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Statistical Analysis of Rainfall Variations in Duhok City and Semel District, Kurdistan Region of Iraq

Najmaldin Ezaldin Hassan*

Faculty of Science, Environmental Department, University of Zakho, Kurdistan region, Iraq

Corresponding Authors:** ***Najmaldin Ezaldin Hassan, *Faculty of Science, Environmental Department, University of Zakho, Kurdistan region, Iraq*

Abstract: *Data on rainfall are a crucial meteorological input for planning and management studies of water resources as well as agricultural modeling systems. Environmental conditions, particularly rainfall and water availability, have a significant impact on crop choice and agricultural production output. The influence of climate variables, such as rainfall, is so strong in Kurdistan that overall agricultural productions are now in danger. In this study, rainfall data of 48 years (1974 to 2022) were used to determine variation in rainfall in Duhok city and Semel district in Kurdistan Region of Iraq. Annually rainfall amount data of forty-eight years (1974- 2022) was obtained from the Directorate of Agriculture (Duhok and Semele). An analysis of rainfall variations in the Duhok city and Semel district shows that 1974-1975 (158 and135mm, respectively) recorded the least average rainfall across the study area and over the years while the highest average rainfall was recorded in 2018-2019 (1199.3, 991mm, respectively). Although in 2007-2008 recorded the second least average rainfall (216 and 141.6mm, respectively), and the second highest rainfall in Semel district is in 1988-1989, but in Duhok city is in (1987-1988) over the study period. Non availability of rainfall data for 1990 year in Semel was a major limitation to this study; because in this year the uprising began and people migrated abroad. Similarly, trend analysis shows that there are increasing (+ve), decreasing (-ve) and somewhat constant trends for the different years. Statistical measures (mean, median, maximum, minimum, standard deviation, variance, skewness, kurtosis and coefficient of variation, etc.) have been used. The analysis of rainfall variations from the study area shows that Duhok city and Semel district recorded the average annual rainfall amount of (533.7 and 437.18mm) over the years. The results indicated that for the annual rainfall, median, maximum, minimum, standard deviation, variance, skewness, kurtosis, coefficient of variation and correlation coefficients was found as (540.8, 463.7mm), (1199.3, 991mm), (158, 135mm), (207.1, 169.95mm), (42871.4, 28884.49mm), (0.6596, 0.419mm), (1.009, 1.282mm), (38.79, 38.88%), and (0.715) respectively during the study period. A reliable indicator of climate trends can be found in the temporal fluctuation of rainfall. In addition, these rainfall variations are used in many engineering aspects, including design of massive civil engineering structures like dams, design of water supply networks, it greatly contributes in water resources system planning and management, etc. Furthermore, the rainfall variations are not only important in engineering aspects but also heavily in agriculture. Therefore, this research paper presents an analysis of temporal variation of rainfall in Semel, Kurdistan Region. Initial results show some interesting trends in rainfall over a period of 48 years.*

Keywords: *Annual rainfall, Trends, Skewness, Kurtosis, Duhok city and Semel district.*

1. INTRODUCTION

The rain is a renewable resource that is very variable in place and time and is prone to dwindling or increasing as a result of both manmade and natural factors [1]. The main environmental issue preventing the development of semiarid regions is rainfall, which is a meteorological phenomenon with a significant impact on human activity [2]. The amount of rainfall is a climatic factor that influences how people live. Every aspect of the biological system is impacted, but particularly the fauna and flora [3]. Rainfall is a crucial climate variable that has a big impact on agricultural output and the growth of the national economy [4]. The amount of water that is available to satisfy various demands, including those for agricultural, industrial, domestic water supply, and hydroelectric power generation, depends significantly on the amount of rainfall that an area receives [5]. Less rainfall has a negative impact on the economy, agricultural productivity, and water resources [6]. Rainfall is the single most crucial component of climate affecting agriculture and water management in each region since its availability or absence dictates the amount of wetness or dryness during the growing season [7].

Understanding rainfall variability is crucial for managing precious water resources, which are constantly under pressure from rising water demands, population growth, and economic development [8]. It is generally known that global warming is affecting rainfall on both a global and regional basis [9-10].

According to Odjugo [11], the time and length of the rainy and dry seasons had shifted, as have the seasonal variability of the weather and climate and the seasonal variation of the water bodies.

The authors state that there has been increased worry about the direction and implication of the changes of habitation and infrastructures because rainfall as a climatic element is known to be shifting globally. According to Ekpoh, & Nsa [12], there is enough evidence to support the hypothesis that global temperatures are rising as a result of increased emissions of greenhouse gases into the atmosphere, specifically Carbon Dioxide, Nitrous Oxide, Methane, and Chlorofluorocarbons. They argue that this increased global warming has the potential to cause significant climatic disturbances that could have a significant impact on rainfall [12]. Rainfall has an impact on reducing air pollution [13, 14] and odour [15] in the regions, as noted in previous studies.

Several researches had revealed that the frequency and intensity of rainfall is changing along with the temperature [16-19]. Rains starting later in the season, having more dry days during the rainy season, and having higher maximum temperatures are all signs of climate change [20].

According to Obioha [21], the Sahelian zone of northeastern Nigeria have been going through a climate change that is being marked by a decline in rainfall and an increase in the rate of dryness and heat. Similar trends in change were seen between 1900 and 2005 in several locations, including Eastern North America, Eastern South America, Northern Europe, Central Asia, Southern Africa, and Southern Asia [22].

Understanding the nature of various climatic systems and their effects on the environment and society requires knowledge of climate variability over the course of instrumental records and beyond at various temporal and spatial scales [23].

In Nigeria, 28 meteorological stations were examined by Adefolalu [24] to examine rainfall trends from 1911 to 1980. A 40-year moving average of the data revealed a tendency towards decreasing rainfall.

Eludoyin et al. [25] observed some variations in most of the months across the two decades when analyzing the monthly rainfall distribution in Nigeria during 1985-1994 and 1995-2004.

Ayansina et al. [26] also looked at the seasonal variation in rainfall in Nigeria's Guinea savannah region and came to the conclusion that this variation is continuing to rise due to climate change. This suggests that location, distance, and time all affect rainfall trends globally.

This study's objective is to determine changes in the seasonal variation of rainfall and its impacts in the study areas. Adding to the current understanding of rainfall variability and distribution across Kurdistan would also help to improve decision-making and planning in the water and agriculture sectors.

In order to keep this information current for everyone's use, we also advise that research on rainfall variability was conducted continuously as and when new rainfall data become available.

2. MATERIALS AND METHODS

2.1. Study Area

Both study areas are located in the Iraqi Kurdistan Region. Duhok city (lies between latitudes 36°85′75″ N longitudes 42°97′29″ E) and Semel (lies between latitudes 36°51′30″ N longitudes 42°51′35″ E). Semel is 8.7 miles west of the town of Dohuk (Figure1). Both locations can be found between 430 and 450 meters above sea level [27]. With a mean annual temperature and precipitation of 19.2°C and 450–500 mm/year, respectively, those regions have a semi-arid climate. Duhok experiences hot, nearly rainless summers and chilly to cold, wet winters, much like the majority of Upper Mesopotamia. The colder months see the majority of precipitation, with late winter and early spring being just the wettest. Rainfall in study areas takes place during November to April.

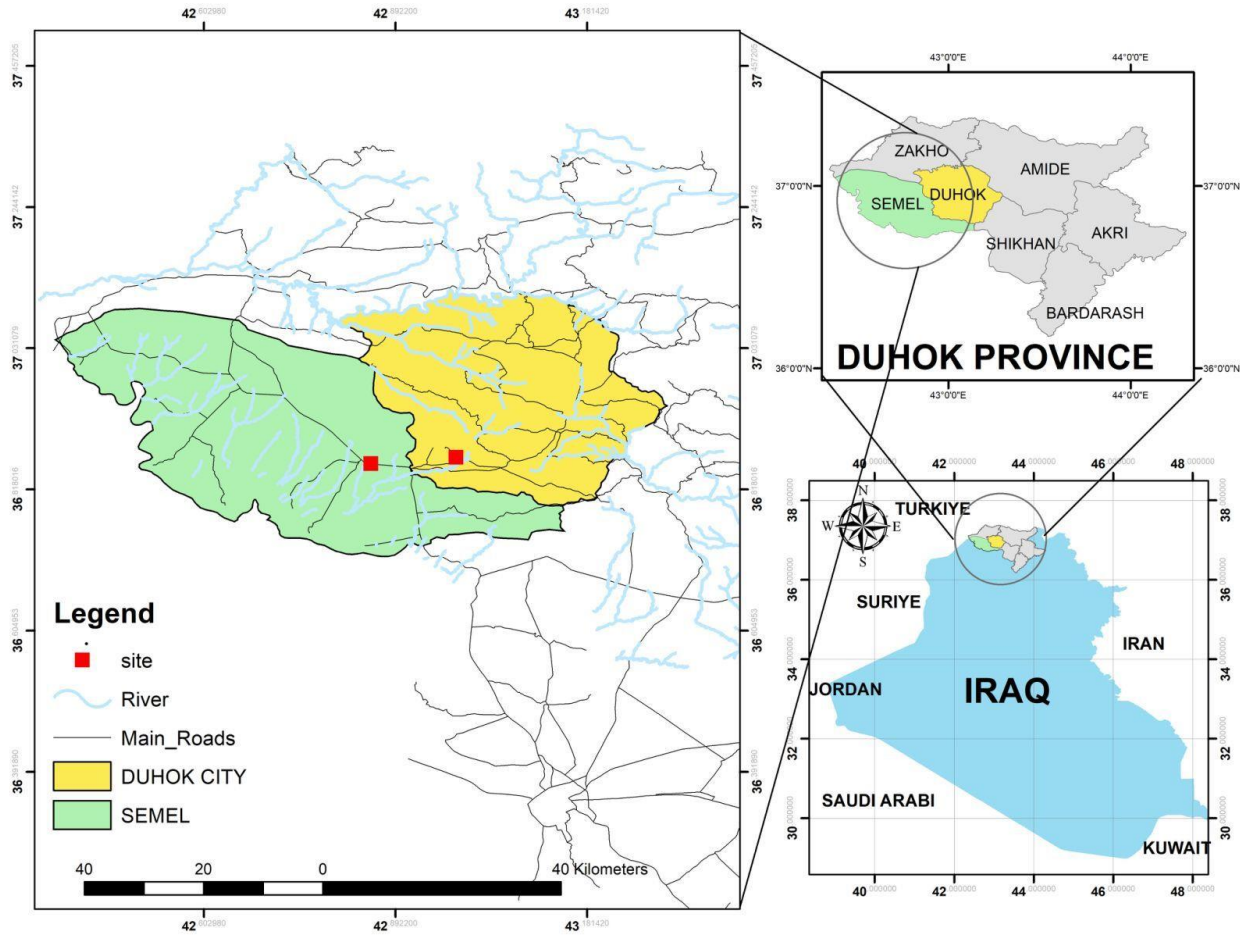

Figure1. *Location map of rain gauge stations in the study areas*

2.2. Data Collection

The data were collected on total annual rainfall for a period of 48 years (1974 to 2022) for two meteorological stations (fig. 1) in Duhok city and Semel district of Kurdistan Region that are representative of the study areas. There was a gap in 1990-1991 in Semel district and no data were recorded and this is due to the occurrence of the uprising in this year (We did not use this year's data). These data were supplemented by Duhok and Semel Agriculture Administrations in Kurdistan Region. The data collected were processed into total annual values for all the locations.

2.3. Data Analysis Techniques

For this study's analysis of rainfall variability and trend, many statistical techniques have been used. The data collected were subjected to statistical analysis using the Graphpad prism 5 and Past3 software program [28]. The data were subjected to statistical analysis such as the average, mode, median, standard deviation (SD), standard error (SE), skewness, kurtosis, coefficient of variation (CV), biodiversity index, etc. (Table 2,3).

3. Results and Discussion

Table 1 shows the statistical summation, trends and difference of rainfall summaries by all annual. It shows the amount of rainfall during 48 years, which is 25620mm and 20547.5 mm in Duhok city and Semel district, respectively. The highest amount of annual rainfall in the Duhok city from 2018-2019 with total sum of 1199.3mm, followed by 1987-1988 (909.5mm) and 1992-1993 with 891.4mm respectively. Also, the highest amount of annual rainfall in the Semel district from 2018-2019 with total sum of 991mm, followed by 1988-1989 (732.5mm) and 2019-2020 with 705mm respectively. While, the least amount was recorded in Duhok city at 1974-1975 with the sum of 158mm, followed by 2007-2008 with 216.6mm and 1998-1999 with the sum of 220mm respectively. Also, the least amount was recorded at 1974-1975 with the sum of 135mm, followed by 2007-2008 with 141.6mm and 1982-1983 with the sum of 153.5mm respectively.

The trends are not so different and are very close to each other and constantly changing annually. The distribution of the data in Duhok city is positively trends in 1975-1976, 1977-1978, 1979-1980, 1980-1981, 1984-1985, 1986-1987, 1987-1988, 1989-1990, 1991-1992, 1992-1993, 1994-1995, 1996-1997, 1999-2000, 2000-2001, 2002-2003, 2005-2006, 2008-2009, 2009-2010, 2012-2013, 2017-2018 and 2018-2019. Also, the distribution of the data in Semel district is positively trends in 1975-1976, 1978-1979, 1979-1980, 1983-1984, 1984-1985, 1985-1986, 1986-1987, 1988-1989, 1991-1992, 1993-1994, 1994-1995, 1996-1997, 1999-2000, 2000-2001, 2002-2003, 2003-2004, 2005-2006, 2008-2009, 2009-2010, 2012-2013, 2017-2018, 2018-2019 and 2021-2022. Other years not mentioned were negatively trends. The overall results show that Duhok has received the highest rainfall in the past 48 years and the rainfall difference is about 5000mm.

The results generally show that the rainfall varied more on annually over the study areas. As a result, not only will the produce from farms be impacted, but also the amount and quality of freshwater will be impaired. This has ramifications for both rain-fed agriculture and the freshwater system [29]. Therefore, better water resource management practices are required.

Table1. *Statistics of mean annual rainfall summaries in the study areas (1974-2022)*

Year	Sum		Trends		Difference	Year	Sum		Trends		Difference
	Semel	Duhok	Semel	Duhok			Semel	Duhok	Semel	Duhok	
1974-1975	135	158	------	------	-23	**1998-1999**	188.2	220	-ve	-ve	-31.8
1975-1976	463.7	583.1	+ve	+ve	-119.4	**1999-2000**	263.1	440	+ve	+ve	-176.9
1976-1977	415.7	314.9	-ve	-ve	100.8	**2000-2001**	560.1	541.6	+ve	+ve	18.5
1977-1978	331.4	448.9	-ve	+ve	-117.5	**2001-2002**	435.7	539.9	-ve	-ve	-104.2
1978-1979	455.8	313.8	+ve	-ve	142	**2002-2003**	517.6	731.1	+ve	+ve	-213.5
1979-1980	589.3	693	+ve	+ve	-103.7	**2003-2004**	532.1	558.5	+ve	-ve	-26.4
1980-1981	557.6	701.9	-ve	+ve	-144.3	**2004-2005**	448	554.2	-ve	-ve	-106.2
1981-1982	534.3	570.4	-ve	-ve	-36.1	**2005-2006**	548.9	690.9	+ve	+ve	-142
1982-1983	153.5	419.1	-ve	-ve	-265.6	**2006-2007**	499.1	606.6	-ve	-ve	-107.5
1983-1984	307.6	298	+ve	-ve	9.6	**2007-2008**	141.6	216	-ve	-ve	-74.4
1984-1985	401.4	472.9	+ve	+ve	-71.5	**2008-2009**	306.5	346.4	+ve	+ve	-39.9
1985-1986	406.4	434.6	+ve	-ve	-28.2	**2009-2010**	495.5	597.2	+ve	+ve	-101.7
1986-1987	526.5	445.4	+ve	+ve	81.1	**2010-2011**	390	450.5	-ve	-ve	-60.5
1987-1988	484.9	909.5	-ve	+ve	-424.6	**2011-2012**	266.6	345	-ve	-ve	-78.4
1988-1989	732.5	316.1	+ve	-ve	416.4	**2012-2013**	559	772.2	+ve	+ve	-213.2
1989-1990	154.2	443.3	-ve	+ve	-289.1	**2013-2014**	495.5	561.8	-ve	-ve	-66.3
1990-1991	--------	386.8	-------	-ve	------	**2014-2015**	491.5	605.6	-ve	+ve	-114.1
1991-1992	546	784.7	+ve	+ve	-238.7	**2015-2016**	467.2	590.1	-ve	-ve	-122.9
1992-1993	287.8	891.4	-ve	+ve	-603.6	**2016-2017**	345.5	429.7	-ve	-ve	-84.2
1993-1994	547.6	712.1	+ve	-ve	-164.5	**2017-2018**	403	517.8	+ve	+ve	-114.8
1994-1995	661	797.3	+ve	+ve	-136.3	**2018-2019**	991	1199.3	+ve	+ve	-208.3
1995-1996	476.5	536.4	-ve	-ve	-59.9	**2019-2020**	705	809.5	-ve	-ve	-104.5
1996-1997	553.6	597.4	+ve	+ve	-43.8	**2020-2021**	210.1	267.9	-ve	-ve	-57.8
1997-1998	302.4	550.1	-ve	-ve	-247.7	**2021-2022**	262	248.6	+ve	-ve	13.4
Sum							**20547.5 mm**	**25620mm**			

The annual rainfall variability indices for the Semel are shown in Fig. (2-5). An upward and downward trend of mean annual rainfall is significant in study areas as shown in figure 2, 3, 4 and 5 respectively. The annual timescale of the indices shows that the three years (1974-1975, 1982-1983 and 2007-2008 in Semel) and (1974-1975, 1998-1999 and 2007-2008 in Duhok city) recorded extreme drought with 1974-1975 been the driest year. Moderate drought occurred in four years in Semel district (1999-2000, 2011-2012, 2020-2021, and 2021-2022) and two years in Duhok city (2020-2021 and 2021-2022), and the remaining years were devoid of drought. Among the years with no drought in study areas, the wettest year was 2018-2019.

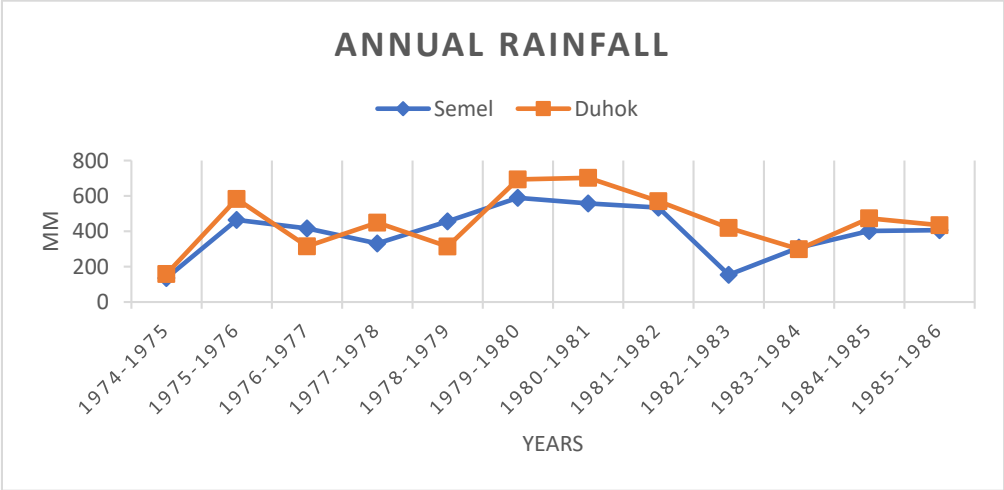

Figure2. *Total annual rainfall in Duhok city and Semel from (1974-1975) to (1985-1986)*

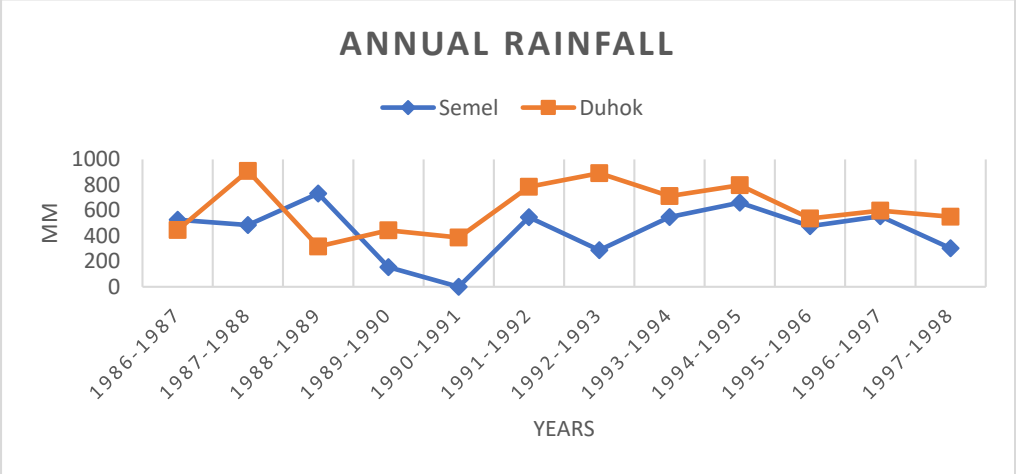

Figure3. *Total annual rainfall in Duhok city and Semel from (1986-1987) to (1997-1998)*

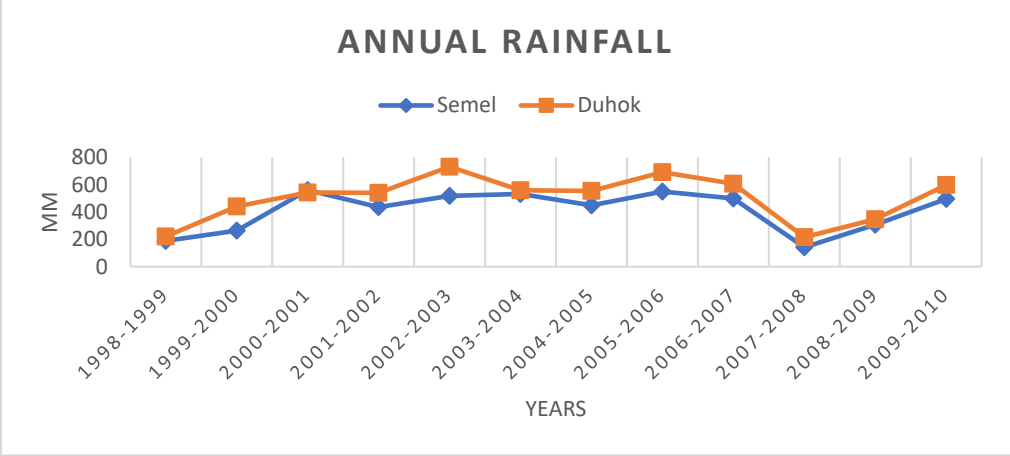

Figure4. *Total annual rainfall in Duhok city and Semel from (1998-1999) to (2009-2010)*

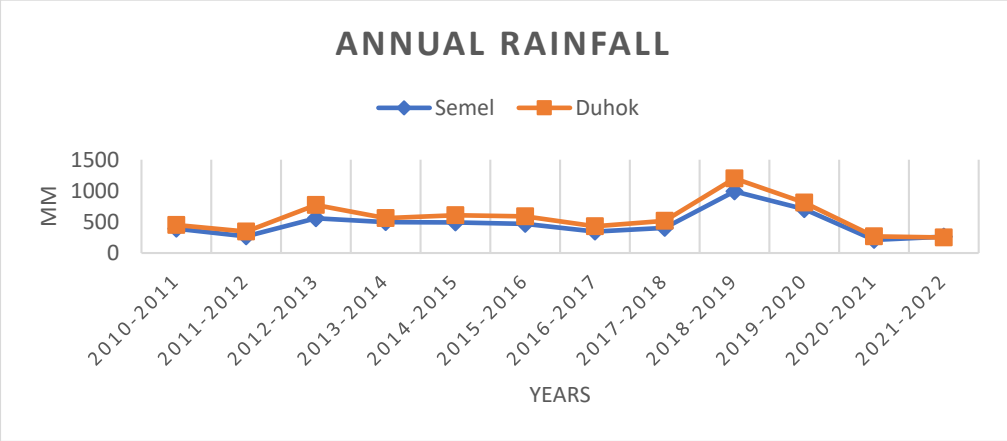

Figure5. *Total annual rainfall in Duhok city and Semel from (2010-2011) to (2021-2022)*

The results of the statistical analyses for the 48- years' time series of rainfall (1974-2022) are presented in Table 2. The average annual rainfall in Duhok city and Semel district was (533.7, 437.18 mm/yr) having a standard deviation of (207.1, 169.95 mm/yr), respectively. The minimum annual rainfall experienced was (158, 135 mm) while the maximum was (1199.3, 991 mm), respectively. The range between highest and least value of rainfall are (1041.3, 856mm), respectively, and this difference is a huge amount. The coefficients of kurtosis and skewness were (1.009, 1.282) and (0.6596, 0.419), respectively, which suggest that the data is positively skewed and normally distributed [30]. The coefficient of variation shows that the temporal variability of annual rainfall was (38.79, 38.875%), respectively. The Correlation coefficients, t test, F test and Chi^2 between study areas are (0.715, 2.4816, 1.4842 and 1.7822), respectively. During the study period, there were often upward and downward fluctuations.

Table2. *Statistical properties of annual rainfall at Duhok city and Semel gauged stations for 48 years*

Statistical properties	Semel	Duhok	**Statistical properties**	Semel	Duhok
No. of years	47	48	**Std.error**	24.79	29.89
Sum	20547.5	25620	**Mode**	495.5	NA
Average	437.18	533.7	**Skewness**	0.419	0.6596
Median	463.7	540.8	**kurtosis**	1.282	1.009
Minimum	135	158	**Geometric mean**	400.75	493.3
Maximum	991	1199.3	**t, df**	t=17.64, df=46	t=17.86 df=47
Range	856	1041	**P value (two tailed)**	< 0.0001	< 0.0001
SD	169.95	207.1	**CV%**	38.88%	38.79%
Variance	28884.49	42871.4	**Significant (alpha=0.05)?**	Yes	Yes
Correlation coefficients	0.715		**Chi^2**	1.7822	
t test	2.4816		**F test**	1.4842	

Table 3 indicate that rainfall diversity index during (1974-2022) are very well in Duhok city and Semel district, include Simpson (0.9761, 0.9756), Shannon (3.799, 3.775) and Evenness (0.9302, 0.9273), respectively. Simpson's index has a value between 0 and 1, however currently the higher the number, the more diverse the sample. Also, the value of Shannon index ranges between 0 and 5, usually ranging from 1.5 to 3.5, but now, the greater the value, the greater the sample diversity.

Table3. *Rainfall diversity index during (1974-2022)*

Alpha diversity index		
	Semel	**Duhok**
Individuals	20530	25599
Dominance_D	0.02438	0.02387
Simpson_1-D	0.9756	0.9761
Shannon_H	3.775	3.799

Evenness_e^H/S	0.9273	0.9302
Brillouin	3.756	3.783
Menhinick	0.3279	0.2999
Margalef	4.633	4.63
Equitability_J	0.9804	0.9813
Fisher_alpha	5.744	5.708
Berger-Parker	0.04823	0.0468

4. CONCLUSION

In this paper, the annual trends of rainfall were investigated in Duhok city and Semel city rainfall gauging stations. This study provides valuable insight into various degrees of rainfall as well as variability over the study areas. It records from study areas rain gauge station over 48 years from 1974–1975 to 2021–2022 were analyzed. The results indicated that the trends are not so different and are very close to each other and constantly changing annually.

Annual rainfall analysis shows that maximum rain showers are recorded during the 2018-2019 and the lowest rainfall intensity is recorded during 1974-1975 in the study areas. The results revealed that the average annual rainfall was recorded in Duhok city and Semel district are (533.7, 437.18), respectively, it also has the value of (38.79%, 38.88%) of coefficient of variation, respectively.

The positive findings of this study could aid hydraulic civil and water resource engineers in the development of hydraulic structures. Further studies should be carried out using rainfall and temperature base on climatic zones of the study areas.

Due to the lack of recent rainfall data, it is advised that environmental agencies and the meteorological agency work diligently to maintain up-to-date records of climate and weather indicators and make them freely available to researchers and the general public. For this will help sieve out climatic trends and improve on extreme weather prediction and forecasting in Kurdistan Region.

The impacts of rainfall on agricultural sustainability vary from economic condition of countries, regions and over a period of time. Any single moment of the crop cycle, as well as any conceivable combinations of timing for the crop cycle, could have an impact on the agriculture industry, whether it be little rainfall or excessive rainfall. Therefore, changing the crop cycle will not be beneficial. Crop damages in such circumstances have become a common occurrence in recent years.

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