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Analyzing and Quantifying Rainfall Changes in Erbil Area 1992 – 2014 Using Standard Normal Period WMO-SNP

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ABSTRACT:

Rainfall is one of the vital climatic factors that can indicate climate change. Spatial and temporal changes of rainfall would influence runoff, soil moisture and groundwater reserves. Analysis of precipitation trends is important in studying the impacts of climate change for water resources planning and management. The present study was conducted to determine changes in the annual and seasonal total rainfall over Erbil Area region in Iraqi Kurdistan Region using 23 years (1992-2014) monthly rainfall data at three rain-gauge stations, the widely used WMO 1961 – 1990 (61 – 90) standard normal period is compared to other consecutive 30-year normal periods in detail.

The results indicated that a decreasing trend varied between 11.6 mm/year at Pirmam station and 10.8 mm/year at Erbil station, and 28.0 mm/year at Makhmur station. The presence of trend in annual and seasonal rainfall series determined by the widely used WMO 1961 – 1990 (61 – 90) standard normal period which is compared to other consecutive 23-year normal periods in detail and the analysis is being made of the seasonal and annual average of rainfall in the period (1992-2014) by analyzing their deviation from the average of the SNP (1961-1990).

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تحليل وقياس تغيرات الأمطار في منطقة اربيل ١٩٩٢ - ٢٠١٤ باستخدام بيانات الفترة القياسية الطبيعية WMO-SNP

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الكلمات المفتاحية:

الـــخُـــلاصـــة:

تعتبر هطول الأمطار أحدى العوامل المناخية الحيوية التي يمكن أن تشير إلى تغير المناخ. تؤثر التغيرات المكانية والزمانية للأمطار على المياه السطحية ورطوبة التربة واحتياطيات المياه الجوفية. تعتبر تحليل اتجاهات الهطول مهمة في دراسة تأثيرات تغير المناخ على تخطيط وإدارة الموارد المائية. أجريت هذه الدراسة لتحديد التغيرات في إجمالي تساقط الأمطار السنوي والموسمي في منطقة أربيل في إقليم كردستان العراق باستخدام بيانات تساقط الأمطار الشهرية في ثلاث محطات لمدة 23 سنة (1992-2014) لقياس المطر ومقارنتها بالفترة القياسية الطبيعية التي اعتمدتها منظمة المناخ العالمي WMO والتي تتمثل بالفترة من 1960 – 1990، والتي يتم من خلالها مقارنة بيانات فترة الدراسة مع بيانات الفترة القياسية ذو الـ 30 سنة .

كما هو معروف، أن المناخ العالمي يتغير في الوقت الحالي، وقد كان العقد الأخير من القرن العشرين وبداية القرن الواحد والعشرين أشد فترات الأرض حرارة. تشير التغيرات المناخية إلى أي تغيير كبير في قياس المناخ الدائم لفترة زمنية طويلة، ويشمل تغييرات كبيرة في العناصر المناخية، واقترحت المنظمة العالمية للأرصاد الجوية مصطلح تغير المناخ ليشمل جميع أشكال التقلبات المناخية على نطاق زمني أطول من 10 سنوات بصرف النظر عن الأسباب يسبب أي تغير في درجات الحرارة والامطار حدوث تغير في المناخ العام او الإقليمي وحتى المحلي، لقد بدا الباحثون خلال الثلاثين سنة الماضية بتحليل التقلبات والتغيرات في درجة حرارة الهواء ودراستها من خلال تحديد اتجاه التغيرات ومقدارها في مواقع عديدة من العالم. وبهدف المقارنة والتحليل، اعتمد معدل عناصر المناخ خلال الفترة من 1961 – 1990 كمعدل عالمي من قبل منظمة الأرصاد الجوية العالمية.WMO

تعتبر بيانات الفترة القياسية الطبيعية المعتمدة من قبل منظمة (WMO) للفترة 1961-1990 (61-90) فترة أساسية في هذه الدراسة وتمت مقارنتها مع باقي فترات الدراسة المتتالية من 23 سنة من هذه الدراسة بالتفصيل لاستخراج النسب الإيجابية والسلبية للتغيرات في المتوسط السنوي والموسمي لتساقط الأمطار بين الفترتين والتغير الحالي في كميات الأمطار نسبة إلى عام 1961 - .1990

وقد تم التحقيق من التغييرات السنوية والموسمية للأمطار بمقارنتها مع الفترة القياسية الطبيعية WMO-SNP المعتمدة من قبل منظمة الارصاد الجوية العالمية.

ولتحقيق هذا الهدف تم الاعتماد على قراءات 3 محطات مناخية منتشرة في منطقة الدراسة للفترة بين 1992 – 2014 وتحليل بياناتها الخاصة بالأمطار، وقد بينت النتائج ان هناك اتجاه عام لانخفاض المعدلات السنوية للامطار في محطات منطقة الدراسة، وقد بلغ هذا الانخفاض مقدار 11.6 ملم لمحطة بيرمام و10.8 لمحطة أربيل و28 لمحطة مخمور، وقد تم استخراج نسب الانخفاض هذه من خلال مقارنة بيانات كل سنة من سنوات فترة الدراسة ببيانات الفترة القياسية 1960 – 1990 المعتمدة من منظمة الأرصاد الجوية العالمية.

إن معرفة الانماط الزمنية لاتجاهات تساقط الأمطار التي تم تحليلها في هذه الدراسة تعتبر اساسية ومهمة للتخطيط الزراعي وإدارة الموارد المائية.

1. CLIMATE CHANGE – CONCEPTS & DEFINITIONS

As well known, that the global climate is currently changing, the last decade of 20th century and the beginning of 21st century were the warmest period in the earth.

Climate change refers to any significant change in the measure of climate lasting for an extended period of time, it includes major changes in climate elements.

The WMO proposed the term climate change to encompass all forms of climatic variability on time scale longer than 10 years regardless to the causes.

Climate change is a long-term shift in weather conditions identified by changes in temperature, precipitation, winds, and other indicators. Climate change can involve both changes in average conditions and changes in variability, including, for example, extreme events.

Climate change has been identified as one of the most significant challenges affecting the humankind today. These changes in climate include, but are not limited to, changes in precipitation, temperature, air composition, atmospheric circulations, weather extremes, and solar radiation.

Changes in the climate are not new. In fact, changes in climate are as old as our planet. The overall tendency of the global temperature over the course of geological time shows that the climate has been rather hot, except for the 5 ice ages. The last one of which is the Quaternary Era, in which we are currently living.

The main causes of climate changes are the natural process such as volcanic eruption, variations in Earth's orbit or changes in the sun's intensity are possible causes, and; However, human's activities can also cause changes to the climate for example by creating greenhouse gases emissions or cutting down forests, the Earth's climate has never been completely static and in the past the planet's climate has changed due to natural causes.

Climate change is a problem and is the greatest environmental challenge facing the world today that has far-reaching effects on the social, environmental and economic facets of the planet earth. Climate change has been identified as one of the most significant challenges affecting the humanity today. It is an extremely broad area that includes changes in the physical and chemical climate, the associated impacts on agriculture, food security, and feedbacks. These changes in climate include, but are not limited to, changes in precipitation, temperature, air composition, atmospheric circulations, weather extremes, and solar radiation. It can affect the length of growing season, the high and low temperatures, precipitation, soil organic carbon, growth of vegetation (El-Zoghbi,2009)

The climate changes are those climatical changes, which faces the globe in the recent decades, which has become the subject of attention of researchers, scientific centers, governments and international NGO's, and many international conferences has been held to identify the reasons of their occurrence and face them and determine the responsibilities of countries about in respect thereof.

Climate change in IPCC (intergovernmental panel on climate change) usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity, that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods, (Rajendra K. Pachauri, etl. 2007 & UNFCCC,1992), thus, this definition distinguished between the climate changes attributed directly to human activities which causes changes in the atmosphere, and the climate fluctuations attributed to natural causes.

(Petit) (Petit, Jean-Robert; et al. (1999)) defines climate changes as (a long-term shift from the weather statistics, including their averages). (Petit, Jean-Robert; et al. (1999))

Ian Allison (Allison, 2010) believes that Climate change is when the average long-term weather patterns of a region are altered for an extended period of time, typically decades or longer. Examples include shifts in wind patterns, the average temperature or the amount of precipitation. These changes can affect one region, many regions or the whole planet (Allison, 2010). while the royal society – London believes that Climate changes are caused by changes in the total amount of energy that is kept within the Earth's atmosphere. This change in energy is then spread out around the globe mainly by ocean currents as well as wind and weather patterns to affect the climates of different regions. (Royal Society, 2010)

While Selvaraju Ramamasy and Stephan Baas (Ramamasy, etl., 2007) believe that climate change refers to any change in climate over time, whether due to natural variability or anthropogenic forces, and the climate change is attributed to both natural variability and human activities. Variation in climate parameters is generally attributed to natural causes. However, because of changes in the earth's climate since the pre-industrial era, some of these changes are now considered attributable to human activities. (Ramamasy, et al., 2007).

2. DEFINING THE STUDY AREA

The study area occupies the central and southern parts of Irbil Governorate and covers (6116,8 km2) (611,680 hectares)) and constitutes about (%) of the total area of Erbil Governorate, Based on the map of the Irbil region and surrounding areas, the area of Erbil can be defined as follows:

1. The study area (Erbil Area) has an irregular shape, forming the Kore and Tauska valleys are defining its northern borders and the valleies of

Gomaspan and Bastora and Sharabot heights at the contour line (600 m)(Sabah, 2012) and the small valley of little Zab are defining its eastern border. The Awana Mountain series and the administrative borders of Erbil are its southern and south-western borders, while its western borders are the greater Zab river.

2. The study area in this definition occupies the northeastern parts of the semi-mountainous region within Erbil governorate.
3. The study area (Erbil region) is located within the limits previously mentioned between the two latitudes (58 '25 ° 35', '40' 37 ° 36 ") and longitude ('08' 17 ° 43 ") 24 '20 ° 44) east.
4. The total area of the study area is about 6116,795 km2.
5. The study area is distributed to the administrative units (districts and sub-districts) of Erbil governorate as shown in Map (1) and Table (1)

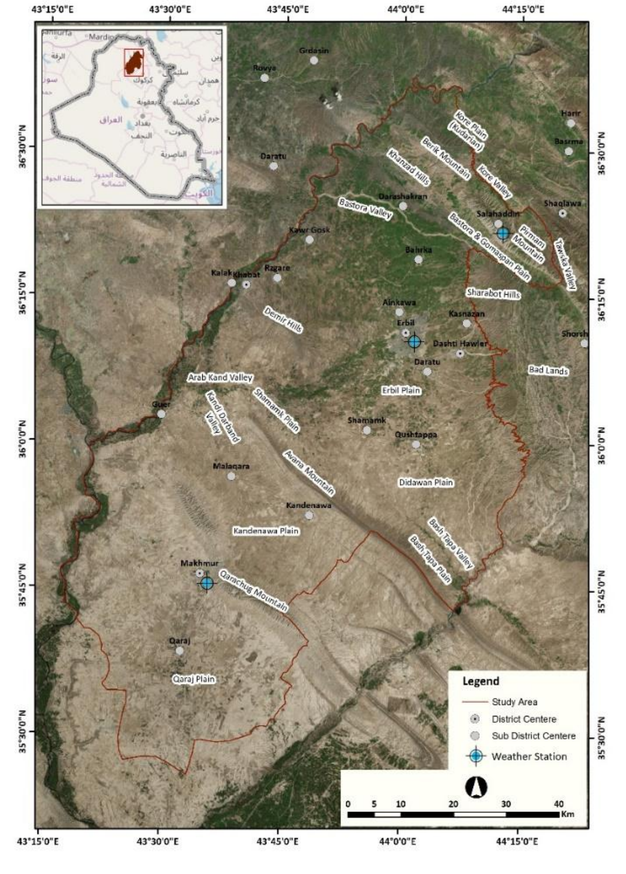

Figure 1: Administration Units and Topography of Study Area.

Table 1: Administration Units Area Size (Km^2) in Study Area.

ID	Sub Districts	District	Area Km^2	% of Erbil Area
1	Qaraj	Makhmur	1058.7	17.3
2	Kandenawa		503.1	8.2
3	Gwer		513.0	8.4
4	Malaqara		240.6	3.9
5	Makhmur		530.1	8.7
Total			2845.5	46.5
6	Darashkran	Khabat	296.8	4.9
7	Rizgari		253.0	4.1
8	Kawr Gosk		111.6	1.8
9	Khabat		43.2	0.7
Total			704.5	11.5
10	Qushtapa	Dashti Hawler	786.3	12.9
11	Daratu		151.4	2.5
12	Kasnazan		24.9	0.4
13	Bnaslawa		57.8	0.9
Total			1020.3	16.7
14	Bahrka	Erbil	370.9	6.1
15	Erbil Center		152.8	2.5
16	Shamamk		558.7	9.1
17	Ainkawa		36.3	0.6
Total			1118.7	18.3
18	Salahaddin	Shaqlawa	334.9	5.5
19	Harir		92.9	1.5
Total			427.8	7.0
Total			**6116.8**	**100.0**

Reference: Kurdistan Regional Government, Iraq, Ministry of Planning, KRSO, Administrative units of Erbil Governorate, non-published data

3. RAINFALL CHANGES IN ERBIL AREA

3.1.Methods of Analysis:

Statistical & mathematical procedure, analysis method, tools used in the study of rainfall variability for Erbil area are discussed.

3.2.Data Collection & Weather Stations:

As explained previously in chapter one of this study, the researcher depended on the temperature and rainfall data of three main weather stations (Pirmam – Erbil Center – Makhmur) which are located inside the boundary of the study area to find out the characteristics of the climate of the study area and determine the reality of changes in the value of the temperature and precipitation data changes in the study area because of the importance of those two elements in the climatic studies and in the in the study of climate change through the analysis of changing trends in the last two and half decades.

The data for the analysis of the period 1992 – 2014 were used from the three main weather stations located within the boundary of the study area (Pirmam – Erbil – Makumur)

In addition to the temperature and rainfall data of the three mentioned above weather stations, the historical data of Mousel Station (82 Km West of Erbil Station & 77 Km North West of Makhmur Station) and Kerkuk station (88 Km South East of Erbil Station & 81 Km South East of Makhmur Station) has been used to extract the historical data (1961 – 1992) of the study area.

The historical data (1961 – 1990) of Pirmam station has been obtained from both General directorate of meteorology & seismology – Kurdistan Regional Government and from the Iraqi meteorological organization & Seismology.

Pirmam station is classified according to Koppen's climate classification as a Dry-summer or Mediterranean Sea climate (Csa) with humid winter and dry summer, and the other four stations ar classified according to Koppen's classification as a Steppe climate (Semi-Arid) – Hot Steppe (BSh).

(Table (2) shows the weather stations which their data has been used in this study).

Table (2) Weather Stations used in the study

Station	Longitude	Latitude	Elevation (M)	Climate Class (Koppen)
Pirmam	44.20	36.37	1088	Csa
Erbil	44.03	36.19	414	BSh
Makhmur	43.58	35.77	270	BSh
Mosul	43.14	36.37	223	BSh
Kerkuk	44.34	35.49	331	BSh

Reference:

- Kurdistan Regional Government, Ministry of Transportation & Communication, General Directorate of Meteorology & Seismology, Statistical Information about Weather Stations, unpublished data.
- Republic of Iraq, Ministry of Transportation, Iraqi Meteorological Organization & Seismology, Statistical Information about Weather Stations, unpublished data

The way of calculating and replacing the temperature & rainfall data of Mosul and Kerkuk stations with the ones of Erbil & Makhmur weather stations in the study area was as follow:

1. For Pirmam station, the historical data (1961 – 1990) has been obtained from the Iraqi meteorological organization & Seismology.
2. For Erbil station, there was no historical records for temperatures, while the historical rainfall data was available since 1935, and Erbil station started recording the data of temperature in 1981.
3. For Makhmur station, there was no historical data of both rainfall & temperature, because this station started recording temperature and rainfall data in 1987.
4. The method of calculating and replacing the missing historical data of both Erbil & Makhmur stations was through obtaining the deep detailed and historical data of Mosul & Kerkuk stations between 1961 – 2014, and calculating the values of monthly means of minimum and maximum temperatures and the means of monthly rainfall values of Erbil & Makhmur stations for the periods (Erbil: 1981 – 2014) and (Makhmur: 1987 – 2014), and calculating the averages of both Mosul & Kerkuk data for the same period of each of Erbil and Makhmur, then calculating the negative or positive differences between the values to extract the difference factor, then applying that difference factor of each of Erbil and Makhmur with the averages of (Mosul & Kerkuk) on the averages of the historical data of Mosul & Kerkuk to extract the missing historical data of Erbil & Makhmur

3.3.Data Analysis Methods:

The method of Climate Normal's VS Current Climate Situation was used for the analysis of rainfall data of Erbil area to determine the changes in climate through the elements of rainfall.

4. CLIMATE STANDARD NORMAL PERIOD (SNP) VS CURRENT CLIMATE SITUATION:

Any long-term changes in temperature or rainfall causes changes of the general or regional climate or even local climate, in the previous 30 years, researchers started to analyze fluctuations and changes in temperature & rainfall, and study theme through the trends and quantities of those changes in different areas in the world. And for the purpose of comparison and analysis, the averages of different climate elements of the period (1961 – 1990) has been considered as global averages by the worlds Meteorological Organization (WMO). (Sulaiman A. Ismaeel, 1992 – 2014).

Climate data are often more useful when they are compared with standard or normal values. The technical regulations define normal as "Period averages computed for uniform and relatively long period comprising at least three consecutive ten – year periods" and climatological standard normal as "Averages of climatological data computed of 30 years as follows: 1. January. 1901 to 31. December. 1930, 1. January. 1931 to 1 December. 1960, and the current standard normal period 1. January. 1961 to 31. December. 1990, … etc.", and the next update will be in 2021, when the 1991-2020 period will become the new standard. (World meteorological organization; William Wright; Omar Baddour) The World Meteorological Organization (WMO) and its predecessor, the International Meteorological Organization (IMO), have been coordinating the publication of global climate normals at the monthly scale for about 75 years. Member nations of the IMO/WMO were first mandated to compute climate normals for their respective countries for the 1901–30 period, and are required to update these climate normals every 30 years (Anthony Arguez and Russell S. Vose ,2011; IPCC-TGCIA,1999; Eugenia Monaco, Antonello Bonfante,2014)

The widely used WMO 1961–1990 (61–90) standard normal period is considered as baseline period in this study and had been compared to other consecutive 23-years periods of this study in detail to extract the positive and negative percentages of changes in the annual, monthly and seasonal averages of temperature and rainfall between both periods, and the current change in temperature and rainfall relative to 1961 - 1990.

many studies have been published comparing recent conditions with the last reference period 1961–1990, (Lívia LABUDOVÁ and others) studied the (Changes in climate and changing climate regions in Slovakia), and their study has been divided in to two main parts, the trends of annual, seasonal and monthly average air temperature, as well as annual, seasonal and monthly precipitation totals in Slovakia, are presented to point out changes which will probably show up in the next reference period 1991–2020. In the second part of the paper, changes in the climate regions in Slovakia are analyzed, comparing spatial distributions in the period 1961–1990 and in the period 1961–2010.

(Lívia labudová and others) calculated the spatial average temperature in Slovakia from 13 stations, and they found that the period 1991 to 2014 is characterized by an increasing trend of air temperature characteristics, and the long-term averages of spatial precipitation totals for the reference periods show only small changes in each month, season, half-year and year, opposite to the temperature trends. (labudová, l., faško, p., ivaňáková, g., (2015))

(simon c. Scherrer and his colleagues) studied the (temperature trends in Switzerland and Europe: implications for climate normals), they used the data of 5 five weather stations, and they used the widely used WMO 1961–1990 (61–90) standard normal period is compared to other consecutive 30-year (1971 – 2000) normal periods in detail, they mainly focused on the temperature distribution in Switzerland and on the European continent, and Other climate elements such as precipitation are not considered.

The results of their study show that observed Swiss temperature in the last decade exhibit characteristics that were never found in the last 140 years. Absolute trends are greater in winter than in summer, but owing to the smaller interannual variability, the summer months' exhibit higher statistical significance. The autumn months September, October and November show small trends and are still close to the 61–90 conditions. (Simon c. Scherrer, christof appenzeller and mark a. Liniger, 2006) (fawaz al – moussa) performed a statistical & climatological analysis study of air temperature and its indices in Aleppo, he studied the daily, monthly and annual average of temperatures (minimum, maximum and average) in the period (1946- 2013) by analyzing their deviation from the average of the period (1961-1990), specifying their periodicality and the general trend of the average temperature in Aleppo City in the period in question, he found in his study that there is a general trend of increasing temperatures (minimum, maximum and average) which are of great significance. the second finding is that there are short-term periodicals (2 years), medi-term periodicals (4-6 years), and long-term periodicals (10-12 years) in the general trend of increase. (Fawaz Al-Moussa,2014)

(tank, and g. P. Ko¨ nnen) studied the (trends in indices of daily temperature and precipitation extremes in europe, 1946–99), in their study they consternated on the trends in indices of climate extremes on the basis of daily series of temperature and precipitation observations from more than 100 meteorological stations in Europe for the period 1946 – 1999.

They depended on the base line period 1961 – 1990 as a standard for the comparisons of the climate data in their study with their study period 1976 - 1999, about half of the indices considered in their study are expressions of anomalies relative to local climatology in the standard-normal period 1961–90, enabling comparisons between stations in different countries and regions. The values of the percentile thresholds in this study were determined empirically from the observed station series in the climatological standard-normal period 1961 – 1990, and the results of their study shown considerably large trends for the warming of 1976–99 period than expected from the observed trends in the corresponding indices of cold extremes. (tank, and g. P. Ko¨ nnen, 1946–1999)

(Donald Brown) and his colleagues performed a study about (Climate change - impacts, vulnerability and adaptation in Zimbabwe), in this study they review impacts, vulnerability and adaptation to climate change in Zimbabwe, with the intention of providing a broad overview of the key issues related to climate change facing this country, they examined climate trends, scenarios and projections for Zimbabwe and draw upon a variety of case studies on adaptation projects, they found out that due to the increasing trends of temperatures in 2007, evaporation led to extremely low water levels in most of Zimbabwe's dams, causing many to be decommissioned, the situation becomes worse with climate change where evaporation is predicted to increase by between 4-25 per cent in the river basins. Runoff is also projected to decline by up to 40 per cent, with the Zambezi Basin worst affected. At the same time, annual rainfall levels based on the 1961–90 average are projected to decline between 5–20 per cent by 2080 in all of the country's major river basins. (Donald Brown & IIED,2012)

5. DATA ANALYSIS

For the purpose of analyzing the rainfall data of the study period (1992 – 2014), the monthly averages of rainfall have been used to extract the annual and seasons - annual averages of rainfall for each year of the consecutive 23-years of the study period, then compare all this to the corresponding rainfall in the widely used WMO 1961 – 1990 standard normal period which has been considered as a baseline period in this study. All these, to extract the percentage of negative or positive changes in rainfall between each year of the consecutive 23-years of the study period and the 1961 – 1990 standard normal period.

3.4.Annual Rainfall averages:

Rainfall is the most important factor for aquifer recharge in the region, the season of rainfall starts from September till May, but most of the rainfall occurs in the region from October through April.

The climate of Kurdistan region has been identified according to Koppen classification as (steppe - BSh and Mediterranean – Csa) climate. it is hot and dry in summer and cold and wet in winter, with short spring and autumn seasons compared to summer and winter

The rainfall varies in study area substantially year to year and sharply decrease from North to South. (ExxonMobil Kurdistan Region of Iraq, 2012)

The rainfall regime in Kurdistan region is highly affected by the orographical features; consequently, the rainfall amount is increasing as moving from south west to the north-east part of the region.

The orographical effect on rainfall distribution is confirmed by the spatial distribution of rainfall, Table (2). With the lowest station in the region Makhmur (having an elevation of 270m above the sea level), the mean annual rainfall amount is 263.5 mm which is the lowest in the study area, and the highest station is Pirmam (with an elevation of 1088m above the sea level) having 587.4 mm rainfall. (Abbas ،2008)

The actual rainfall season in Kurdistan region usually starts from October and lasts until end of May, about eight months, the rest of the year is almost completely dry except for some traces before the starting and after the end of rainy season.

From the annual mean distribution of rainfall in Kurdistan region, the criteria of division of the region to the guarantied, semi-guarantied and non-guaranteed sub-region by the Ministry of agriculture of Kurdistan region is confirmed. This division is shown in Map (2), and as follows:

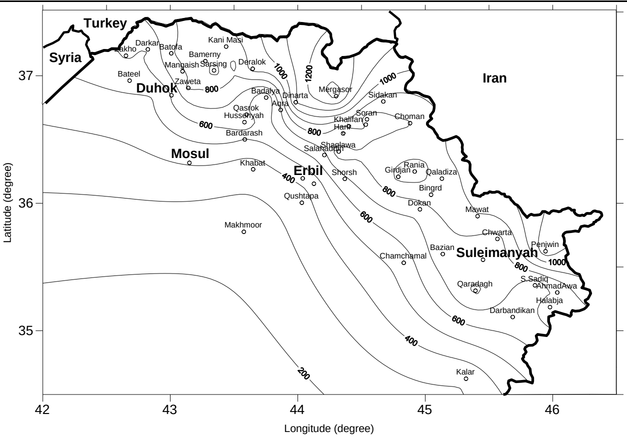

Figure 2: map of mean Annual Rainfall (mm) in Kurdistanregion..

Reference: Akram Abbas,2008

1. The guaranteed rainfall region, where annual rainfall exceeds 500 mm.
2. The semi-guarantied rainfall region, where annual rainfall less than 500 mm and more than 300 mm.
3. The non-guaranteed rainfall region, where annual rainfall less than 300 mm. (Khalid Akram Abbas,2008, Ministry of agriculture/ Kurdistan Region-Iraq 2007)
4. Table (3) below shows the annual rainfall averages of the consecutive 23-years of the study period 1992 – 2014 compared to the SNP average of 1961 – 1990, the outcome of the data in this table can be summarized as follow:
5. The annual rainfall averages for the SNP 61 – 90 were (664.7, 451.9 and 365.8 mm) for the three stations Pirmam, Erbil and Makhmur respectively, and the average of the three stations of the study area was 494.1 mm.
6. The annual rainfall averages of the 3 stations for the consecutive 23 years of the study period were (587.4, 403.2, 263.5 mm) for the three stations Pirmam, Erbil and Makhmur respectively, and the average of the three stations of the study area was (418.05 mm).
7. Based on the fact in point 1 above, Pirmam station was within the guaranteed rainfall region in the SNP 1961 – 1990 with a rainfall average of (664.7 mm), and both Erbil and Makhmur stations were within the semi guaranteed rainfall region in the SNP 1961 – 1990 with rainfall averages of (451 mm) for Erbil station and (365.8 mm) for Makhmur station.
8. Based on the facts in point 2 above, In the consecutive 23-years of the study period, Pirmam station stayed within the guaranteed rainfall region with a total rainfall average of (587.4 mm), and Erbil station stayed within the semi guaranteed rainfall region with a total rainfall average of (403.2 mm), while Makhmur station has been shifted down from the semi guaranteed rainfall region to the non-guaranteed rainfall region due to the decrease of its total rainfall average to (263.54 mm) which is less than the average of the semi guaranteed by (36.5 mm) and less than the average of the SNP by (102.3 mm).
9. Based on the facts in point 1 and 2 above, all the three stations in the study area recorded a negative change in the annual rainfall averages, and among the three stations, Makhmur station recorded the highest negative change in the annual rainfall average with a percentage of change (- 28.0 %) and an decrease of (- 102.3 mm) compared to the average of the SNP 61 – 90, and Pirmam station also recorded a positive change of annual rainfall average and came in the second rank with percentage of change (- 11.6 %) and an decrease of (- 77.3 mm) compared to the average of the SNP 61 – 90, and Erbil station also recorded negative change of annual rainfall average and came in the third rank with percentage of change (- 10.8 %) and an decrease of (- 48.7 mm)

compared to the average of the SNP 61 – 90, and the average of the three stations was a also negative percentage of change with a percentage of change (- 15.4 %) and an decrease of (- 76.1 mm).

10. The results of the standard deviation (SD) of the percentages of change for the consecutive 23 years of the study period shows that Pirmam station was the most stable station among the three stations of the study area with the lowest SD value (25.1), and Makhmur station was the most unstable station among the three stations of the study area with the highest SD value (34.1), while the SD value of Erbil station was (30.4), and those SD values were proved by the results of the percentage of change in annual rainfall averages which Makhmur station has the highest.
11. In Pirmam station, only 9 years among the consecutive 23 years of the study period recorded a Positive change in the annual rainfall averages compared to the SNP average of 1961 – 1990, while in 14 years a Negative change in the annual rainfall average has been recorded. The maximum negative change in Pirmam stations annual rainfall was recorded in 2008 with a decrease percentage of (-56.2 %) and a decrease of (-373.5 mm), and the maximum positive change in Pirmam stations annual rainfall average was recorded in 1994 with an increase percentage of (17.2 %) and an increase of (155.4 mm) compared to the SNP average of 1961 – 1990.
12. In Erbil station, only 8 years out of the consecutive 23 years of the study period recorded a positive change in the annual rainfall averages compared to the SNP average of 1961 – 1990, while in 15 years a negative change in the annual rainfall average has been recorded. The maximum negative change in Erbil Stations annual rainfall average was recorded in 2008 with a decrease percentage of (-60.7 %) and a decrease of (274.1 mm), and the maximum positive change in Erbil stations annual rainfall average was recorded in 1993 with an increase percentage of (64.5 %) and an increase of (291.6 mm) compared to the SNP average of 1961 – 1990.
13. In Makhmur station, only 2 years among the consecutive 23 years of the study period recorded a positive change in the annual rainfall averages compared to the SNP average of 1961 – 1990, while in 21 years a negative change in the annual rainfall average has been recorded. The maximum negative change in Makhmur Stations annual rainfall was recorded in 1999 with a decrease percentage of (-73.2 %) and a decrease of (267.7 mm), and the maximum positive change in Makhmur stations annual rainfall average was recorded in 1993 with an increase percentage of (83.5 %) and an increase of (305.4 mm) compared to the SNP average of 1961 – 1990.
14. Regarding the averages of annual rainfall of the three stations in the study area, only 7 years out of the consecutive 23 years of the study period recorded a positive change in the annual rainfall averages compared to the SNP average of 1961 – 1990, while in 16 years a negative change in the annual rainfall average has been recorded. The maximum negative change in the average of the three stations in the study area for the annual rainfall was recorded in 2008 with a decrease percentage of (-59.9 %) and a decrease of (-295.9 mm), and the maximum positive change in the average of the three stations in the study area for the annual rainfall average was recorded in 1993 with an increase percentage of (48 %) and an increase of (237.1 mm) compared to the SNP average of 1961 – 1990.

In both Erbil and Pirmam stations, the last Positive change in the annual rainfall was recorded in 2013; While in Makhmur station, the last positive change in the annual rainfall averages was in 1995 and from 1996 onward the annual rainfall averages decreased in different percentages each year.

Table 3: Annual Rainfall Averages in Erbil Area

Annual Rain															
Pirmam				Erbil				Makhmur				Erbil Area			
Year	Annual	change	Difference	Year	Annual	change	Difference	Year	Annual	change	Difference	Year	Annual	change	Difference
60 - 90	664.7	%		60 - 90	451.9	0		60 - 90	365.8	0		60 - 90	494.1	0	
1992	686.5	3.3	21.8	1992	522.9	15.7	71.0	1992	203.8	-44.3	-162.0	1992	471.07	-4.7	-23.0
1993	778.8	17.2	114.1	1993	743.5	64.5	291.6	1993	671.2	83.5	305.4	1993	731.17	48.0	237.1
1994	820.1	23.4	155.4	1994	505.7	11.9	53.8	1994	319.9	-12.5	-45.9	1994	548.57	11.0	54.5
1995	745.0	12.1	80.3	1995	652.4	44.4	200.5	1995	450.3	23.1	84.5	1995	615.90	24.6	121.8
1996	523.3	-21.3	-141.4	1996	359.5	-20.4	-92.4	1996	322.2	-11.9	-43.6	1996	401.67	-18.7	-92.4
1997	464.4	-30.1	-200.3	1997	395.1	-12.6	-56.8	1997	279.0	-23.7	-86.8	1997	379.50	-23.2	-114.6
1998	794.0	19.5	129.3	1998	461.6	2.1	9.7	1998	296.6	-18.9	-69.2	1998	517.40	4.7	23.3
1999	358.3	-46.1	-306.4	1999	188.1	-58.4	-263.8	1999	98.1	-73.2	-267.7	1999	214.83	-56.5	-279.3
2000	381.1	-42.7	-283.6	2000	267.0	-40.9	-184.9	2000	134.6	-63.2	-231.2	2000	260.90	-47.2	-233.2
2001	430.9	-35.2	-233.8	2001	346.7	-23.3	-105.2	2001	230.8	-36.9	-135.0	2001	336.13	-32.0	-158.0
2002	660.8	-0.6	-3.9	2002	356.1	-21.2	-95.8	2002	249.5	-31.8	-116.3	2002	422.13	-14.6	-72.0
2003	748.2	12.6	83.5	2003	528.2	16.9	76.3	2003	306.6	-16.2	-59.2	2003	527.67	6.8	33.6
2004	738.3	11.1	73.6	2004	496.5	9.9	44.6	2004	344.6	-5.8	-21.2	2004	526.47	6.5	32.4
2005	652.2	-1.9	-12.5	2005	412.2	-8.8	-39.7	2005	260.2	-28.9	-105.6	2005	441.53	-10.6	-52.6
2006	708.5	6.6	43.8	2006	431.6	-4.5	-20.3	2006	339.2	-7.3	-26.6	2006	493.10	-0.2	-1.0
2007	616.3	-7.3	-48.4	2007	386.0	-14.6	-65.9	2007	275.5	-24.7	-90.3	2007	425.93	-13.8	-68.2
2008	291.2	-56.2	-373.5	2008	177.8	-60.7	-274.1	2008	125.7	-65.6	-240.1	2008	198.23	-59.9	-295.9
2009	404.9	-39.1	-259.8	2009	287.6	-36.4	-164.3	2009	144.6	-60.5	-221.2	2009	279.03	-43.5	-215.1
2010	634.7	-4.5	-30.0	2010	369.6	-18.2	-82.3	2010	208.3	-43.1	-157.5	2010	404.20	-18.2	-89.9
2011	461.6	-30.6	-203.1	2011	350.9	-22.4	-101.0	2011	194.4	-46.9	-171.4	2011	335.63	-32.1	-158.5
2012	380.6	-42.7	-284.1	2012	242.9	-46.2	-209.0	2012	110.5	-69.8	-255.3	2012	244.67	-50.5	-249.4
2013	771.6	16.1	106.9	2013	491.3	8.7	39.4	2013	303.7	-17.0	-62.1	2013	522.20	5.7	28.1
2014	458.9	-31.0	-205.8	2014	300.7	-33.5	-151.2	2014	192.0	-47.5	-173.8	2014	317.20	-35.8	-176.9
Average	587.4	-11.6	-77.3		403.2	-10.8	-48.7		263.54	-28.0	-102.3		418.05	-15.4	-76.1
sd		25.1				30.4				34.1				27.2	

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- Kurdistan Regional Government, Ministry of Transportation & Communication, General Directorate of Meteorology & Seismology, Statistical Information about Weather Stations, unpublished data.
- Republic of Iraq, Ministry of Transportation, Iraqi Meteorological Organization & Seismology, Statistical Information about Weather Stations, unpublished data

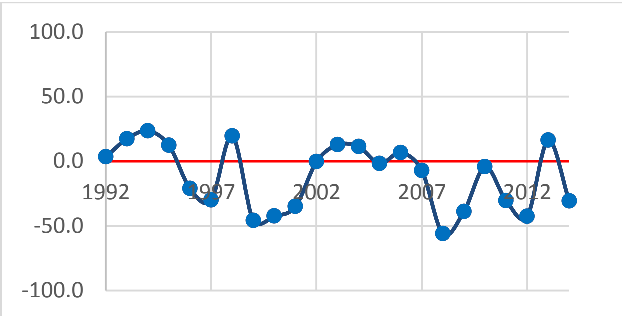

Figure 3: Pirmam Station Annual

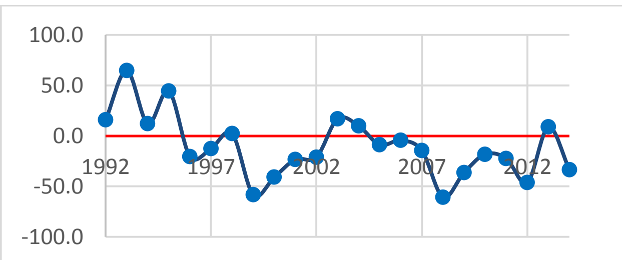

Figure 4: Erbil Station Annual Rainfall Change mm.

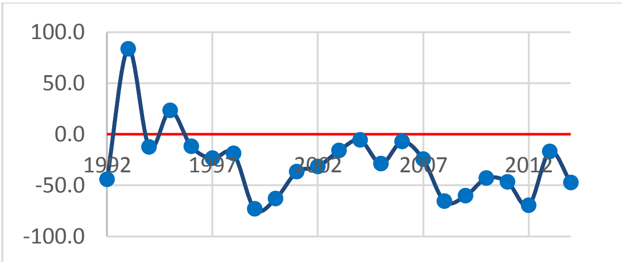

Figure 5: Makhmur Station Annual Rainfall Change mm

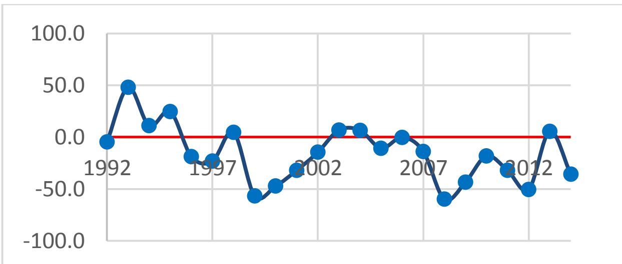

Figure 6: Erbil Area Annual Rainfall Change mm

3.5.Seasonal rainfall averages:

3.5.1. Annual rainfall averages of Winter:

Table (4) below shows the annual rainfall of winter for the consecutive 23-years of the study period compared to the SNP average of 1961 – 1990, the outcome of the data in this table can be summarized as follow:

1. The annual rainfall average of winter for the SNP 61 – 90 was 330.2, 240.7 and 188.5 mm for the three stations Pirmam, Erbil and Makhmur respectively, and the average of the three stations of the study area was 253.1 mm.

2. The annual rainfall average of winter for the 3 stations for the consecutive 23 years of the study period were 315.5, 211.9 and 136.8 mm for the three stations Pirmam, Erbil and Makhmur respectively, and the average of the three stations of the study area was 221.4 mm.

3. Based on the facts in point 1 and 2 above, and similar to the annual rainfall averages, all the three stations in the study area recorded a negative change in winters annual rainfall averages but with different quantities and decrease percentages, and among the three stations, Makhmur station stayed with the highest negative change among the stations of the study area and recorded the highest negative change in the annual rainfall of winter with a percentage of change (- 27.4 %) and an decrease of (51.7 mm) compared to the average of the SNP 61 – 90, and Erbil station also recorded a negative change of winters annual rainfall and came in the second rank with percentage of change (- 12.0 %) and an decrease of (28.8 mm) compared to the average of the SNP 61 – 90, and Pirmam station was in the third rank but also recorded a negative change of winters annual rainfall with a percentage of change (- 4.5 %) and an decrease of (14.7 mm) compared to the average of the SNP 61 – 90, while the average of the three stations was a negative change with a percentage of change (- 12.5 %) and an decrease of (31.7 mm).

4. The results of the standard deviation (SD) of the percentages of change of winters annual rainfall for the consecutive 23 years of the study period shows that Pirmam station has the highest SD value due to the high values for both negative and positive changes, and Erbil station has the second highest SD value and Makhmur station has the lowest SD value among the three station due to the low values of the positive change in winters annual rainfall averages; Pirmam station has the highest SD value 35.8, and Erbil station has the second highest SD value 31.7 and Makhmur station has the lowest SD value of 29.1, while the SD value for the average of the three stations was 30.3.

5. In Pirmam station, only 8 years out of the consecutive 23 years of the study period recorded a positive change in winters annual rainfall averages compared to the SNP average of 1961 – 1990, while in 15 years a negative change in the annual rainfall average has been recorded. The maximum negative change in Pirmam stations winter annual rainfall was recorded in 2009 with a decrease percentage of (-66.0 %) and a decrease of (218 mm), and the maximum positive change in Pirmam station winters annual rainfall average was recorded in 2013 with an increase percentage of (66.2. %) and an increase of (218.6 mm) compared to the SNP average of 1961 – 1990.

6. Similar to Pirmam station, In Erbil station, 8 years out of the consecutive 23 years of the study period recorded a positive change in winters annual rainfall averages compared to the SNP average of 1961 – 1990, while in 15 years a negative change in winters annual rainfall average has been recorded. The maximum positive change in Erbil Stations annual rainfall of winter was recorded in 1992 with a decrease percentage of (41.9 %) and an increase of (100.8 mm), and the maximum negative

change in Erbil station winters annual rainfall average was recorded in 2009 with a decrease percentage of (73.9 %) and a decrease of (177.9 mm) compared to the SNP average of 1961 – 1990.

7. In Makhmur station, 6 years out of the consecutive 23 years of the study period recorded a positive change in winters annual rainfall averages compared to the SNP average of 1961 – 1990, while in 17 years a negative change in winters annual rainfall average has been recorded. The maximum positive change in Makhmur Stations winter annual rainfall was recorded in 2006 with a decrease percentage of (16.9 %) and an increase of (31.9 mm), and the maximum negative change in Makhmur stations winter annual rainfall average was recorded in 2009 with a decrease percentage of (81.0 %) and a decrease of (-152.7 mm) compared to the SNP average of 1961 – 1990.

Regarding the averages of winters annual rainfall of the three stations in the study area, only 8 years out of the consecutive 23 years of the study period recorded a positive change in winters annual rainfall averages compared to the SNP average of 1961 – 1990, while in 15 years a negative change in winters annual rainfall average has been recorded. The maximum positive change in the average of the three stations in the study area for winters annual rainfall was recorded in 2013 with an increase percentage of (42.4 %) and an increase of (107.4 mm), and the maximum negative change in winters average of the three stations in the study area for the annual rainfall average of winter was recorded in 2009 with a decrease percentage of (- 72.2 %) and an increase of (182.8 mm) compared to the SNP average of 1961 – 1990.

Table 4: Annual Rainfall Averages of Winter in Erbil Area

Winter Rain															
Pirmam				Erbil				Makhmur				Erbil Area			
Year	Winter	Change	New - Old	Year	Winter	Change	New - Old	Year	Winter	Change	New - Old	Year	Winter	change	New - Old
60 - 90	330.2	%		60 - 90	240.7	%		60 - 90	188.5	%		60 - 90	253.1	%	
1992	500.8	51.7	170.6	1992	341.5	41.9	100.8	1992	117.6	-37.6	-70.9	1992	320.0	26.4	66.9
1993	328.5	-0.5	-1.7	1993	273.9	13.8	33.2	1993	203.3	7.9	14.8	1993	268.6	6.1	15.5
1994	301.6	-8.7	-28.6	1994	198.3	-17.6	-42.4	1994	146.2	-22.4	-42.3	1994	215.4	-14.9	-37.7
1995	325.9	-1.3	-4.3	1995	293.8	22.1	53.1	1995	206.3	9.4	17.8	1995	275.3	8.8	22.2
1996	226.2	-31.5	-104.0	1996	147.7	-38.6	-93.0	1996	158.5	-15.9	-30.0	1996	177.5	-29.9	-75.6
1997	220.0	-33.4	-110.2	1997	234.0	-2.8	-6.7	1997	217.2	15.2	28.7	1997	223.7	-11.6	-29.4
1998	471.4	42.8	141.2	1998	249.2	3.5	8.5	1998	145.6	-22.8	-42.9	1998	288.7	14.1	35.6
1999	242.8	-26.5	-87.4	1999	149.7	-37.8	-91.0	1999	84.3	-55.3	-104.2	1999	158.9	-37.2	-94.2
2000	271.6	-17.7	-58.6	2000	201.1	-16.5	-39.6	2000	88.6	-53.0	-99.9	2000	187.1	-26.1	-66.0
2001	224.8	-31.9	-105.4	2001	179.1	-25.6	-61.6	2001	107.3	-43.1	-81.2	2001	170.4	-32.7	-82.7
2002	345.2	4.5	15.0	2002	139.3	-42.1	-101.4	2002	109.0	-42.2	-79.5	2002	197.8	-21.8	-55.3
2003	447.6	35.6	117.4	2003	298.6	24.1	57.9	2003	188.1	-0.2	-0.4	2003	311.4	23.0	58.3
2004	467.7	41.6	137.5	2004	309.6	28.6	68.9	2004	190.2	0.9	1.7	2004	322.5	27.4	69.4
2005	270.5	-18.1	-59.7	2005	204.2	-15.2	-36.5	2005	161.0	-14.6	-27.5	2005	211.9	-16.3	-41.2
2006	477.1	44.5	146.9	2006	293.3	21.9	52.6	2006	220.4	16.9	31.9	2006	330.3	30.5	77.2
2007	260.9	-21.0	-69.3	2007	170.2	-29.3	-70.5	2007	120.9	-35.9	-67.6	2007	184.0	-27.3	-69.1
2008	171.3	-48.1	-158.9	2008	104.4	-56.6	-136.3	2008	69.3	-63.2	-119.2	2008	115.0	-54.6	-138.1
2009	112.2	-66.0	-218.0	2009	62.8	-73.9	-177.9	2009	35.8	-81.0	-152.7	2009	70.3	-72.2	-182.8
2010	351.8	6.5	21.6	2010	214.8	-10.8	-25.9	2010	102.7	-45.5	-85.8	2010	223.1	-11.9	-30.0
2011	272.4	-17.5	-57.8	2011	200.0	-16.9	-40.7	2011	99.0	-47.5	-89.5	2011	190.5	-24.7	-62.6
2012	184.3	-44.2	-145.9	2012	112.6	-53.2	-128.1	2012	56.4	-70.1	-132.1	2012	117.8	-53.5	-135.3
2013	548.8	66.2	218.6	2013	326.1	35.5	85.4	2013	206.7	9.7	18.2	2013	360.5	42.4	107.4
2014	232.4	-29.6	-97.8	2014	169.7	-29.5	-71.0	2014	111.7	-40.7	-76.8	2014	171.3	-32.3	-81.8
Average	315.5	-4.5	-14.7	Average	211.9	-12.0	-28.8	Average	136.8	-27.4	-51.7	Average	221.4	-12.5	-31.7
sd		35.8		sd		31.7		sd		29.1		sd		30.3	

References:

- Kurdistan Regional Government, Ministry of Transportation & Communication, General Directorate of Meteorology & Seismology, Statistical Information about Weather Stations, unpublished data.

- Republic of Iraq, Ministry of Transportation, Iraqi Meteorological Organization & Seismology, Statistical Information about Weather Stations, unpublished data

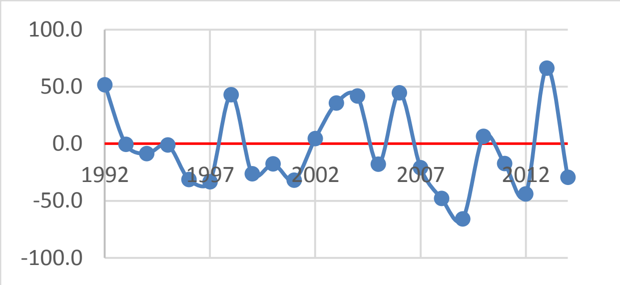

Figure 7: Pirmam Station Annual Rainfall Change mm – Winter

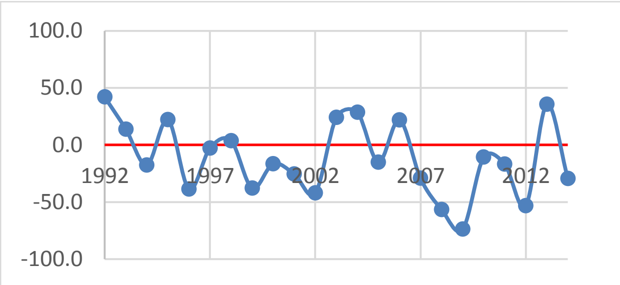

Figure 8: Erbil Station Annual Rainfall Change mm – Winter

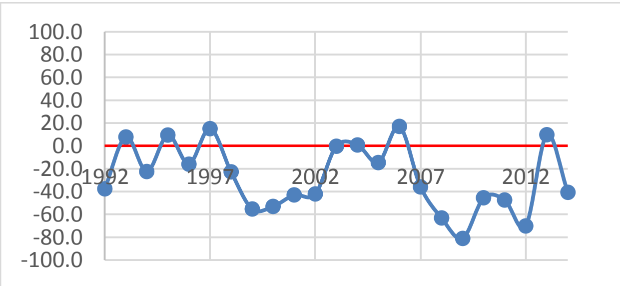

Figure 9: Makhmur Station Annual Rainfall Change mm – Winter

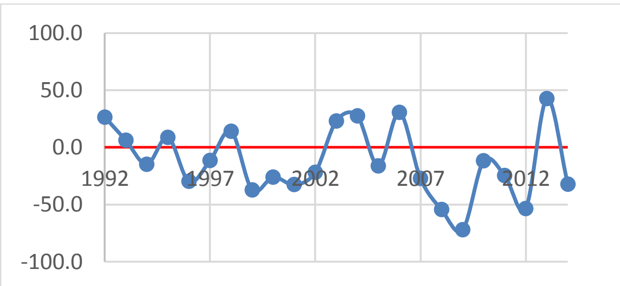

Figure 10: Erbil Area Annual Rainfall Change mm – Winter

3.5.2. Annual rainfall averages of Spring:

Table (5) below shows the annual rainfall of spring for the consecutive 23-years of the study period compared to the SNP average of 1961 – 1990, the outcome of the data in this table can be summarized as follow:

1. The annual rainfall averages of spring for the SNP 61 – 90 were 215.5, 157.1 and 124.4 mm for the three stations Pirmam, Erbil and Makhmur respectively, and the average of the three stations of the study area was 165.7 mm.
2. The annual rainfall average of spring for the 3 stations for the consecutive 23 years of the study period were 172.3, 124.8 and 80.3 mm for the three stations Pirmam, Erbil and Makhmur respectively, and the average of the three stations of the study area was 125.8 mm.
3. Based on the facts in point 1 and 2 above, and similar to the annual rainfall averages and winters annual rainfall averages, all the three stations in the study area recorded a negative change in Springs annual rainfall averages but with different quantities and decrease percentages, and among the three stations, Makhmur station stayed with the highest negative change among the stations of the study area and recorded the highest negative change in the annual rainfall of winter with a percentage of change (- 35.4 %) and an decrease of (44.1 mm) compared to the average of the SNP 61 – 90, and Erbil station also recorded a negative change of Springs annual rainfall and came in the second rank with percentage of change (- 20.5 %) and a decrease of (32.3 mm) compared to the average of the SNP 61 – 90, and Pirmam station was in the third rank but also recorded a negative change of Springs annual rainfall with a percentage of change (- 20.0 %) and an decrease of (43.2 mm) compared to the average of the SNP 61 – 90, while the average of the three stations was a negative change with a percentage of change (- 24.1 %) and an decrease of (39.9 mm).

4. The results of the standard deviation (SD) of the percentages of change for Springs annual rainfall averages for the consecutive 23 years of the study period shows that Pirmam station was the most stable station among the three stations of the study area with the lowest SD value (25.5), and Makhmur station was the most unstable station among the three stations of the study area with the highest SD value (48.2), while the SD value of Erbil station was (32.3), and those SD values were proved by the results of the percentage of change in Springs annual rainfall averages which Makhmur station has the highest.

5. In Pirmam station, only 4 years out of the consecutive 23 years of the study period recorded a positive change in Springs annual rainfall averages compared to the SNP average of 1961 – 1990, while in 19 years a negative change in the annual rainfall average has been recorded. The maximum negative change in Pirmam stations winter annual rainfall was recorded in 1999 with a decrease percentage of (-72.7 %) and a decrease of (156.7 mm), and the maximum positive change in Pirmam station Springs annual rainfall average was recorded in 1994 with an increase percentage of (36.1 %) and an increase of (77.8 mm) compared to the SNP average of 1961 – 1990.

6. In Erbil station, 6 years out of the consecutive 23 years of the study period recorded a positive change in Springs annual rainfall averages compared to the SNP average of 1961 – 1990, while in 17 years a negative change in Springs annual rainfall average has been recorded. The maximum positive change in Erbil Stations annual rainfall of Springs was recorded in 1993 with an increase percentage of (75.1 %) and an increase of (118.0 mm), and the maximum negative change in Erbil station winters annual rainfall average was recorded in 1999 with a decrease percentage of (80.3 %) and a decrease of (126.1 mm) compared to the SNP average of 1961 – 1990.

7. In Makhmur station, only 2 years out of the consecutive 23 years of the study period recorded a positive change in Springs annual rainfall averages compared to the SNP average of 1961 – 1990, while in 21 years a negative change in winters annual rainfall average has been recorded. The maximum positive change in Makhmur Stations Spring annual rainfall was recorded in 1993 with an increase percentage of (155.5 %) and an increase of (193.4 mm), and the maximum negative change in Makhmur stations Spring annual rainfall average was recorded in 1999 with a decrease percentage of (- 90.0 %) and a decrease of (- 111.9 mm) compared to the SNP average of 1961 – 1990.

8. Regarding the averages of Springs annual rainfall of the three stations in the study area, only 4 years out of the consecutive 23 years of the study period recorded a positive change in Springs annual rainfall averages compared to the SNP average of 1961 – 1990, while in 19 years a negative change in Springs annual rainfall average has been recorded. The maximum positive change in the average of the three stations in the study area for Springs annual rainfall was recorded in 1993 with an increase percentage of (61.8 %) and an increase of (102.5 mm), and the maximum negative change in Springs average of the three stations in the study area for the annual rainfall average of Spring was recorded in 1999 with a decrease percentage of (- 79.4 %) and an increase of (131.6 mm) compared to the SNP average of 1961 – 1990.

9. In both Erbil and Pirmam stations, the last positive change in Springs annual rainfall average was recorded in 2003 and from 2004 onward the annual rainfall averages of Spring decreased in different percentages each year.

While in Makhmur station, the last positive change in Springs annual rainfall average was recorded in 1996, and from 1997 onward the annual rainfall averages of Spring decreased in different percentages each year.

Table 5: Annual Rainfall Averages of Spring in Erbil Area

Spring Rain															
Pirmam				Erbil				Makhmur				Erbil Area			
Year	Spring	Change	New - Old	Year	Spring	Change	New - Old	Year	Spring	Change	New - Old	Year	Spring	change	New - Old
60 - 90	215.5	%		60 - 90	157.1			60 - 90	124.4			60 - 90	165.7		
1992	152.3	-29.3	-63.2	1992	121.4	-22.7	-35.7	1992	83.1	-33.2	-41.3	1992	118.9	-28.2	-46.8
1993	211.6	-1.8	-3.9	1993	275.1	75.1	118.0	1993	317.8	155.5	193.4	1993	268.2	61.8	102.5
1994	293.3	36.1	77.8	1994	169.2	7.7	12.1	1994	51.2	-58.8	-73.2	1994	171.2	3.3	5.5
1995	133.5	-38.1	-82.0	1995	159.3	1.4	2.2	1995	96.1	-22.7	-28.3	1995	129.6	-21.8	-36.1
1996	203.0	-5.8	-12.5	1996	164.2	4.5	7.1	1996	140.0	12.5	15.6	1996	169.1	2.0	3.4
1997	191.0	-11.4	-24.5	1997	133.8	-14.8	-23.3	1997	46.2	-62.9	-78.2	1997	123.7	-25.4	-42.0
1998	219.8	2.0	4.3	1998	129.6	-17.5	-27.5	1998	67.0	-46.1	-57.4	1998	138.8	-16.2	-26.9
1999	58.8	-72.7	-156.7	1999	31.0	-80.3	-126.1	1999	12.5	-90.0	-111.9	1999	34.1	-79.4	-131.6
2000	74.1	-65.6	-141.4	2000	44.8	-71.5	-112.3	2000	28.1	-77.4	-96.3	2000	49.0	-70.4	-116.7
2001	172.4	-20.0	-43.1	2001	144.6	-8.0	-12.5	2001	83.0	-33.3	-41.4	2001	133.3	-19.5	-32.4
2002	246.4	14.3	30.9	2002	189.1	20.4	32.0	2002	119.9	-3.6	-4.5	2002	185.1	11.7	19.4
2003	231.6	7.5	16.1	2003	159.9	1.8	2.8	2003	93.4	-24.9	-31.0	2003	161.6	-2.5	-4.1
2004	165.5	-23.2	-50.0	2004	90.0	-42.7	-67.1	2004	81.0	-34.9	-43.4	2004	112.2	-32.3	-53.5
2005	176.5	-18.1	-39.0	2005	94.1	-40.1	-63.0	2005	42.4	-65.9	-82.0	2005	104.3	-37.0	-61.4
2006	175.0	-18.8	-40.5	2006	110.1	-29.9	-47.0	2006	103.2	-17.0	-21.2	2006	129.4	-21.9	-36.3
2007	184.8	-14.2	-30.7	2007	103.7	-34.0	-53.4	2007	71.7	-42.4	-52.7	2007	120.1	-27.5	-45.6
2008	100.2	-53.5	-115.3	2008	67.9	-56.8	-89.2	2008	54.5	-56.2	-69.9	2008	74.2	-55.2	-91.5
2009	174.3	-19.1	-41.2	2009	117.4	-25.3	-39.7	2009	68.5	-44.9	-55.9	2009	120.1	-27.5	-45.6
2010	215.2	-0.1	-0.3	2010	101.8	-35.2	-55.3	2010	70.9	-43.0	-53.5	2010	129.3	-22.0	-36.4
2011	178.4	-17.2	-37.1	2011	144.7	-7.9	-12.4	2011	88.1	-29.2	-36.3	2011	137.1	-17.3	-28.6
2012	159.7	-25.9	-55.8	2012	113.4	-27.8	-43.7	2012	37.8	-69.6	-86.6	2012	103.6	-37.5	-62.1
2013	99.1	-54.0	-116.4	2013	95.7	-39.1	-61.4	2013	30.6	-75.4	-93.8	2013	75.1	-54.7	-90.6
2014	147.4	-31.6	-68.1	2014	110.6	-29.6	-46.5	2014	60.7	-51.2	-63.7	2014	106.2	-35.9	-59.5
Average	**172.3**	**-20.0**	-43.2	**Average**	**124.8**	**-20.5**	-32.3	**Average**	**80.3**	**-35.4**	-44.1	**Average**	**125.8**	**-24.1**	-39.9
sd		**25.5**		**sd**		**32.3**		**sd**		**48.2**		**sd**		**28.9**	

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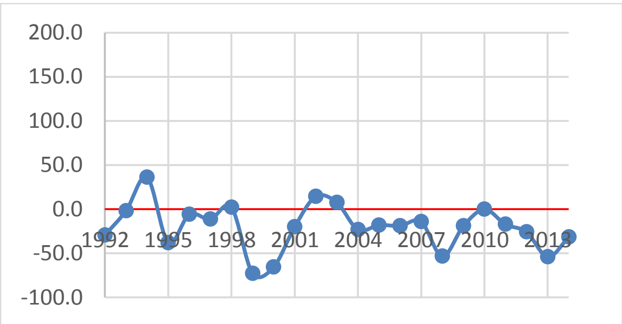

Figure 11: Pirmam Station Annual Rainfall Change mm – Spring.

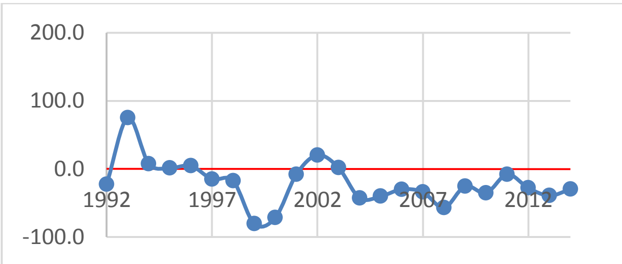

Figure 12: Erbil Station Annual Rainfall Change mm – Winter

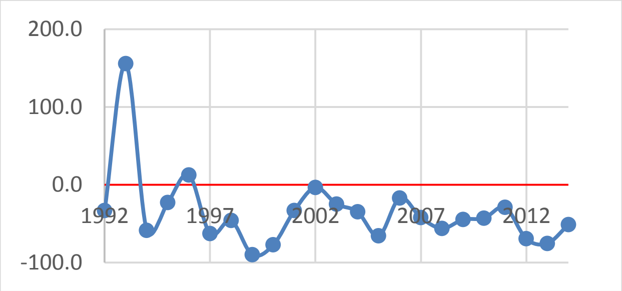

Figure 13: Makhmur Station Annual Rainfall Change mm – Winter

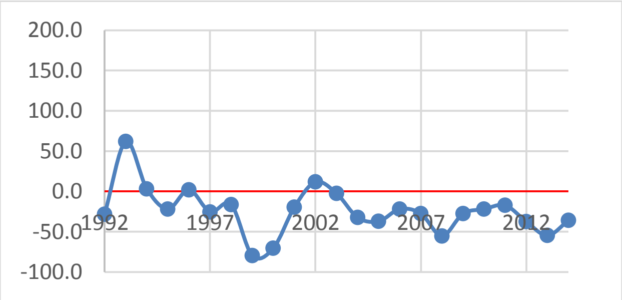

Figure 14: Erbil Area Annual Rainfall Change mm – Winter

3.5.3. Annual rainfall averages of Fall:

Table (2-13) below shows the annual rainfall of Fall season for the consecutive 23-years of the study period compared to the SNP average of 1961 – 1990, the outcome of the data in this table can be summarized as follow:

1. The annual rainfall averages of Fall season for the SNP 61 – 90 were 117.1, 53.9 and 52.9 mm for the three stations Pirmam, Erbil and Makhmur respectively, and the average of the three stations of the study area was 74.6 mm.

2. The annual rainfall average of Fall for the 3 stations for the consecutive 23 years of the study period were 96.5, 64.2 and 45.3 mm for the three stations Pirmam, Erbil and Makhmur respectively, and the average of the three stations of the study area was 68.67 mm.

3. Based on the facts in point 1 and 2 above, only two stations in the study area (Pirmam & Makhmur) recorded a negative change in Falls annual rainfall averages but with different quantities and decrease percentages, and among the two stations, Pirmam station recorded the highest negative change among the stations of the study area and recorded the highest negative change in the annual rainfall of Fall with a percentage of change (- 17.6 %) and an decrease of (- 20.6 mm) compared to the average of the SNP 61 – 90, and Makhmur station also recorded a negative change of Falls annual rainfall and came in the second rank with percentage of change (- 14.4 %) and a decrease of (- 7.6 mm) compared to the average of the SNP 61 – 90.

4. While Erbil station was the only station which recorded a positive change of Falls annual rainfall averages with a percentage of change (+ 19.2 %) and an increase of (10.3 mm) compared to the average of the SNP 61 – 90, while the average of the three stations was also a negative change with a percentage of change (- 7.9 %) and a decrease of (- 5.9 mm).

5. The results of the standard deviation (SD) of the percentages of change for Falls annual rainfall averages for the consecutive 23 years of the study period shows that Erbil station has the largest SD value among the stations of the study area (102.8) due to the wide fluctuation of its average compared to the average of SNP, , and Makhmur station has the second highest SD value among the three stations of the study area with an SD value (82.3), while the SD value of Pirmam station was the lowest (64.5).

6. In Pirmam station, only 5 years out of the consecutive 23 years of the study period recorded a positive change in Falls annual rainfall averages compared to the SNP average of 1961 – 1990, while in 18 years a negative change in falls annual rainfall average has been recorded. The maximum negative change in Pirmam stations winter annual rainfall was recorded in 2011 with a decrease percentage of (-92 %) and a decrease of (107.7 mm), and the maximum positive change in Pirmam station Springs annual rainfall average was recorded in 1995 with an increase percentage of (138.5

%) and an increase of (162.2 mm) compared to the SNP average of 1961 – 1990.

7. In Erbil station, 10 years out of the consecutive 23 years of the study period recorded a positive change in Falls annual rainfall averages compared to the SNP average of 1961 – 1990, while in 13 years a negative change in Falls annual rainfall average has been recorded. The maximum positive change in Erbil Stations annual rainfall of Fall was recorded in 1993 with an increase percentage of (259.9 %) and an increase of (140.1 mm), and the maximum negative change in Erbil station Falls annual rainfall average was recorded in 2008 with a decrease percentage of (- 90.0 %) and a decrease of (- 48.5 mm) compared to the SNP average of 1961 – 1990.

8. In Makhmur station, only 8 years out of the consecutive 23 years of the study period recorded a positive change in Falls annual rainfall averages compared to the SNP average of 1961 – 1990, while in 15 years a negative change in Falls annual rainfall average has been recorded. The maximum positive change in Makhmur Station Falls annual rainfall was recorded in 1993 with an increase percentage of (183.7 %) and an increase of (97.2 mm), and the maximum negative change in Makhmur station Falls annual rainfall average was recorded in 1999 with a decrease percentage of (- 97.7 %) and a decrease of (- 51.7 mm) compared to the SNP average of 1961 – 1990.

9. Regarding the averages of Falls annual rainfall of the three stations in the study area, only 9 years out of the consecutive 23 years of the study period recorded a positive change in Springs annual rainfall averages compared to the SNP average of 1961 – 1990, while in 14 years a negative change in Falls annual rainfall average has been recorded. The maximum positive change in the average of the three stations in the study area for Falls annual rainfall was recorded in 1995 with an increase percentage of (167.2 %) and an increase of (124.7 mm), and the maximum negative change in Falls average of the three stations in the study area for the annual rainfall average of Fall was recorded in 2011 with a decrease percentage of (- 89.8 %) and an increase of (- 67.0 mm) compared to the SNP average of 1961 – 1990.

Table 6: Annual Rainfall Averages of Fall in Erbil Area

Fall Rain															
Pirmam				Erbil				Makhmur				Erbil Area			
Year	Fall	Change	New - Old	Year	Fall	Change	New - Old	Year	Fall	Change	New - Old	Year	Fall	change	New - Old
60 - 90	117.1	%		60 - 90	53.9	%		60 - 90	52.9	%		60 - 90	74.6	%	
1992	29.8	-74.6	-87.3	1992	53.9	0.0	0.0	1992	1.5	-97.2	-51.4	1992	28.4	-61.9	-46.2
1993	238.4	103.6	121.3	1993	194	259.9	140.1	1993	150.1	183.7	97.2	1993	194.2	160.3	119.6
1994	224.4	91.6	107.3	1994	137.9	155.8	84.0	1994	122.5	131.6	69.6	1994	161.6	116.6	87.0
1995	279.3	138.5	162.2	1995	186.2	245.5	132.3	1995	132.5	150.5	79.6	1995	199.3	167.2	124.7
1996	94	-19.7	-23.1	1996	47.5	-11.9	-6.4	1996	21.9	-58.6	-31.0	1996	54.5	-27.0	-20.1
1997	51.9	-55.7	-65.2	1997	25.9	-51.9	-28.0	1997	15.5	-70.7	-37.4	1997	31.1	-58.3	-43.5
1998	99.6	-14.9	-17.5	1998	77.1	43.0	23.2	1998	82.2	55.4	29.3	1998	86.3	15.7	11.7
1999	43.4	-62.9	-73.7	1999	6.5	-87.9	-47.4	1999	1.2	-97.7	-51.7	1999	17.0	-77.2	-57.6
2000	35.3	-69.9	-81.8	2000	21	-61.0	-32.9	2000	17.9	-66.2	-35.0	2000	24.7	-66.8	-49.9
2001	33.6	-71.3	-83.5	2001	22.8	-57.7	-31.1	2001	40.3	-23.8	-12.6	2001	32.2	-56.8	-42.4
2002	65.5	-44.1	-51.6	2002	26.2	-51.4	-27.7	2002	20.6	-61.1	-32.3	2002	37.4	-49.8	-37.2
2003	65.2	-44.3	-51.9	2003	60.6	12.4	6.7	2003	25.0	-52.7	-27.9	2003	50.3	-32.6	-24.3
2004	105	-10.3	-12.1	2004	96.9	79.8	43.0	2004	73.3	38.6	20.4	2004	91.7	23.0	17.1
2005	201.2	71.8	84.1	2005	113.9	111.3	60.0	2005	54.8	3.6	1.9	2005	123.3	65.3	48.7
2006	56.1	-52.1	-61.0	2006	24.3	-54.9	-29.6	2006	15.5	-70.7	-37.4	2006	32.0	-57.1	-42.6
2007	167.4	43.0	50.3	2007	110.6	105.2	56.7	2007	82.9	56.7	30.0	2007	120.3	61.3	45.7
2008	18.4	-84.3	-98.7	2008	5.4	-90.0	-48.5	2008	1.8	-96.6	-51.1	2008	8.5	-88.6	-66.1
2009	114.9	-1.9	-2.2	2009	101.9	89.1	48.0	2009	40.3	-23.8	-12.6	2009	85.7	14.9	11.1
2010	67.6	-42.3	-49.5	2010	52.9	-1.9	-1.0	2010	34.7	-34.4	-18.2	2010	51.7	-30.7	-22.9
2011	9.4	-92.0	-107.7	2011	6.1	-88.7	-47.8	2011	7.3	-86.2	-45.6	2011	7.6	-89.8	-67.0
2012	36.4	-68.9	-80.7	2012	16.7	-69.0	-37.2	2012	16.3	-69.2	-36.6	2012	23.1	-69.0	-51.5
2013	108.6	-7.3	-8.5	2013	69.5	28.9	15.6	2013	66.4	25.5	13.5	2013	81.5	9.2	6.9
2014	73.5	-37.2	-43.6	2014	19.4	-64.0	-34.5	2014	17.6	-66.7	-35.3	2014	36.8	-50.6	-37.8
Average	96.5	-17.6	-20.6	Average	64.2	19.2	10.3	Average	45.3	-14.4	-7.6	Average	68.67	-7.9	-5.9
sd		64.5		sd		102.8		sd		82.3		sd		76.1	

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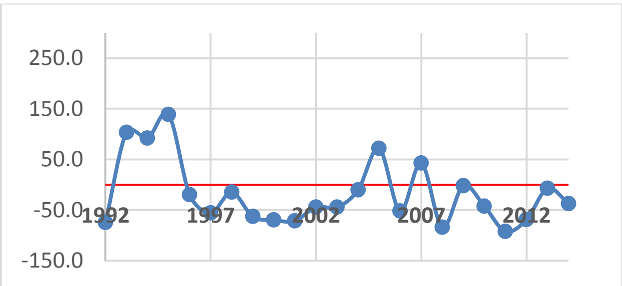

Figure 15: Pirmam Station Annual Rainfall Change mm – Fall

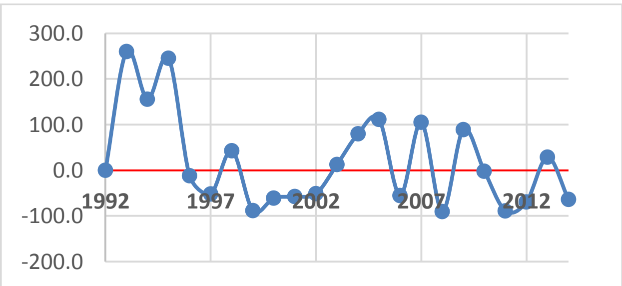

Figure 16: Erbil Station Annual Rainfall Change mm – Spring

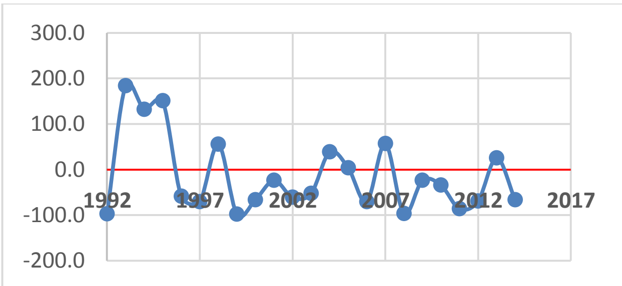

Figure 17: Makhmur Station Annual Rainfall Change mm – Spring

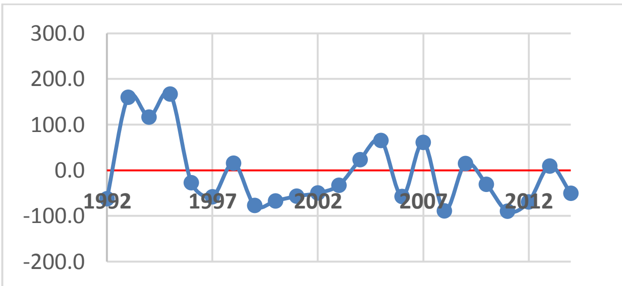

Figure 18: Erbil Area Annual Rainfall Change mm – Spring

Table 7: Summary of Annual \ Seasons Annual average rainfall changes in Erbil Area Stations

Number of Years with Positive & Negative Changes compared with 1961 – 1990 SNP

Station	Annual (-) Change	Annual (+) Change	Winter (-) Change	Winter (+) Change	Spring (-) Change	Spring (+) Change	Fall (-) Change	Fall (+) Change
Pirmam	14	9	17	6	19	4	18	5
Erbil	15	8	15	8	17	6	13	10
Makhmur	21	2	17	6	21	2	15	8
EA	16	7	15	8	19	4	14	9

Figure 19: Summary of Annual \ Seasons Annual average rainfall changes in Erbil Area Stations

Number of Years with Positive & Negative Changes compared with 1961 – 1990 SNP

6. CONCLUSION

Rainfall is one of the vital climatic factors that can indicate climate change. Spatial and temporal changes of rainfall would influence runoff, soil moisture and groundwater reserves. Analysis of

precipitation trends is important in studying the impacts of climate change for water resources planning and management. The present study was conducted to determine changes in the annual and seasonal total rainfall over Erbil Area region in Iraqi Kurdistan Region using 23 years (1992-2014) monthly rainfall data at three rain-gauge stations, the widely used WMO 1961 – 1990 (61 – 90) standard normal period is compared to other consecutive 30-year normal periods in detail.

As well known, that the global climate is currently changing, the last decade of 20th century and the beginning of 21st century were the warmest period in the earth.

Climate change refers to any significant change in the measure of climate lasting for an extended period of time, it includes major changes in climate elements.

The WMO proposed the term climate change to encompass all forms of climatic variability on time scale longer than 10 years regardless to the causes.

Any long-term changes in temperature or rainfall causes changes of the general or regional climate or even local climate, in the previous 30 years, researchers started to analyze fluctuations and changes in temperature & rainfall, and study theme through the trends and quantities of those changes in different areas in the world. And for the purpose of comparison and analysis, the averages of different climate elements of the period (1961 – 1990) has been considered as global averages by the worlds Meteorological Organization (WMO) (A. Ismaeel, 2015).

The widely used WMO 1961–1990 (61–90) standard normal period is considered as baseline period in this study and had been compared to other consecutive 23-years periods of this study in detail to extract the positive and negative percentages of changes in the annual, monthly and seasonal averages of temperature and rainfall between both periods, and the current change in temperature and rainfall relative to 1961 - 1990.

The annual and seasonal changes of rainfall were investigated by comparing them with WMO-SNP (World Metrological Organization – Standard Normal Period).

For this purpose, records from 3 stations over the study area (Erbil Area) for the period of 1992– 2014 were analyzed, the results indicated that a decreasing trend varied between 11.6 mm/year at Pirmam station and 10.8 mm/year at Erbil station, and 28.0 mm/year at Makhmur station. The presence of trend in annual and seasonal rainfall series determined by the widely used WMO 1961 – 1990 (61 – 90) standard normal period which is compared to other consecutive 23-year normal periods in detail and the analysis is being made of the seasonal and annual average of rainfall in the period (1992- 2014) by analyzing their deviation from the average of the SNP (1961-1990).

The knowledge of temporal pattern of rainfall trends analyzed in this study is a basic and important requirement for agricultural planning and management of water resources.

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