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Assessment of Spatial and Temporal Monthly Rainfall Trend over Iraq

Sara Ali Muter*, ***Monim H. Al-Jiboori***, ***Yaseen K. Al-Timimi***

Department of Atmospheric Sciences, College of science, Mustansiriyah University, Baghdad, Iraq.
*Corresponding Author.

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Abstract

Rainfall time series are considered a parameter that can provide clues to climate change. Based on data from 39 stations, monthly rainfall to cover all regions of Iraq for a period (1980–2021) was analyzed statistically by using Microsoft Office Excel 2013. Rainfall patterns and the factors affecting them is determined using (GIS).The results show that Iraqi rainfall is highly dynamic and their pattern are not a cyclical pattern. The amount of rain decreases as we orient from the north towards the south, with the highest mean reaching in Ducan Station then decreasing as it goes southward, reaching Nukaib Station. There is a decreasing trend in rainfall for all stations, except for the stations (Baghdad, Kut, Hilla, Amarah, and Samawah). According to the calculation, the 2000s were drier than normal, the driest year was observed in 2021 over 42 years. The stations (Ducan, Amadiyah, Sulaymaniyah, Zakho, Dohuk and Salah al-Din) recorded the highest amounts of rain among the 39 stations, have the highest standard deviation values compared to the rest of the stations, have recorded a decrease from the averages greater than the other stations. We saw signs of a shift to a drier climate, especially in the stations that represent Northeast. The Pearson coefficient (R) was used to test the relationship between rainfall and elevation, and it was found that a strong relationship found to be 0.71. This indicates that elevation is not the only variable that affects the rainfall process, but it is one of the important factors.

Keywords: Iraq, Monthly data, Rainfall, Spatial, Temporal.

Introduction

Climate change has appeared as a result of global warming due to human activities that have increased by burning more fossil fuels, which has led to an increase in the concentration of gases. This has negatively affected the climate of Iraq, such as rising temperatures and reducing rainfall[1]. Rainfall is one of the most important factors affecting local weather during a given period and in the long term, affect the climate of the region. Low rainfall rates can lead to dry climate, and thus the region may turn into a dry desert, because rainfall plays a major role in the formation of the ambient environment[2]. One of the steps needed to better understand this natural phenomenon is to be able to measure it accurately, which is very difficult given the large variations in rainfall over time and different places within region an especially in high lands. This process requires at least 30 years of data to determine average annual rainfall over the region[3]. In this our research, data covering a period of 42 years, so we were able to determine the annual average rainfall for each station, which makes it possible to classify regions according to their annual rate[4]. In Iraq, rain is a very important resource as the country faces a semi-arid climate with long, hot summers and short, mild winters. The wet season in Iraq usually occurs between November and May, whereas this period is associated with the arrival of medium depressions in Iraq[5]. Seasonal rainfall in Iraq is an important weather event due to its significant impact on agriculture, water resources and people's daily lives. The most important factors that affect seasonal rainfall in Iraq are air currents, storms, atmospheric depressions, and natural factors such as the El Nino and La Nina phenomena and temperature changes in the oceans[6]. The rainy season in Iraq usually begins in October and ends in June. However, Iraq experiences fluctuations in seasonal rainfall from year to year[7].

The variability and trends of precipitation patterns have been documented by many researchers in Iraq. Hussein et al [8];. Identify trends for the annual and monthly rainfall time series data from 1963–1964 to 2018–2019 for Erbil city using the Mann-Kendall test. The annual trend analysis revealed decreasing trend in November, January, February, March, April, and May and increasing trend in months of October and December. Ahmed and Al-Manmi [9] The trend of annual rainfall in Sulaymaniyah was investigated by using the Mann–Kendall trend test and Sen's slope estimator at 5 stations, slight trend was negative observed in Sulaymaniyah Station, while moderate trend with negative and positive increases appeared in Halabja and Chamchamal stations, respectively. Al-Budeiri [10], spatial and temporal assessment of rainfall trends in Iraq for the period from 1979 to 2018 using the above test, and found clear spatial and temporal variations, taking into account that most of the stations were characterized by a decrease in the amounts of rain during the spring and autumn seasons and at the annual level as well, while the autumn recorded an increase in the amounts of rain in most of the stations. Hajani et al; [11] This study investigated changes in rainfall data series due to climate change across 10 stations in the Kurdistan Region, Iraq Hajani and Klari[12]; This study examines changes in rainfall data at-site location in Duhok city, Iraq using rainfall data for 42 years covering the period of 1976–2017.The non-parametric tests (Mann–Kendall and Modified Mann–Kendall) with the Innovative Trend Analysis method have been used to assess the change in monthly, seasonal, and annual rainfall series. The results of Mandel's k method showed that no outlier was detected in the study area. The trend test results revealed an increasing trend in some rainfall data series and a decreasing trend in some other data series in the study area. This study aims to investigate the temporal and spatial rainfall variability, characteristics of trends for all regions of Iraq which included 39 stations, and analyze them statistically to determine the geographical distribution of precipitation in whole Iraq, including southern, middle and northern regions for the longer (1980-2021). It includes a deep understanding of the geographical distribution of rainfall and its trends, which contributes to understanding weather fluctuations and climate changes in Iraq over the years.

Materials and Methods

The study area and data source

The study area is the Republic of Iraq, located in the southwestern corner of the Asian continent which is geographically located in the subtropical latitudes (dominated by tropical highs in summer) of the northern hemisphere between low equator (29.5˚ to midlatitude 37.5˚) and longitudes (38.45˚ to 48.45˚ east of Greenwich Meridian)[13]. Iraq shares borders with six countries: Turkey (north), Iran (east), Kuwait (south), Saudi Arabia (southeast), Jordan (west), and Syria (northwest). The height above sea level varies widely, from marine remnants (reed swamps) in the southeast to mountains as high as 3583 meters in the north and northeast along the borders with Iran and Turkey[14]. The topography consists of four main regions: highlands (north and northeast), alluvial plains (central and southeast), deserts (west and southwest), and hilly uplands (northwest). Iraq's territory was divided into three main parts: southern, central, and northern, and each part was represented by the major cities of Basra, Baghdad, and Mosul[15]. Iraq's rains are subject to the Mediterranean rain regime, and last from mid-autumn to late spring. That is, the areas where the majority of the rainfall (80% or more) is concentrated during the winter months.

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The general distribution of seasonal rainfall in Iraq in Climate Atlas illustrates, the lower rainfall in the south and southwest and increase towards to the north and north-east[16]. Iraq climate is described as continental, subtropical climate which features four distinct seasons[17]. The spatial analysis of mean temperature shows that the mean temperature gradient is found to be from the south to the north of Iraq[18]. The annual average of wind speed in the study area "Iraq" was 3.6 m/s[19]. The Arabian Gulf and the Mediterranean Sea are Iraq's most influential bodies of water, that have a significant impact on its climate and thermal characteristics[20]. In the trend analysis, If the data set is not long enough, it is difficult to determine trends in the rainfall data series if is due to natural variability in weather and climate, or whether there have been man-made changes in the atmosphere. Data on monthly means of rainfall were obtained in the current study from Iraqi Meteorological Organization and Seismology (IMOS) and official website of NASA at spatial resolution (0.5° latitude × 0.5° longitude), for long-term trend analysis for monthly and annual precipitation data series (mm) for 42 years from 1980 to 2021 are available for 39 rainfall stations within the study area. Details of those stations from Geographic coordinates such as latitude, longitude, and mean sea level (MSL) are presented in (Table 1). The locations of 39 observations stations were taken within the study area as shown in Fig 1.

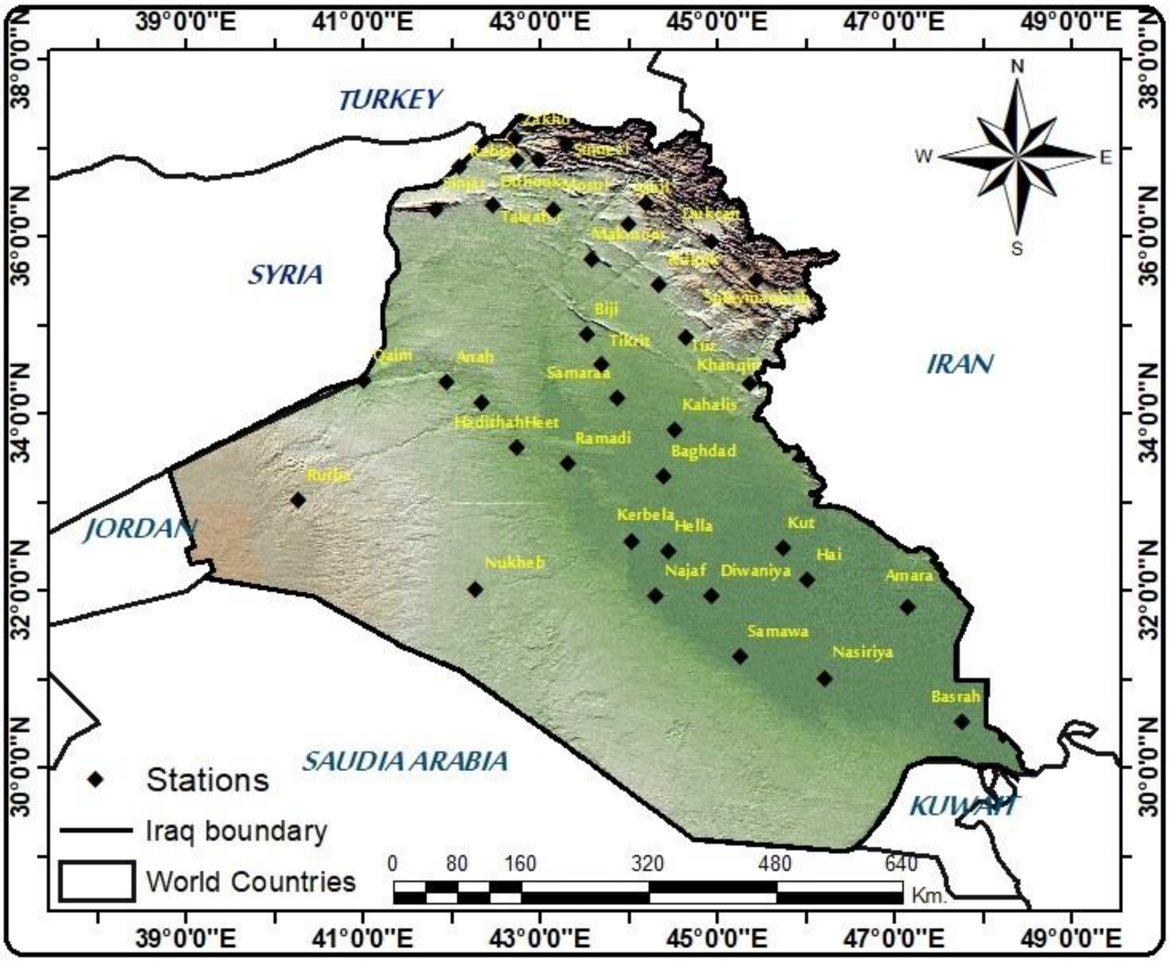

Figure 1. Study area with location of Meteorological Stations In Iraq.

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Table 1. Details of The spatial location of the rainfall stations used for trend analysis in this study.

	Stations	Latitude (°)	Longitude (°)	Altitude (m)	Index	Stations	Latitude (°)	Longitude (°)	Altitude (m)
1	Emadiah	37.05	43.29	1236	21	Samaraa	34.11	043.53	75
2	Sumeel	36.86	42.85	250	22	Haditha	34.04	042.22	140
3	Rabiah	36.48	042.06	382	23	Al-Khalis	33.50	044.32	44
4	Tel-Afer	36.22	042.29	373	24	Heet	33.38	043.45	58
5	Sinjar	36.19	041.50	476	25	Ramadi	33.27	043.9	48
6	Ducan	36.12	44.92	276	26	Baghdad	33.14	044.14	34
7	Zakho	37.08	042.41	442	27	Rutbah	33.02	040.17	615
8	Duhook	36.52	043.00	276	28	Karbalaa	32.37	044.01	29
9	Salahaddin	36.37	044.13	1088	29	Kut	32.30	045.49	19
10	Mosul	36.19	043.09	223	30	Hella	32.27	044.27	27
11	Erbeel	36.09	044.00	420	31	Kut-Al-Hai	32.10	046.03	15
12	Makhmoor	35.45	043.36	270	32	Nukaib	32.02	042.15	305
13	Sulaimaniya	35.33	045.27	853	33	Najaf	32.01	44.20	53
14	Kirkuk	35.28	044.24	331	34	Diwaniya	31.59	044.59	20
15	Baiji	34.56	043.29	150	35	Amarah	31.51	047.10	9
16	Tuz	34.53	044.39	220	36	Semawa	31.18	045.16	6
17	Tikrit	34.34	043.42	107	37	Nasiriya	31.05	046.14	3
18	Ana	34.28	041.57	150	38	Basrah	30.34	047.47	2
19	Al-Kaem	34.23	041.01	178	39	Fao	29.59	048.30	2
20	Kanaqin	34.18	045.26	202					

Methodology

In this study, Statistical analysis of monthly rainfall data for all stations (39) which obtained from ground stations from the Meteorological Organization and Seismology of Iraq (IMOS) in the study area was investigated in terms of Yearly, monthly averages, and rainfall intensity were calculated using Microsoft Office Excel 2013 to given Temporal and Spatial analysis of rainfall for 42 years (1980-2021). All statistical parameters were computed using the software Microsoft Office Excel 2013, in which functions (SUM, MAX, AVERAGE and STDEV) were used[21]. The general TREND, is a form of time series that is characterized by the fact that it extends over a long time, and the data change is gradual, whether toward an increase or a decrease[22]. Pearson correlation coefficient, is a measure of the strength of the relationship between two variables and their association with each other[23]. SLOPE, is a number that describes both the direction and the steepness of the line[24]. The assessment of Rainfall pattern in Iraq and the factors influencing it is determined using Geographic Information System (GIS) ArcMap version 10.4.1 is defined as the system for collecting, storing, manipulating, analyzing and displaying spatial or geographic data. GIS allows users to create maps, analyze data, and share information with others[25]. The study of time series requires the analyzing data to to study the behavior of a phenomenon over time, that's called time series analysis. Time series data is a collection of observations obtained by repeated measurements over time. The longer the period of data, the more accurate the results, so you can get a clear picture of the time series[26]. Finally, a linear regression method was used to analyze rainfall trends. This method allows you to see the trends in your data using the following Eq 1.

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$$Y = a + bx \quad \text{……....1}$$

Where x is the explanatory variable (years), Y is the dependent variable (rainfall, mm), b is the slope of the line (mm/year) and a is the intercept[27].

Results and Discussion

Temporal analysis of Monthly Rainfall Data

Statistical analysis of monthly rainfall data series for selected stations in Iraq as shown in (Table 2) provides evidence of irregular rainfall, that there is significant variation in rainfall patterns from north to south, i.e mean is not constant in all regions, because variability in rainfall is a prominent feature of the region's regime. These changes and fluctuations in rainfall amounts in Iraq are related to the patterns of wind currents and climate systems that prevail in the region during certain seasons. This is due to the impact of climate variability, change and irregularity, in addition to the possibility of the influence of global climates and phenomena such as El Nino and La Nina, changes in surface temperatures of the global oceans, in addition to pollution, environmental changes and land use, with the importance of the effect of the region's topography on rainfall. Overall, these climatic and geographic factors are essential in explaining the distribution of rainfall in Iraq throughout the year. The most rainfall occurs during the winter months due to the increased frequency of moderate weather depressions during those months. Then come the spring months (March, April), while October and November are the last in the quantity of rain. Rainfall ceases from May to the end of September (Because of the Red Sea depression that forms in the summer, which brings dry and hot air towards the regions of Iraq, which reduces rainfall and increases temperatures). Most of the studied stations indicated that there is a decreasing trend in rainfall, except for the stations (Baghdad, Kut, Hilla, Amarah and Samawah), which confirms the trend of climate change towards decreasing rain. We found that the general trend for all stations was negative, except for the five stations mentioned, whose slope ranged from 0.26 to 0.99, while the general trend values for the rest of the stations ranged from -0.14 to -14.99. However, Iraq has experienced drought and water shortages due to a significant decrease in rainfall in recent years. Due to changing dynamic factors, such as the weakening of the flow of moisture-laden air from the tropics, this leads to a decrease in rainfall rate, and this is due to the air pressure systems affecting Iraq, which include the Red Sea depressions and air depressions coming from the Mediterranean Sea.

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Table 2. Statistical summary of rainfall data for the study area.

SN	Station Name	Accumulate rainfall (mm)	Std. Dev. (mm)	Maximum (mm)	Trend for all period	Style
1	Emadiah	606.2	227.25	1067.0	-10.46	Decrease
2	Sumeel	434.23	134.69	732	-4.73	Decrease
3	Rabiah	339.23	107.41	207.1	-3.20	Decrease
4	Tel-Afer	308.82	108.62	614.4	-2.39	Decrease
5	Sinjar	331.82	130.71	663	-5.72	Decrease
6	Ducan	624.41	240.09	1080.2	-13.32	Decrease
7	Zakho	526.22	195.14	978.1	-10.42	Decrease
8	Duhook	487.52	175.33	909.7	-5.86	Decrease
9	Salahaddin	451.56	251.31	927.1	-13.85	Decrease
10	Mosul	358.41	131.16	205.6	-1.54	Decrease
11	Erbeel	392.87	126.82	192.0	-5.19	Decrease
12	Makhmoor	292.7	108.61	203.0	-1.98	Decrease
13	Sulaimaniya	595.7	281.54	1052.1	-14.99	Decrease
14	Kirkuk	337.8	128.64	191.9	-3.80	Decrease
15	Baiji	194.44	71.60	116.8	-1.31	Decrease
16	Tuz	269.56	99.92	478.2	-0.61	Decrease
17	Tikrit	162.64	73.25	304.601	-1.68	Decrease
18	Ana	124.32	50.82	297.1	-1.98	Decrease
19	Al-Kaem	118.8	53.92	240.7	-2.07	Decrease
20	Kanaqin	287.51	97.90	185.8	-2.05	Decrease
21	Samaraa	153.19	66.95	315.4	-2.41	Decrease
22	Haditha	115.9	51.49	140.0	-2.03	Decrease
23	Al-Khalis	171.77	63.18	300.8	-0.85	Decrease
24	Heet	110.47	57.1	141.7	-1.92	Decrease
25	Ramadi	107.51	46.49	241.1	-1.28	Decrease
26	Baghdad	120.47	57.92	172.7	0.997	Increase
27	Rutbah	106.13	57.01	163	-1.24	Decrease
28	Karbalaa	90.32	34.79	73.83	-0.58	Decrease
29	Kut	139.2	53.24	100.2	0.41	Increase
30	Hella	105.72	41.04	141.2	0.26	Increase
31	Kut-Al-Hai	131.11	58.16	139.1	-0.048	Decrease
32	Nukaib	76.17	40.58	200.21	-1.04	Decrease
33	Najaf	94.2	45.04	190.7	-0.43	Decrease
34	Diwaniya	101.95	44.93	223.40	-0.14	Decrease
35	Amarah	173.63	81.05	352.9	0.50	Increase
36	Semawa	99.12	51.18	247.90	0.49	Increase
37	Nasiriya	119.93	58.63	245.8	-0.50	Decrease
38	Basrah	126.49	58.17	84.38	-1.72	Decrease
39	Fao	126.8	59.69	242.1	-2.39	Decrease

Spatial analysis of Monthly Rainfall Data

ArcGIS was used to display the spatial rainfall distribution using spatial analytic tools. The variation at the place level shows that, the northern region occupies the first place in the amount of annual rainfall, the highest amount of accumulated rainfall was recorded in these areas (624.2, 595.7, 526.2, 487.5, 451.6 mm) for stations (Dokan, Amadiya, Sulaymaniyah, Zakho, Dohuk, and Salah al-Din), respectively. and this is due to the factor of altitude and the increase in the frequency of Mediterranean depressions. The central region ranks second in annual rainfall, while the southern region ranks third due to the low frequency of Mediterranean depression the lowest amount of precipitation was in the southern stations by (76.2, 90.32, 94.2, 99.12 mm) for stations Al-Nukhayb, Karbala, Najaf, and Samawa(respectively. In general, the amount of rain decreases as we orient from the north and northeast

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of Iraq towards the south and southwest as we see in Fig. 2. This is related to several climatic as well as geographical factors. Iraq is characterized by a diverse terrain, including mountain ranges, plateaus and plains. The northern and western regions of Iraq rise above sea level and are characterized by mountainous terrain and plateaus that help in the formation of clouds and rainfall. The southern and eastern regions are characterized by desert terrain and flat plains, which reduces the chances of the formation of cumulus clouds and rainfall. The northern regions of Iraq also benefit from the influence of marine moisture flowing from the Mediterranean Sea. This moisture helps to form rain clouds and increases the amount of rain in those areas. While marine humidity is generally lower in the southern regions.

This decrease is due to the lack of recurrence of the Mediterranean depressions, the distance from its main path, as well as the disappearance of part of it during the long distance it travels from the Mediterranean, in addition to the decrease in the surface level. Despite this gradual decrease in the amount of rainfall from northern to southern Iraq, we must note that there is a variation in rainfall amounts within each region as well. There may be other local factors that affect precipitation, such as local elevations and nearby bodies of water. These are some of the reasons that could contribute to the decrease in the amount of rain in Iraq as we head from north to south. However, it should be noted that Iraq sometimes experiences a period of rainfall, and general fluctuations in the rainfall pattern may occur throughout the year. If the surface of Iraq was flat and devoid of elevations, the spatial variation in the amount of precipitation would be small, as is the case in the southern and central regions of Iraq, where the rainfall varies very little. That is why the northern region of Iraq is considered as a rainy oasis in a desert region with a distinct climatic region, with agricultural, tourism and water potentials great. It also provides large amounts of water to the Tigris River, and this is what gives the region its importance. Higher rainfall is expected over most of the world’s continents under climate change, except for a few specific regions where models project robust declines. Among these, the Mediterranean (Climate Change Hot Spot) stands out as a result of the magnitude and significance of its winter rainfall decline. Mediterranean circulation trends can be seen as the combined response to two independent forcings: robust changes in large-scale, upper-tropospheric flow and the reduction in the regional land–sea temperature gradient that is characteristic of this region[28]. Northern parts of the country experienced below-average rainfall. The general trend recorded significant decreasing values, especially in the northern regions, where the trend -14.99, -13.85, -13.32, -10.46, -10.42, -5.86 was recorded for the stations (Sulaymaniyah, Salah al-Din, Dokan, Amadiya, Zakho and Dohuk), respectively. This was detrimental to their communities as they relied heavily on rainwater to grow their agriculture. Iraq is also affected by general climatic effects, such as the El Nino and La Niña phenomena and changes in surface and sea temperature. These factors can affect the rainfall pattern in the region in general and contribute to annual and seasonal fluctuations in the amount of rainfall. It has been shown that there is a positive effect of the El Nino phenomenon on increasing rainfall rates in northern and northeastern Iraq, considering that central and southern Iraq are less affected by this phenomenon[29].

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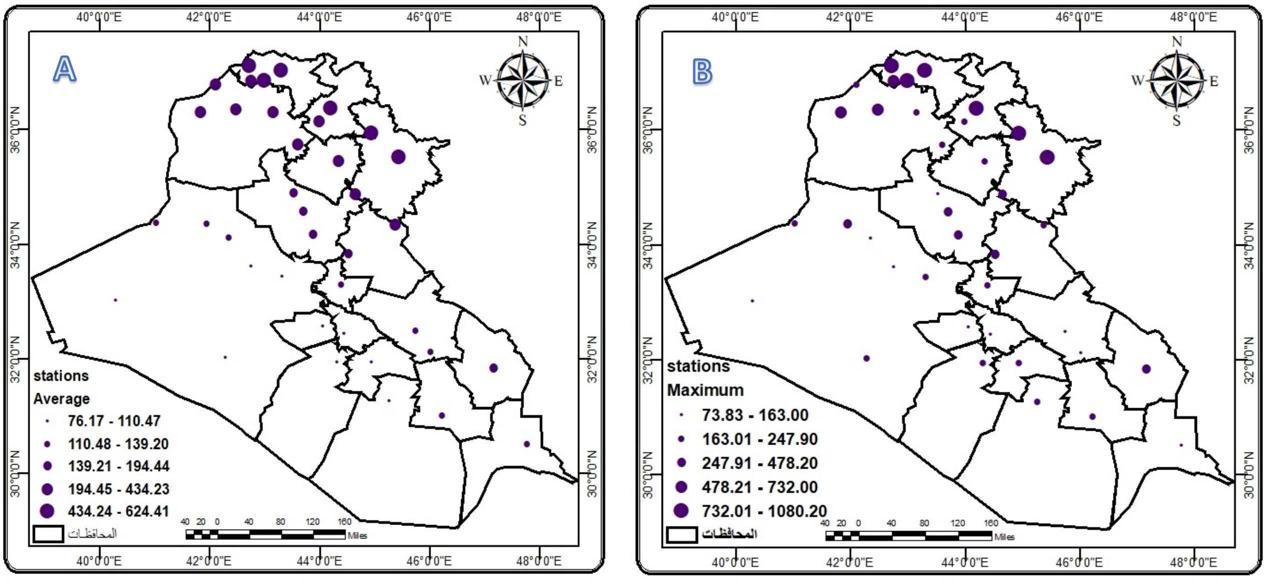

Figure 2. Study area with (A) Average accumulate and (B) the maximum of rainfall.

Rainfall pattern and factors influencing it in Iraq

The study stations show a decrease in the general trend of Rainfall, except for five stations (Baghdad, Kut, Hilla, Amara, and Samawah) that witnessed an increase in Rainfall amounts compared to the general average during the study period. The five stations referred to represent the central areas of the study area, which are characterized by being the lowest in elevation compared to the rest of the stations, as shown in Fig. 5, which shows the height of all the study stations. It was found that the highest altitude stations are in the northeast and the north of the study area, then the western regions, then the central and southern regions, which have the lowest altitude. That is, the elevation of areas greatly affects the amount of rain falling in those areas.

The highest amount of rain recorded for all the study stations is shown in Fig 2A, B, where it was shown that the stations (Dokan, Amadiyah, Sulaymaniyah, Zakho, Dohuk and Salah al-Din) recorded the highest amounts of rain among the 39 stations, with quantities between (900-1000) mm. This is consistent with the general precipitation rate for all study stations shown in (Table 2), which confirmed that the highest rates of rainfall were in the northern and northeastern regions of the above-mentioned stations, with rates of (624, 606, 595, 526, 487, and 451) mm, respectively.

Standard deviation refers to the level of dispersion or variation in data values from the data average. It is used to measure the degree of dispersion in a data set. The higher the value, the greater the dispersion and vice versa. The standard deviation for all study stations is shown in Fig 3B, where it became clear that the stations (Sulaymaniyah, Salah al-Din, Dokan, Amadiyah, Zakho and Dohuk) have the highest standard deviation values compared to the rest of the study stations. This means that the data at stations in the northern regions vary greatly from the general average, which indicates the greatest fluctuations in the amount of rainfall, which is an indicator of the instability of rainfall in the northern region compared to the rest of the regions. Then the standard deviation values for the rest of the stations decrease, from the northeastern regions down to the central and southern stations, which record the lowest standard deviation values, which is considered an indication that the data is less dispersed and more stable. Fig 3A represents the slope of the general trend of precipitation for all study stations and how it recorded a decrease from the averages, especially the stations (Sulaymaniyah, Salah al-Din, Dokan, Amadiyah, Zakho and Dohuk), which recorded a slope of (-15, -13, -13, -10, -10, -6). respectively. Note that all stations recorded a decrease from the general trend of precipitation, except for five stations (Baghdad, Kut, Hilla, Amara, and Samawa), which recorded a slight increase not exceeding (1) from their normal levels.

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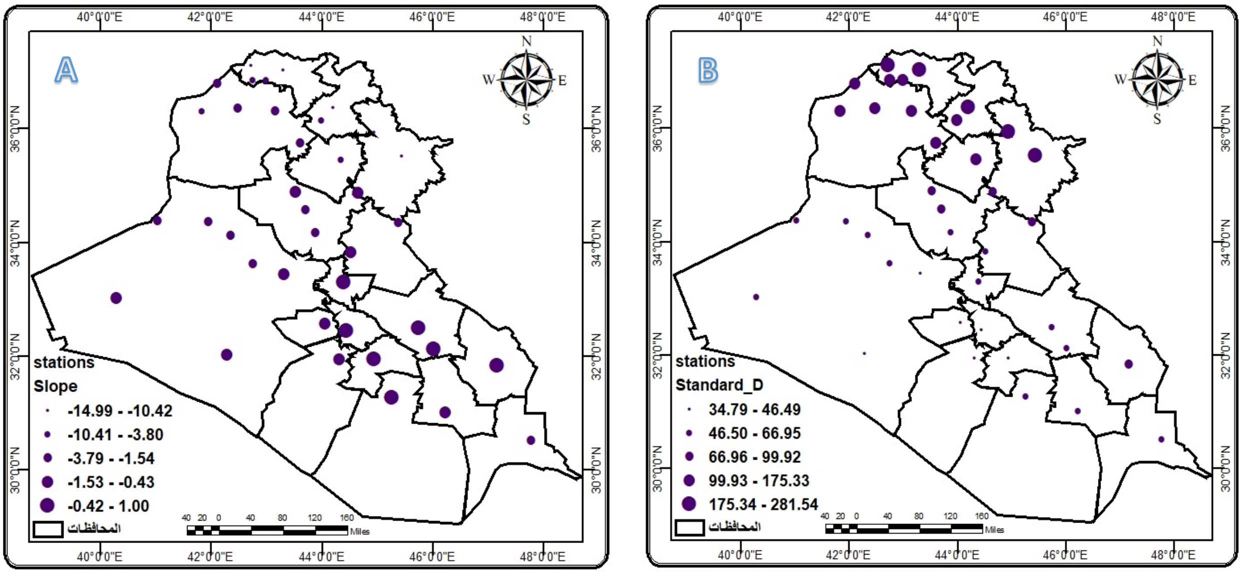

Figure 3. Statistical Rainfall pattern represents (A) Slope and (B) Standard Deviation.

Iraq is characterized by diverse terrain, which leads to differences in rainfall from one region to another. The lack of rain in Iraq is primarily due to its location, so the shape of its surface plays an important role in the variation of rainfall between one place and another in the country[30]. Among the factors affecting the amount of rainfall are terrain and height above sea level. Rain is abundant in the regions of northern Iraq, as the highlands and mountain peaks attract a large amount of rain, which is attributed to several climatic and geographical factors, including the monsoon winds, which are more active in the northern and northwestern regions of Iraq, which increases the chances of rainfall in those areas. To a greater extent. Also, northern Iraq is located near the Zagros Mountain range and the mountains of Kurdistan. This mountain range acts as a natural barrier to wind currents and moisture coming from the seas and oceans. When these currents come to these areas, they are cooled and intensified resulting in rainfall. In short, these factors combine to make northern Iraq more rain-receptive than other areas of the country. On the contrary, we found a decrease in the amount of rain in the areas of southern Iraq because the areas of southern Iraq are located far from the mountainous areas and mountain ranges that receive larger amounts of rain. This means that they are less susceptible to the influence of monsoon winds and the influx of moisture from seas and oceans. In addition, a large part of southern Iraq is desert, such as the Basra Desert and the Arabian Desert, and these areas are usually naturally dry. For these reasons, rainfall amounts in southern Iraq are lower than in other regions of the country.

Seasonal Rainfall Rates Data

Iraq is characterized by a seasonal pattern of rainfall, with the winter period being the main rainy season. We notice the highest amounts of rainfall in Iraq are often recorded in January, February and March and December. The highest amount of rain was recorded during the study period in March in the Amadiya station, (Feburary, December and January) in Ducan station, January in Sulaimaniya station, with an amount of (112.8, 112, 111.3, 104.7, 101.4) mm respectively. This increase in rainfall is a result of lower temperatures, which increases the ability of the air to absorb moisture and condense it into rain and the influence of the Mediterranean Depression, which forms in the Mediterranean Basin region, affects different seasons, especially the fall and winter seasons. It brings with it moist and cold air towards the surrounding areas, including Iraq, causing rain and unstable stormy weather conditions. Across all stations the lowest amount of rain was recorded in May at Al-Faw station in the far south of Iraq, with an amount of 1.2mm. While the summer season has a seasonal pattern that tends toward drought and is relatively stable. However, it should be noted that limited rain showers or thunderstorms may occasionally occur during the summer period, but they are usually not of the same continuous and

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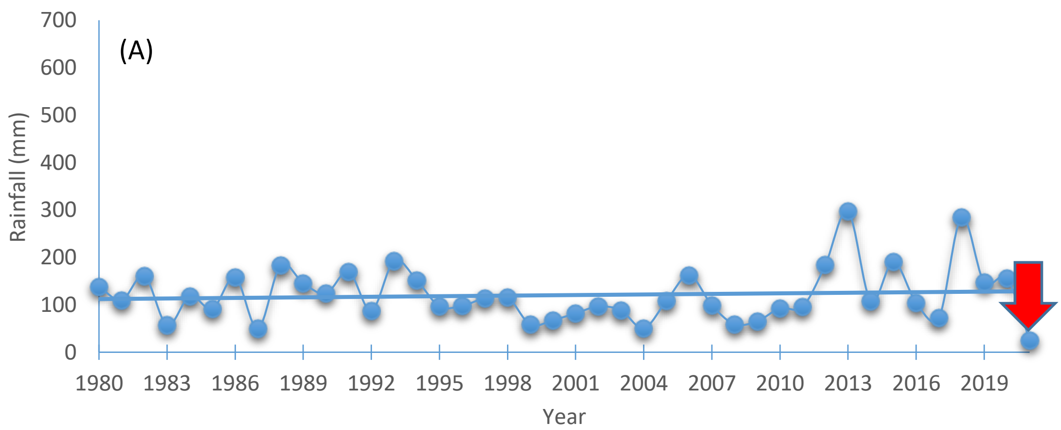
abundant nature as in the winter. That is the reason we found the seasonal total of rain is less than the annual total because there are small amounts of rain recorded outside the months of rainy seasons, which are recorded in the annual total. We noticed that the summer season is considered a dry period, and therefore rain is less common during this period, as the lowest amounts of rainfall were recorded in this season. Specifically in June, July and August. These months represent a period of drought, as they are characterized by high temperatures and low rainfall, Because of the Red Sea depression that forms in the Red Sea region and the Arabian Peninsula, which mainly affects the summer, bringing with it dry and hot air towards the surrounding areas, including Iraq, causing a rise in temperatures and a decrease in rainfall. This drought could greatly affect the country's water resources and agriculture. In these months, dry winds can blow from the Iraqi desert and neighboring deserts such as the surrounding Arabian Desert, many areas in Iraq are also witnessing a rise in temperatures, and this leads to the formation of a thermal depression over the region, Iraq is also affected during the summer by an air system known as tropical high pressure. All these reasons increase the dryness in the atmosphere and reduce the moisture available to form rain clouds. which causes a decrease in humidity in the air, the dispersal of clouds, and the disappearance of chances of rain. For these reasons, rainfall amounts decrease significantly in the summer months in Iraq, making it less suitable for agriculture and meeting water needs.

Trends in Annual Rainfall Data

Annual rainfall is usually defined as the accumulative total amount of rainfall that fall somewhere throughout the year. The annual rainfall is consistent with the topographical changes in the study area. In this part of the research paper, three stations were taken as models covering the three main regions in Iraq that were mentioned in the study area, represented by a station for the northern (Mosul station), central (Baghdad station) and southern regions (Basra station), respectively. Based on the statistical analysis of annual rainfall, we found that rains are characterized by irregularity in their amounts and intensity, with the highest rainfall reaching Ducan Station (624.41mm) (the elevation of topography has caused the northern parts of Iraq to rainfall more than other regions.), then decreasing as it goes southward, reaching Nukaib Station with an annual rate of (76.17 mm) (because this site represents the most drier site in Iraq according to records of the total rainfall), as shown in (Table 2). In 2021, Iraq experienced the driest season in 42 years, with record lowest rainfall across all stations. These trends are related to the summarized climate change outcomes of global warming. Fig. 3, represents the general trend of the annual rainfall total for Three stations for the period 1980-2021as examples. The 2000s were drier than normal, as shown in the graph below.



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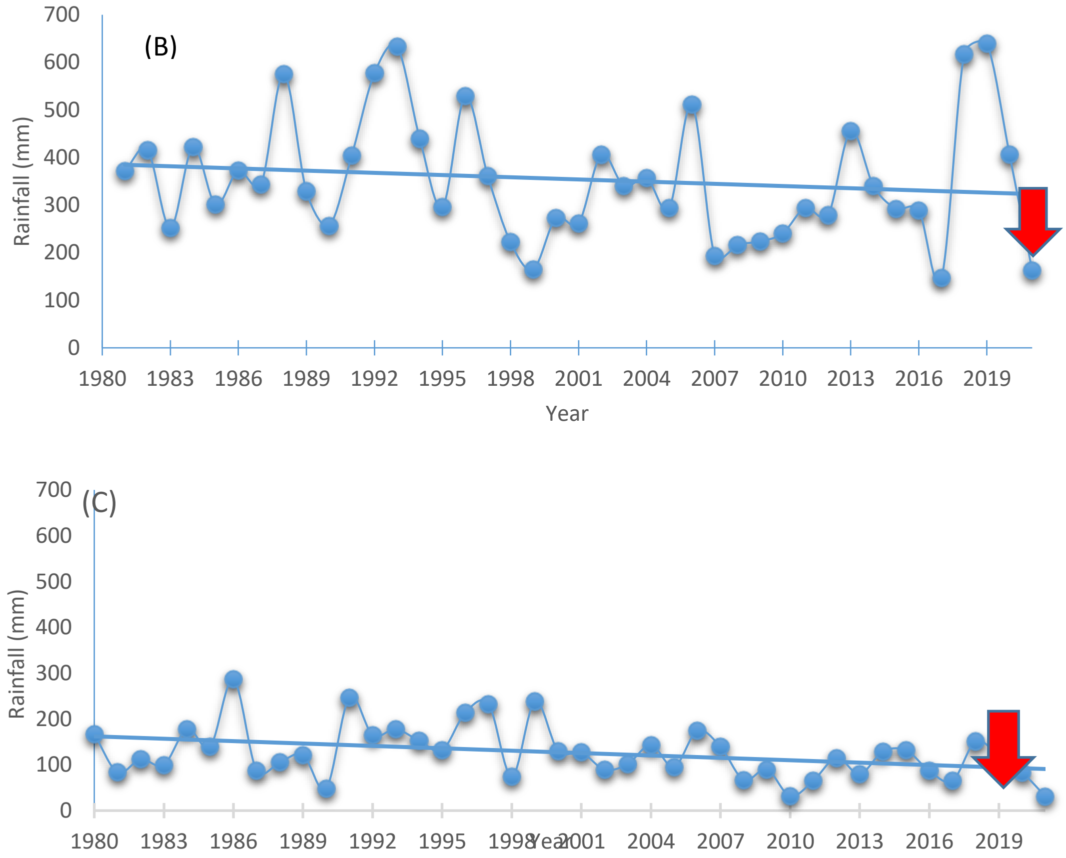

Figure 4. The general trend of the time series for annual rainfall total for the (A) Mosul station (B) Baghdad station and (C) Basra station, respectifally for the period 1980-2021.

The Pearson correlation coefficient was used to test the relationship between the topography of the study area, represented by surface elevation, and rainfall amounts during the study period and for all stations represented in Fig. 4,5,6. The results showed that the values are dispersed, which led to the value of the Pearson correlation coefficient being less than one, which indicates that surface height is not the only factor affecting the amount of precipitation, but it represents one of the important factors because its value is 0.7, which means that there is a good relationship between them.

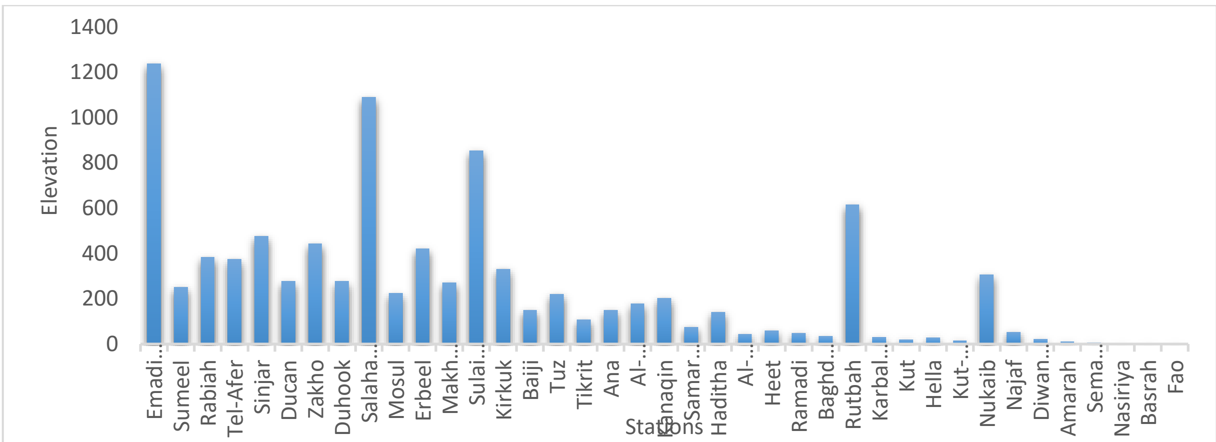

Figure 5. Station height and its explanatory capacity for rainfall rate.

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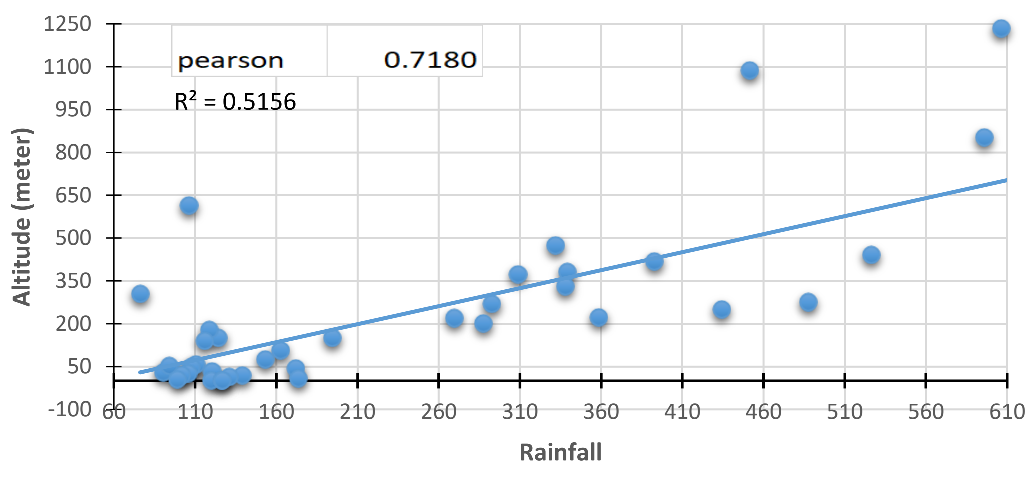

Figure 6. Pearson correlation coefficient between Rainfall and Altitude.

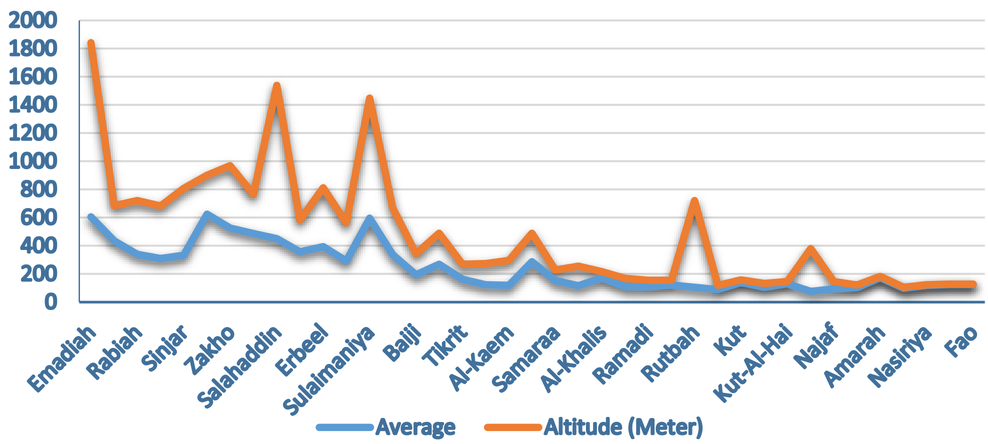

Figure 7. The relationship between Altitude and accumulated rainfall for all study stations.

Conclusion

This study focuses on the analysis trends of long-term monthly and annual precipitation data series at 39 selected precipitation stations in Iraq, Which covers all parts of Iraq from the north and center to the south. The study concluded with a set of results, most notably: Iraq is one of the countries that suffers from declining rainfall, which negatively affects its water, food, social and health security. So, there are similarities in the climatic drought events experienced by Iraq, especially recent regional trends, consistent with previous research. Iraqi rainfall is highly dynamic and varies in time and space, That is Iraq's rainfall pattern is not a cyclical pattern. We found wide temporal and spatial variation in rainfall. The 2000s were drier than normal, where in 2021, Iraq experienced the driest season in 42 years, with record lowest rainfall across all stations. The average rainfall in the southern and western regions is less than the central regions, which is less than the eastern regions, noting that the maximum amounts of rainfall were in the northern regions. This shows the effect of terrain on rainfall in Iraq. It turns out to be a difference The overall monthly precipitation trend varied significantly from year to year and between stations, so January and April had the greatest impact on trend movements and deviations. While we find that October has a limited effect due to the decrease in the amount of rain in this month or being locked up for many years.

Most of the study stations indicated that there is a decreasing trend in the overall precipitation trend, except for the stations (Baghdad, Kut, Hilla, Amarah, and Samawah). The stations (Ducan, Amadiyah, Sulaymaniyah, Zakho, Dohuk and Salah al-Din) recorded the highest amounts of rain among the 39 stations, have the highest standard deviation values compared to the rest of the stations, have recorded a decrease from the averages greater than the other stations. The high values of rainfall total indices appeared in the northwestern part of Iraq, whereas the lowest values of these indices appeared in western and southern regions. The highest amount of rainfall recorded in Iraq was at a Ducan Station (624.41mm), While the station Nukaib (76.17 mm) recorded the least amount of rainfall among the 39 stations. According to the results of the study we suggest that the Iraqi government needs to take quick actions like designing a national water master plan and implementing regional cooperation and coordination. The results of this analysis will be of interest to water resource managers and policy makers for effective water resource planning and management in Iraq.

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Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images that are not ours have been included with the necessary permission for re-publication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at the University of Mustansiriyah.

Authors' Contribution Statement:

SA collected the data, analyzed, interpretation and drafting the MS, MH Conception, design, revision and proofreading, YK design, acquisition of data, revision and proofreading.

References

1. Abed Qf. Climate change in the temperature and rain of Iraq. J Coll Basic Educ Educ Hum Sci. 2019; 45: 339-367.
2. AM Abdul Ja bbar, AK Abdulkareem. Predicted the Cumulative Annual Rainfall in Iraq using SDSM Modal. MJS. 2021; 32(2): 11-17. https://doi.org/10.23851/mjs.v32i2.977
3. Mutar AG, Khtan A, George LE. Synoptic Characteristics of Torrential Rains in Southwest and Southeast Iraq: A Case Study. MJS. 2021; 32 (3): 1-7. https://doi.org/10.23851/mjs.v32i3.957
4. Kaur Sukhpal, Rakshit Madhuchanda. Seasonal and Periodic Autoregressive Time Series Models Used for Forecasting Analysis of Rainfall Data. Int J Adv Eng Technol. 2020; 10 (1): 230-242.
5. Alsalhy,Sarmad&Hameed, Jasim. Verification of the amount of Annual rainfall using satellite images and GIS analysis in Iraq. MJPAS P. 2024.
6. Issa shatha, Kadhum J. Dynamical Analysis of Severe Rain Events over Iraq. MJS. 2019; 30 (1): 15-22. https://doi.org/10.23851/mjs.v30i1.586
7. Shaghati YA. Study of Some Patterns for Severe Rainfalls Over Iraq. MJS. 2024; 31(4): 9-14. https://doi.org/10.23851/mjs.v31i4.878
8. Hussien SA, Mustafa BY, Medhat FK. Trend Analysis of Annual and Monthly Rainfall in Erbil City, Kurdistan Region, Iraq. Polytechnic j. 2019; 9 (2): 30-6. https://doi.org/10.25156/ptj.v9n2y2019.pp30-36
9. Ahmed G, Al-Manmi D. Trend detection of average annual rainfall and temperature in Sulaymaniyah

governorate, Iraq. Anbar J Agric Sci. 2021; 19 (2): 221-233. https://doi.org/10.32649/ajas.2021.175995
10. Al-Budeiri AL. Trends in temperature and rain change in Iraq and its future projections. Anbar J Agric Sci. 2021; 3(137): 443-72. https://doi.org/10.31973/aj.v3i137.1129
11. Hajani E, Shajee K, Kaleel F, Abdulhaq H. et al. Characteristics of changes in rainfall data in the Kurdistan Region, Iraq. Arab J Geosci. 2022; 15(509): 509. https://doi.org/10.1007/s12517-022-09809-6
12. Hajani Evan, Klari Zahraa. Trends analysis in rainfall data series in Duhok city, Kurdistan region, Iraq. Model Earth Syst Environ. 2022; 8: 1-14. http://dx.doi.org/10.1007/s40808-022-01354-1
13. Eptehaal M Deagan, Monim H Al-Jiboori. The Relationship of CLWC and Rainfall to the Synoptic Cases of Two Case Studies Over Iraq. IOP Conf Ser. Earth Environ Sci. 2023; 1262 (8): 082038. https://doi.org/10.1088/1755-1315/1262/8/082038
14. Laheab A Al-Maliki1, Sohaib K Al-Mamoori, Nadhir Al-Ansari, Khaled El-Tawel and Fadi G. Comair. Climate change impact on water resources of Iraq (a review of literature). IOP Conf Ser.: Earth Environ Sci. 2022; 1120. https://doi.org/10.1088/1755-1315/1120/1/012025
15. Al-Ansari, Nadhir. Topography and Climate of Iraq. Journal of Earth Sciences and Geotechnical Engineering. 2021; 11. 1-13. 10.47260/jesge/1121.
16. Abdaki, Mohammed & Al-iraqi, Ahmed & Faisal, Raid. Predicting long-term climate changes in Iraq. IOP Conference Series: Earth and Environmental Science. 2021 779. 012053. 10.1088/1755-1315/779/1/012053.
17. Al-Bayati RM, Adeeb HQ, Al-Salihi AM, Al-Timimi YK. The relationship between the concentration of carbon dioxide and wind using GIS. AIP Conf Proc. 2020; 2290: 050042. https://doi.org/10.1063/5.0027402
18. Hassan AS and Kadhum JH .Analysis the Intensity of CO2 Emissions from Fossil Fuel Combustion in Iraq. 2021; *MJS;* **32:**47-50. https://doi.org/10.23851/mjs.v32i2.982
19. Adeeb HQ, Al-Timimi YK. GIS techniques for mapping of wind speed over Iraq. Iraqi J Agric. Sci. 2019; 50 (6): 1621-1629. https://doi.org/10.36103/ijas.v50i6.852
20. Asraa Khtan, Iqbal Khalaf Al-ATABI. Analyzing and prediction of rainfall trends over Baghdad city. PREPRINT (Version 1). Res Sq. 2021; https://doi.org/10.21203/rs.3.rs-1023267/v1
21. Mutasher WG, Aljuboori AF. New and Existing Approaches Reviewing of Big Data Analysis with Hadoop Tools. Baghdad Sci J. 2022; 19(4): 0887. https://doi.org/10.21123/bsj.2022.19.4.0887
22. Yatish HR, Swamy SR. Recent trends in time series forecasting–A Survey. Int Res J Eng Tech. 2020; 07(04): 5623- 5628.
23. Kumar NR. Analysis of test for significance of Pearson’s correlation coefficient. Int J Mod Eng Res. 2021; 10 (46).
24. Huang F, Xiong H, Chen S, Lv Zhitao, Huang J, Chang Zh et al. Slope stability prediction based on a long short-term memory neural network: comparisons with convolutional neural networks, support vector machines and random forest models. Int J Coal Sci Technol. 2023; 10 (18). https://doi.org/10.1007/s40789-023-00579-4
25. Mohsen A-ZA, Al-Jiboori MH, Al-Timimi YK. Investigating the Aerodynamic Surface Roughness Length over Baghdad City Utilizing Remote Sensing and GIS Techniques. Baghdad Sci J. 2021; 18(2): 1048. https://doi.org/10.21123/bsj.2021.18.2(Suppl.).1048
26. Rahardja D. Statistical Time-Series Forecast via Microsoft Excel (Forecast.ets) Built-In Function. J Res Appl Math. 2021; 7(11): 69-73.
27. Hajani E, Sarma G. Generation of rainfall data series by using the Markov Chain model in three selected sites in the Kurdistan Region, Iraq. The Journal of the University of Duhok. 2023; 2(5). https://doi.org/10.1007/s43503-023-00014-2
28. Monim H Al-Jiboori, MJ Abu Al-Shaeer, Ahmed S Hassan. Statistical Forecast of Daily Maximum Air Temperature in Arid Areas at Summer time. J Math Fundam Sci. 2020; 52(3). https://doi.org/10.5614/j.math.fund.sci.2020.52.3.8
29. Aqeel Gh Mutar et al. The Impact of ENSO on the Precipitation in Iraq Regions. IOP Conf Ser.: Earth Environ Sci. 2023; 1223. https://doi.org/10.1088/1755-1315/1223/1/012007
30. Zarei AR, Eslamian S. Trend assessment of precipitation and drought index (SPI) using parametric and non-parametric trend analysis methods (case study: arid regions of southern Iran). Int J Hydrol Sci Technol. 2017; 7(1): 12-38. https://doi.org/10.1504/IJHST.2017.080957

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التقييم الزماني والمكاني لاتجاه هطول الامطار الشهرية في العراق

ساره علي مطر، منعم حكيم الجبوري، ياسين كاظم التميمي

قسم علوم الجو، كلية العلوم، الجامعة المستنصرية، بغداد، العراق.

الخلاصة

تعتبر السلاسل الزمنية لهطول الأمطار معلمة يمكن أن توفر أدلة على تغير المناخ. بناءً على بيانات 39 محطة، تم تحليل الهطولات المطرية الشهرية لتغطية كافة مناطق العراق للمدة (1980-2021) إحصائياً باستخدام برنامج Microsoft Office Excel 2013. وتم تحديد أنماط الهطولات المطرية والعوامل المؤثرة فيها باستخدام (GIS). وأظهرت النتائج أن هطول الأمطار في العراق ديناميكي للغاية وأن نمطها ليس نمطًا دوريًا. وتتناقص كمية الأمطار كلما اتجهنا من الشمال نحو الجنوب، حيث يصل أعلى متوسط لها في محطة دوكان ثم تتناقص كلما اتجهت جنوباً حتى محطة النقيب. وهناك اتجاه تنازلي لهطول الأمطار لجميع المحطات ماعدا محطات (بغداد، الكوت، الحلة، العمارة، والسماوة). وفقًا للحسابات، كان العقد الأول من القرن الحادي والعشرين أكثر جفافًا من المعتاد، ولوحظ العام الأكثر جفافًا في عام 2021 على مدار 42 عامًا. سجلت محطات (دوكان، العمادية، السليمانية، زاخو، دهوك وصلاح الدين) أعلى كميات الأمطار من بين الـ 39 محطة، وحققت أعلى قيم الانحراف المعياري مقارنة ببقية المحطات، وسجلت انخفاضاً عن المتوسطات أكبر من المحطات الأخرى. لقد رأينا علامات التحول إلى مناخ أكثر جفافاً، خاصة في المحطات التي تمثل الشمال الشرقي. تم استخدام معامل بيرسون (R) لاختبار العلاقة بين هطول الأمطار والارتفاع، وتبين أن هناك علاقة قوية بلغت 0.71. وهذا يدل على أن الارتفاع ليس هو المتغير الوحيد الذي يؤثر على عملية هطول الأمطار، ولكنه أحد العوامل المهمة.

الكلمات المفتاحية: العراق، بيانات شهرية، الهطول، التحليل المكاني، الزماني.