Climatic Geography*, (in Arabic), second edition, Wael House for Printing and Publishing, Amman, p. 257.

Shehadeh, N. (1985), The Precipitation Faction in the Eastern Basin of the Mediterranean and Arab Asia, (in Arabic), *Journal of Jordanian Studies for Humanities and Social Sciences,* Volume Twelve, Issue Seven, p. 99-100.

Shehadeh, N. (1988), Instabilities that Jordan is Exposed to During the Rainy Season. (in Arabic), *Journal of Arab Research and Studies,* Cairo, No. (20), p. 266.

Shehadeh, N. (2009), *Climate Science*, (in Arabic), 1st Edition, Jordan, Amman: House Al- Safa Publishing and Distribution, p. 143-161.

Siddiq, A.S. (2009), *Climatic Potentials of Duhok Governorate for Cultivating Grains* (MSc research Unpublished, in Arabic), Introduction to the Council of the Faculty of Social Sciences, Koya University,P .5

Smithson, P. Kenneth, A. Kenneth, A.) 2002 (Fundamentals of the Physical Environment, Third Edition, *Rutledge Taylor and Francis Group,* New York. p. 126.

Soliman, M. M. (2020), *Trend Analysis of Temperature and Precipitation in the Northern Part of Libya*, (PhD thesis), Karabuk University,Institute of Graduate Programs, P.441.441.

Taha, D. A. (2013), *The Climate of Duhok Governorate (a Study in Climatic Geography)*, (MSc research, in Arabic), College of Arts, Salah Al-Din University, Erbil, p. 11-53.

Fisher, W. B.(1950) *The mMiddle East* , International King press, London , 39.

Yılmaz, A. (2018).*Trend Analysis of Temperature and Precipitation Data in Western Black Sea in Turkey*, (MSc research Unpublished, in Turkish), Karabük University, Department of Geography.

Zangana, L. M. M. (1999), *The Location of the Jet Stream and its Impact on Iraq's Depressions and Rains*, (MSc research, in Arabic), University of Baghdad, College of Arts,p. 101.

Zangana, L. M. M. (2008), The Location of the Jet Stream and its Impact on the Depressions and Rains of Iraq, (in Arabic), *North Iraq Center for Strategic Studies, Sulaymaniyah*, p. 100.

INTERNET RESOURCES

URL1: https://acikders.ankara.edu.tr/mod/resource/view.php?id=120490 (Access date: 10.02.2021)

URL2: https://docplayer.biz.tr/37310419-Jaa-atpl-egitimi-meteorolojg.html\ (Access date: 02.05.2021).

URL3: https://stringfixer.com/tr/Cold_front (Access date: 13.07.2021).

URL4: https://akdeniztrkiyedeiklim.wordpress.com/author/demiraymerve071 (Access date: 08.1.2022).

URL5: https://acikders.ankara.edu.tr/mod/resource/view.php?id=2151 (Access date: 14.3.2021).

URL6: http://www.investopedia.com/ (Access date: 15.1.2022).

URL7: http://www.researchconnections.org/ (Access date: 24.07.2021).

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

LIST OF ATTACHMENTS

Month	Altitude(m)	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bardarash	365	91.00	75.09	69.13	48.28	11.69	-	-	-	0.49	24.63	52.75	82.69
Qasrok	400	120.49	96.70	86.50	56.86	15.64	-	-	-	1.07	29.84	67.11	109.90
Zakho	435	110.02	90.42	96.29	72.44	26.29	-	-	-	2.49	36.46	62.93	102.28
Semel	456	91.68	67.35	85.39	53.28	18.56	-	-	-	1.21	21.33	54.20	80.40
Duhok	469	122.97	87.16	93.45	62.78	22.49	-	-	-	1.39	25.91	61.55	99.57
Shekhan	486	126.35	95.37	93.12	58.85	15.88	-	-	-	0.48	28.30	55.39	117.48
Bateel	510	91.67	75.55	82.27	54.12	18.47	-	-	-	0.62	24.92	54.77	82.12
Akre	636	142.00	110.53	109.58	70.60	22.69	-	-	-	2.59	31.93	72.49	121.10
Dinarta	771	226.32	167.64	162.33	99.61	38.22	-	-	-	3.14	58.46	107.34	185.96
Zawita	890	199.70	127.65	126.07	83.36	30.98	-	-	-	3.99	34.34	84.95	153.44
Mangesh	948	147.31	112.62	119.90	76.74	34.85	-	-	-	3.84	34.31	77.71	118.53
Chamanke	1000	219.04	155.12	163.23	108.02	33.64	-	-	-	3.43	48.20	85.36	186.12
Sarsink	1019	208.22	144.85	183.29	114.43	44.19	-	-	-	4.10	50.25	102.59	154.09
Amedi	1202	156.02	115.35	154.25	107.21	38.37	-	-	-	5.28	55.73	87.45	130.34
Swaratoka	1211	156.50	118.58	149.86	90.09	46.42	-	-	-	4.48	41.63	88.74	130.81
Bamarne	1220	164.40	123.95	148.54	109.95	38.64	-	-	-	2.41	43.63	81.93	127.99
Batofa	1300	148.60	133.40	134.83	87.86	35.38	-	-	-	3.79	45.03	79.91	109.90
Kani masi	1340	153.24	122.77	158.47	112.31	44.73	-	-	-	6.02	57.08	91.51	133.93
Deralok	1600	182.40	133.91	157.01	101.38	36.33	-	-	-	5.91	51.87	93.17	143.95
Darkar	1670	110.35	98.82	97.73	70.68	22.59	-	-	-	2.20	34.44	53.94	92.49

Appendix 1. Explain the Topography Monthly Spatial Averages of Rainfall Duhok Governments' Stations Between (2000-2020)

Station	Duhok	Zakho	Amedi	Zawita	Semel	Sarsenk	Swaratoka	Akre	Bateel	Mangesh
2000	606.6	558	894.2	816.4	492.8	444	551	525.4	504.4	749.2
2001	393.6	493	665.5	565.9	439.9	1051.4	720.5	652.1	342.6	500.4
2002	659.7	672	944.6	952.3	516.1	1002.5	886.3	754.4	579.8	752.5
2003	687	683	933.5	951.7	537.1	1098	806.8	784.6	587.9	842.5
2004	511	548	570	705.6	444.8	770	626.2	647	499.1	648
2005	506	521	664.5	710.4	420	850	541.6	569	434.8	634.5
2006	805.3	774	1012	1071	700.1	1172.5	1127.2	909.2	757.9	992.5
2007	412.2	379	740.5	620	276	687	616.1	466.1	312.1	552
2008	370.1	358	579	593.5	271.6	575.5	445	416.4	299.7	410
2009	488	567	788.8	684.6	421.6	893.5	715.5	668.9	508	615
2010	337.9	403	651	561.9	301	666.5	646	550.6	321	601
2011	434	614	973	627.7	376	906	727	650.6	375	670
2012	549.3	572	944	834.8	382.9	1106	798.5	680.3	362.5	764.5
2013	751.7	720	1165	1149	522.1	1402	1049.5	889	511.5	989.6
2014	699.1	722	977	1046	649.5	1165	928	791.8	561.5	707.2
2015	504.3	639	772.2	759.7	418	969.5	751.5	544.1	445.5	707.8
2016	511.1	696	769.2	873.8	367.5	1263.5	800	653.8	428	557.8
2017	358.4	344	544.4	480.1	281.3	832.5	773.7	328.8	331.5	429.6
2018	953	956	1282	1418	841.1	1646.5	1630.9	1114	797	1213.2
2019	909.4	825	1247	1320	653	1447	1439.6	1045	694.5	1090.3
2020	696	613	803.2	1068	631.1	1225.5	823.8	762.8	537.5	850.7
Average Annual Rain	578	603	853	848	474	1008	829	686	485	728

Station	Darkar	KaniMasi	Deralok	Qasrok	Batofa	Bamarne	Denarta	Bardarash	Chamank	Shekhan	Average
2000	642.3	921.4	818.2	551.3	735.2	495.9	1008.2	489	520.2	566.8	644.535
2001	495.3	745.5	738.2	478.3	657	893.8	905.1	316.8	1048.9	423.4	626.375
2002	771.6	861.8	959.6	607.9	825.9	1032.5	1188.7	504.2	1006.4	602.6	804.06
2003	796.6	912.7	1188.2	764.9	900.9	892.4	1285.5	609.3	1089.5	621	848.635
2004	474.4	702.3	761.5	605.8	683.7	693.5	997.4	466	804	502.5	633.04
2005	313.8	869.8	680.8	417.3	751.2	728	764	425.3	873.6	575	612.505
2006	639.7	1098.8	1145	847.5	1063.3	1182	1330.5	692.6	1197.2	984	975.095
2007	302.1	743	723	393.7	643.9	687.5	688.9	332.3	685.1	452.5	535.635
2008	407.8	514.5	601.5	287.8	507.5	500	676.7	292.1	599.5	320	451.305
2009	597.6	918.2	760.2	535.7	840.5	815.5	1003.6	326.3	930.5	598	683.825
2010	439.6	722	651	372.3	495	660	769.5	303.2	801	493.5	537.325
2011	697.7	995.5	938	579.2	744	875	1075.9	428.4	916	447	702.505
2012	679.4	988.5	813.5	647.8	773	992.5	1117.7	415.1	1033.5	528.5	749.205
2013	826.3	1139	1029.5	656.8	851.1	1071.3	1325.8	514.2	1353.5	647	928.17
2014	666.5	950	971.5	751.5	933	812.6	1130.7	489.3	1150	650	837.615
2015	467.1	729.4	759.5	487.6	714	725.6	847.9	368.5	925	453	649.44
2016	453.2	867.2	946.5	448	704.5	784.6	1095.8	354.1	1158.5	508	712.07
2017	285	592.2	699.5	313	592	530.6	564.8	273.2	742	330	481.315
2018	645.3	1292.6	1435	1100	1313	1261.4	1713.3	821.6	1580	1061	1203.73
2019	957.3	1205.8	1388	827.5	1182.5	1259	1527.2	696	1512	953	1108.98
2020	709.5	797	1047.9	600.5	866	813.2	1071	503.7	1152.5	673.2	812.315
Average Annual Rain	584.2	884.15	907.4	584.5	799	843.2	1052	458	1003.8	590	739.9

Appendix 2. Annual Spatiotemporal Averages of Rainfall in the Study Area Between (2000-2020)

Year	Jan	Feb	Mar	Apr	Ma	Sep	Oct	Nov	Dec
2000	172.25	75.7	76.72	40.79	18.21	0.41	27.97	89.29	143.53
2001	143.39	110.58	97.2	48	20.83	0	14.68	42.21	140.5
2002	153.37	93.11	173.96	131.26	15.1	0	25.85	35	171.63
2003	120.33	196.73	188.15	40.51	8	0	49.17	107.71	136.55
2004	150.89	126.23	38.33	83.82	33.88	0	8.92	156.65	28.32
2005	175.5	142.8	68.5	35.7	41.3	0.35	4.61	37.2	101.8
2006	238.7	237.0	55.9	167.3	20.4	0	121.5	59.7	74.5
2007	84.7	133.2	102.7	127.8	21.2	0	2.41	35.8	25.7
2008	100.0	86.0	60.1	3.3	6.8	11.1	35.9	56.2	88.2
2009	8.7	95.4	121.8	56.8	1.6	15.0	55.2	81.4	247.8
2010	151.8	83.5	65.7	55.6	64.0	0.23	6.8	0.0	106.3
2011	153.1	116.2	63.7	219.9	42.6	7.2	16.5	41.0	38.4
2012	141.0	109.6	133.0	31.9	3.5	0.5	41.9	63.9	216.8
2013	379.6	119.3	76.4	44.6	52.4	1.6	2.7	128.5	123.8
2014	169.7	11.9	188.1	23.2	16.0	2.9	165.3	174.3	78.8
2015	92.0	69.5	101.6	46.5	18.9	23.7	86.2	93.0	113.3
2016	195.0	93.2	141.8	69.1	12.9	0.1	19.3	31.0	141.4
2017	58.3	39.0	134.9	105.3	34.0	0.0	6.0	63.0	40.0
2018	111.5	166.0	45.2	101.4	130.1	0.0	82.4	214.5	345.8
2019	159.8	111.8	371.3	212.0	39.8	0.0	38.5	20.3	156.0
2020	157.0	149.5	289.9	75.8	23.4	0.4	2.1	47.8	61.4

Appendix 3. The Analysis of the Monthly Average of Rainfall in Duhok Governorate

Year	Rain	Temperature	Humidity	Atmospheric Pressure
2010	403	22.7	37	1010.3
2011	614	20.1	41	1010.7
2012	572	20.8	43	1010
2013	720	20.8	44	1009.1
2014	722	21.4	45	1010.2
2015	639	21.1	47	1012.3
2016	696	21.2	44	1012.8
2017	344	21.3	42	1013.1
2018	956	22	49	1011.9
2019	825	22	45	1012.5
2020	613	21.6	43	———

Appendix 4. Climate Phenomena Data in Zakho station

Year	Rain	Temperature	Humidity	Atmospheric Pressure
2010	301	20.3	38	956.6
2011	376	17.9	40	988.6
2012	382.9	19.6	41	1009.8
2013	522.1	19.1	43	1009.6
2014	649.5	20.9	41	1010.1
2015	418	19.6	42	1007.9
2016	367.5	20.5	41	1013.3
2017	281.3	21.4	41	1011
2018	841.1	19.8	42	1010.9
2019	653	19.8	42	1010.2
2020	631.1	20.1	50	———

Appendix 5. Climate Phenomena Data in Semel station

Year	Rain	Temperature	Humidity	Atmospheric Pressure
2010	337.9	22.1	44	1009.4
2011	434	19.8	46	1008
2012	549.3	20.0	49	1010.4
2013	751.7	19.8	48	1012
2014	699.1	20.4	51	1011.2
2015	504.3	20.2	53	1013.8
2016	511.1	20.3	49	1013.6
2017	358.4	20.2	49	1014
2018	953	20.9	54	1012.7
2019	909.4	20.5	52	1013.2
2020	696	20.8	50	———

Appendix 6. Climate Phenomena Data in Duhok station

Year	Rain	Temperature	Humidity	Atmospheric Pressure
2010	550.6	21.9	38	939.7
2011	650.6	19.7	39	939.8
2012	680.3	19.9	39	939.9
2013	889.0	19.8	41	939.7
2014	791.8	21.1	39	940.4
2015	544.1	20.7	40	940.6
2016	653.8	20.7	37	940.5
2017	328.8	21.2	35	940.8
2018	1114.0	21.2	41	940
2019	1045.0	20.7	39	940.3
2020	762.8	20.6	38	———

Appendix 7. Climate Phenomena Data in Akre Station

Year	Rain	Temperature	Humidity	Atmospheric Pressure
2010	561.9	17.3	42	——
2011	627.7	15	44	——
2012	834.8	15.7	43	——
2013	1149	15.9	47	——
2014	1046	17.1	55	——
2015	759.7	18	54	——
2016	873.8	17.5	54	——
2017	480.1	17.5	51	——
2018	1418	17.7	51	——
2019	1320	17.5	51	——
2020	1068	20.1	49	——

Appendix 8. Climate Phenomena Data in Zawita station

Year	Rain	Temperature	Humidity	Atmospheric Pressure
2010	601	17.9	46	906.1
2011	670	17.3	46	906.1
2012	764.5	17.3	47	906
2013	989.6	17	46	906.1
2014	707.2	17.8	47	909.9
2015	707.8	17.3	50	907.3
2016	557.8	17.3	49	907.1
2017	429.6	17.6	48	907.4
2018	1213.2	18.1	42	906.4
2019	1090.3	17.3	44	832.7
2020	850.7	17	48	———

Appendix 9. Climate Phenomena Data in Mangish station

Year	Rain	Temperature	Humidity	Atmospheric Pressure
2010	651	16.2	35	——
2011	973	14.7	34	——
2012	944	16	36	——
2013	1165	16.5	38	——
2014	977	17.1	38	——
2015	772.2	17.3	40	——
2016	769.2	17.3	43	——
2017	544.4	17.5	43	——
2018	1282	17.9	50	——
2019	1247	18.5	52	——
2020	803.2	18.5	48	——

Appendix 10. Climate Phenomena Data in Amedi station

Year	Rain	Temperature	Humidity	Atmospheric Pressure
2010	660	16.8	45	877.4
2011	875	17.2	45	877.5
2012	992.5	17.1	44	877.6
2013	1071.3	17.2	45	877.7
2014	812.6	17.6	45	878
2015	725.6	17.2	46	878.6
2016	784.6	16.7	44	879.3
2017	530.6	17.7	42	879.2
2018	1261.4	17.8	43	879.9
2019	1259	17.1	48	879.1
2020	813.2	17.1	47	———

Appendix 11. Climate Phenomena Data in Bamarne station

The Source of (Table 5), (Table 12) is the researcher's work based on the General Directorate of Atmospheric and Seismic Monitoring in Duhok City, Climate Data Section, unpublished datat.

Station	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Duhok	607	393.6	659.7	687	511	506	805	412	370.1	488	337.9	434	549.3	752	699.1	504.3
Zakho	558	493.3	671.8	682.6	548	520.5	774	379	357.9	567	402.5	614	571.8	720	722.1	638.6
Amedi	894	665.5	944.6	933.5	570	664.5	1012	741	579	789	651	973	944	1165	977	772.2
Zawita	816	565.9	952.3	951.7	705.6	710.4	1071	620	593.5	685	561.9	628	834.8	1149	1046	759.7
Semel	493	439.9	516.1	537.1	444.8	420	700	276	271.6	422	301	376	382.9	522	649.5	418
Sarsenk	444	1051	1003	1098	770	850	1173	687	575.5	894	666.5	906	1106	1402	1165	969.5
Swaratoka	551	720.5	886.3	806.8	626.2	541.6	1127	616	445	716	646	727	798.5	1050	928	751.5
Akre	525	652.1	754.4	784.6	647	569	909	466	416.4	669	550.6	651	680.3	889	791.8	544.1
Bateel	504	342.6	579.8	587.9	499.1	434.8	758	312	299.7	508	321	375	362.5	512	561.5	445.5
Mangash	749	500.4	752.5	842.5	648	634.5	993	552	410	615	601	670	764.5	990	707.2	707.8
Darkar	642	495.3	771.6	796.6	474.4	313.8	640	302	407.8	598	439.6	698	679.4	826	666.5	467.1
Kani masi	921	745.5	861.8	912.7	702.3	869.8	1099	743	514.5	918	722	996	988.5	1139	950	729.4
Deralok	818	738.2	959.6	1188	761.5	680.8	1145	723	601.5	760	651	938	813.5	1030	971.5	759.5
Qasrok	551	478.3	607.9	764.9	605.8	417.3	848	394	287.8	536	372.3	579	647.8	657	751.5	487.6
Batofa	735	657	825.9	900.9	683.7	751.2	1063	644	507.5	841	495	744	773	851	933	714
Bamarny	496	893.8	1033	892.4	693.5	728	1182	688	500	816	660	875	992.5	1071	812.6	725.6
Denarta	1008	905.1	1189	1286	997.4	764	1331	689	676.7	1004	769.5	1076	1118	1326	1131	847.9
Bardarash	489	316.8	504.2	609.3	466	425.3	693	332	292.1	326	303.2	428	415.1	514	489.3	368.5
Chamanke	520	1049	1006	1090	804	873.6	1197	685	599.5	931	801	916	1034	1354	1150	925
Sheikhan	567	423.4	602.6	621	502.5	575	984	453	320	598	493.5	447	528.5	647	650	453

Station	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Duhok	511.1	358.4	953	909	696	655	642.7	461	611	836	861	1051	955	848.4	739.5
Zakho	696.3	343.7	955.8	825	613	687	750.2	551.9	866.8	828.7	917.6	1083.4	1059	1026	733.66
Amedi	769.2	544.4	1282	1247	803	892	972.1	821.04	1253	1230	1252	1330.2	1201	959.9	880.98
Zawita	873.8	480.1	1418	320	1068	998	934	791.24	910.4	1250	1332	1619.7	1440	1370	1064.8
Semel	367.5	281.3	841.1	653	631	543	533.2	405.42	535.2	642	755.7	956.41	807.1	717.9	643.05
Sarsenk	1264	832.5	1647	1447	1226	1286	1299	1000.2	1398	1274	2055	1858.1	1818	1809	1543
Swaratoka	800	773.7	1631	1440	824	1022	1041	981.13	1147	1146	1544	1627.1	1437	1348	1271.5
Akre	653.8	328.8	1114	1045	763	753	771	655.34	797.8	771.8	1013	1038.8	911.8	919.6	644.98
Bateel	428	331.5	797	695	538	589	650.9	431.42	525.8	621	650.3	895.28	841.3	786.9	673.7
Mangash	557.8	429.6	1213	1090	851	832	765.7	775.9	868.1	1023	1045	1045.3	1115	968.3	920.15
Darkar	453.2	285	645.3	957	710	734	749.8	583.27	973.3	965.1	1016	1134.6	1031	793.5	530.49
Kani masi	867.2	592.2	1293	1206	797	851	1059	852.48	1202	1195	1206	1176.2	1083	1057	997.02
Deralok	946.5	699.5	1435	1388	1048	1021	1025	926.23	1397	1281	1448	1628.2	1693	1542	1285.1
Qasrok	448	313	1100	828	601	602	608.5	437.68	702.8	751.9	734.9	901.27	843.3	732.4	521.55
Batofa	704.5	592	1313	1183	866	884	986.2	600.35	930.3	980.1	1012	1207.8	1133	1002	990.43
Bamarny	784.6	530.6	1261	1259	813	865	898.4	735.82	986.8	865.4	1148	1085.6	963	892.2	763.75
Denarta	1096	564.8	1713	1527	1071	1098	1263	1000.1	1440	1471	1591	1695.6	1599	1625	1053.9
Bardarash	354.1	273.2	821.6	696	504	476	359.1	347.73	510.1	547.8	532.9	647.7	651.8	569.2	498.32
Chamanke	1159	742	1580	1512	1153	1176	1198	1058.9	1241	1117	1757	1609.3	1535	1521	1278.6
Sheikhan	508	330	1061	953	673	682	692.4	596.25	561.7	719.2	734.8	882.27	776.9	757.6	692.7

Appendix 12. Future forecasts of rain in the stations of the study area for the period 2030 Appendix (1-13) of the researcher's work, based on the following

1. Iraq, Directorate of Meteorology in Duhok Governorate, Climate Department, unpublished data.

2. Iraq, Ministry of Agriculture and Irrigation, General Directorate of Agriculture in Duhok, Department of Agriculture in Semel District, Climate epartment (Meteorological), unpublished data.

3. Iraq, Ministry of Municipality, Directorate General of Dams and Water Reservoirs in Duhok City, Meteorology Department, unpublished data.

CURRICULUM VITAE

Jiwan Mohammed ABDULLAH. I completed my secondary education at Komata High School, I started my bachelor's program in the Department of Geography at the University of Duhok in 2008-2009 and then in 2013 I started working as a research assistant at the University of Duhok Department of Geography. To complete my master's education, I moved to Karabük University.