MONITORING THE SHIFT OF RAINFED LINE OF 250 mm OVER IRAQ

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ABSTRACT

This study was aimed to analyze the annual rainfall and study the changes in the borders of rainfed regions in Iraq. Monthly rainfall data for 39 meteorological stations affiliated with the Iraqi Ministry of Transportation /Iraqi Meteorological Organization and Seismology have been used. These data represent a Long-term Climate Records from January 1980 to December 2020 have been used to calculate the mean annual rainfall in Iraq over the 41 years. The resultes showed significant spatial and temporal variability in the annual mean rainfall, with higher values in the northern areas of Iraq and lower values in the southern regions. It was examined the succession of the rainfed line at 250mm. The results indicated that there have been clear changes in the rained line of 250 mm during the four different decades (1980–1990, 1990–2000, 2000–2010, and 2010–2020). Iraq was located between the 100 mm rain line at the south and the 1277 mm rain line at the far northeast. Iraq became located between the 100-1000 mm rain line. During the four time periods, the area of the rainfed agriculture region, which depends on a 250 mm rainfall line, amounted to 20.38%, 20.17%, 14.91%, and 17.01%. In general, the area of the region decreased in the southeast and north during the first, second, and third time periods and then expanded slightly during the fourth time period.

Keywords: climate change, agriculture, Mesopotamia, dryland, drought

مراقبة تزحزح الخط المطري 250 ملم فوق العراق

ياسين كاظم التميمي فاضل يونس بكتاش
استاذ استاذ
قسم علوم الجو – كلية العلوم – الجامعة المستنصرية
قسم علوم المحاصيل الحقليه– كلية الزراعة – جامعة بغداد

المستخلص

يهدف البحث إلى تحليل الامطار السنوية ودراسة التغيرات في حدود مناطق الزراعة الديمية في العراق. تم استخدام بيانات الامطار الشهرية لـ 39 محطة انواء جوية تابعة لوزارة النقل العراقية / هيئة الأرصاد الجوية العراقية ورصد الزلازل. تمثل هذه البيانات سجل مناخي طويل الامد يمتد من كانون الثاني سنة 1980 إلى كانون الاول من سنة 2020 تم استخدامها لحساب المعدل السنوي للامطار في العراق على مدى 41 عامًا. أظهرت النتائج تبايناً مكانياً وزمانياً كبيراً في معدل الأمطار السنوي، حيث كانت القيم أعلى في المناطق الشمالية من العراق وقيم أقل في المناطق الجنوبية. قمنا أيضًا بفحص تعاقب الخط الديمي عند 250 ملم. وتشير النتائج إلى وجود تغيرات واضحة في الخط المطري البالغ 250 ملم خلال العقود الأربعة المختلفة (1980–1990، 1990–2000، 2000–2010، و2010–2020). وكان العراق يقع بين خط المطر 100 ملم في الجنوب وخط المطر 1277 ملم في أقصى الشمال الشرقي. وأصبح العراق يقع بين خط المطر 100–1000 ملم. وخلال الفترات الزمنية الأربع بلغت مساحة منطقة الزراعة الديمية التي تعتمد على خط أمطار 250 ملم 20.38%، 20.17%، 14.91%، 17.01%. وبشكل عام انخفضت مساحة المنطقة في الجنوب الشرقي والشمال خلال الفترات الزمنية الأولى والثانية والثالثة ثم توسعت قليلاً خلال الفترة الزمنية الرابعة.

الكلمات المفتاحية: تغير المناخ، الزراعة، بلاد ما بين النهرين، الأراضي الجافة، الجفاف

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INTRODUCTION

Climate change is a result of the development in human civilization that started with the industrial revolution. Imperfect exploitation of natural resources, particularly those of energy, huge urban and industrial expansion endangered the atmospheric composition due to the increased concentrations of greenhouse gases that created an imbalance in the climate system on earth, which, in turn, raised the temperature of the atmosphere by about 0.74^{o}C between 1906 and 2005. Precipitation is one of the most significant environmental factors for diagnosing climate change and may also determine the regional scale eco-environmental approach to climate change (1). Iraq witnessed this kind of change that coincided with serious environmental problems such as the diminution of arable land, urban expansion, and rising pollution levels. All these led to climate change in Iraq. Temperature values rose, amounts of rainfall went down, and dust storm frequency changed. The features of this change were exactly reflected in the geographical distribution of those elements. Consequently, the climatic map in Iraq initiated to change along with global climate change (2). Rainfall in Iraq is characterized by an irregular distribution of temporal and spatial scale. The mean rainfall on a yearly, seasonal, and monthly basis fluctuates significantly throughout time. The amount of rainfall that is recorded at each meteorological station varies depending on the locale's sea surface elevation and meteorological station location (3). Rainfall analysis is essential for many applications, including stream flow estimation, environmental studies, agricultural planning, runoff forecast, and water resource management. In numerous hydrologic studies, the quantity, intensity, and spatial distribution of rainfall are important variables (4). The rainfed agriculture farming line changes throughout the study period based on the fluctuation of rainfed agriculture and the impact of other factors. This is reflected to the decreases in production on the one side and the difficulties facing agriculture in unsecured areas, causing a loss to farmers on the other side (5). Many studies had dealt with the issue of rainfed in Iraq. These studies have confirmed that the minimum amount of rain is 200 mm/year, and there is no study that has relied on less than this value. Many studies considered that the southern limits of rainfed cultivation amount to 250 mm/year and 300 mm/year, while other studies determined the amount of rain to be 350 mm/year and others determined 400 mm/year. The last number represents the amount of rain that has been determined as the southern limit of agriculture in Iraq, which was determined by the Iraqi Ministry of Agriculture in 1970 AD. Observations and experiences indicate that an average of 250-300 mm of rain per year represents the amount relied upon to produce a good crop in Iraq, provided that the amount of rain is distributed appropriately during the winter and spring, while other influencing factors remain appropriate (6).In 1989, Al-Dhahi divided the regions of Iraq, based on climatic data, into seasonal rainwater sufficiency regions, which are located in the northern and northeastern parts of Iraq. The second section is the areas of fluctuating seasonal sufficiency, which are located to the south of the first region. The third section is represented by the areas of rain insufficiency, which are located to the south of the second region and constitute 70% of the area of Iraq (7). Al-Shattawi's 2009, study set the minimum limits for the perennial cultivation area as the wheat crop at the equal rain line of 350 mm, and the minimum limits for the barley crop at the equal rain line of 300 mm (8). Rin-fed agriculture in Iraq in general, and Kirkuk and Mosul in particular, is supported by supplementary irrigation through groundwater on the basis that the distribution of rain is not regular during the agricultural season. It has been found that wheat and barley are the two most prominent crops on which perennial agriculture is based in Iraq.The 250 mm rainfall line is an important line as it defines the southern border of the rain-fed agricultural area. Because of the very high degree of variation in annual rainfall, the southern border of the rain-fed agricultural area does not remain in its fixed position. Rainfall plays a crucial role in shaping the climate, ecosystems, and overall livelihoods of a region. Iraq, a country located in the heart of the Middle East, experiences a varied and

challenging climate, with rainfall being a critical factor influencing its environment. This study was aimed investigating the effect of climate change on the variation in the geographical distribution of some elements and factors of climate in Iraq. The cartographic representation method was used, namely the method of isoclinic lines that illustrate these elements in the climate maps for the three climatic periods of 1980-1990, 1990-2000, 2000-2010, and 2010-20202, respectively.

MATERIALS AND METHODS

Study area and Data: Iraq is located at the southwestern part of Asia, with an estimated area of 438,320 km^2. It is surrounded by many countries, Turkey at the north, Iran in the eastern part, the southwestern part with Kuwait, and the Persian Gulf, and the southern part with Saudi Arabia (1). Iraq located in northern hemisphere between latitude (29.5^o-37.5^{o}N) and longitude (38.45^o-48.45^{o}E) (13). Because of this location, the climate area may be regarded as being similar to a Mediterranean climate (14), is hot and dry during the summer, while cold and rainy during winter (15) Mediterranean Sea together with Arabian Gulf have highest influence upon the climate of Iraq (16).Iraq climate is described as a continental, subtropical climate which features four district seasons (17).Iraq is characteristic with big variance in temperature during the exact day among also between the seasons, and this great difference is mainly defining the case of continental climates (18). Iraq can be divided into three climatic regions depending on the rainfall parameter Arid and Semi-Arid Zone, Steppes Zone, and Desert Zone (19, 20). Iraq climate also characterized with desertification and dust storm rising, and that caused by the lack of rainfall particularly during winter, with rising in evaporation because of amount of solar radiation incident upon the ground which led to more desertification (21). Dust storms can suspend large quantities of sand and cause haze in the boundary layer over local and regional scales. Iraq is one of the countries that is often impacted to a large degree by the occurrences of dust storms (22). The months (April May June) have the most occurrence of numbers of dust storms which mean it occurs between springs and summer seasons (23). Monthly rainfall data were obtained in the current study from Iraqi Meteorological Organization and Seismology (IMOS) affiliated with the Iraqi Ministry of Transportation and official website of NASA at spatial resolution (0.5° latitude × 0.5° longitude), for long-term trend analysis for annual rainfall data series (mm) for 41 years from 1980 to 2020 are available for 39 rainfall stations within fairly evenly spread throughout the study region (Figure 1). These data represent a Long-term Climate Records have been used to calculate the mean annual rainfall in Iraq over the 41 years. The homogeneity of the rainfall time-series was determined by (24).

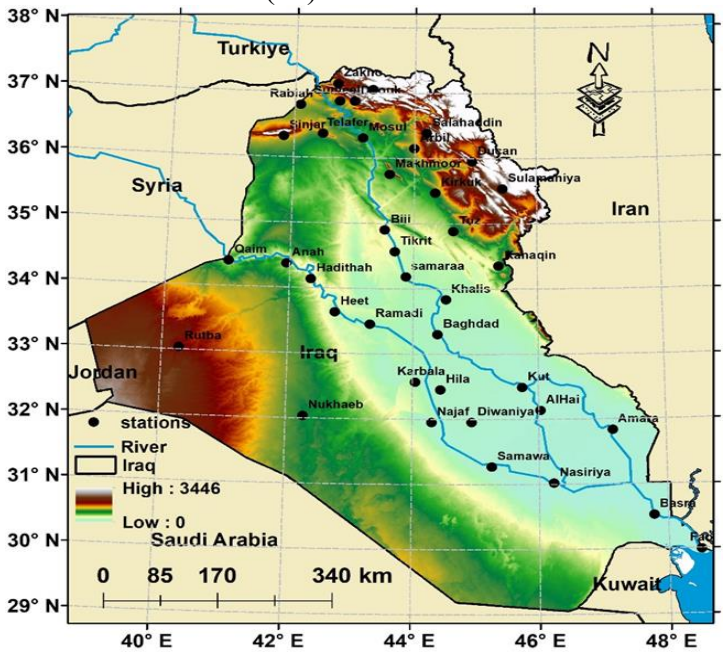

Figure 1. The meteorological stations sites over Iraq

Table (1). shows the details of the stations from Geographic coordinates such as latitude, and longitude, In addition to the descriptive statistics of annual rainfall such as the annual mean (M), Standard Deviation (SD) and coefficients of variation (CV). For the research area, the corresponding annual mean values of rainfall, SD, and CV, were (644 to 77 mm), (266 to 35 mm), and (0.522 to 0.296), respectively. All of the stations had a CV greater than 0.30, with the exception of the northeastern Sumeel station (0.296). The study region has comparatively low mean annual rainfall, ranging from 77 mm at Nukheb to 644 mm at Ducan station. These data demonstrate the complicated and great variability of rainfall in Iraq's semi-arid and desert regions. The research area showed a combination of patterns in rainfall, both increasing and decreasing. This finding implies that local variations in the rainfall regime, as opposed to broad patterns of atmospheric circulation, are responsible for the trends in rainfall observed in a few provinces.

Table 1. Geographical, and descriptive statistics information's of the meteorological stations

Stations	Longitude (Degree)	Latitude (Degree)	Mean (mm)	Standard Deviation (mm)	Minimum (mm)	Maximum (mm)	Coefficient of variation
Zakho	42.72	37.13	543.2	186.2	253.1	978.1	0.343
Emadiyah	43.30	37.05	620.9	222.3	226.8	1067.0	0.358
Sumeel	42.75	36.87	442.7	131.3	188.2	732.0	0.296
Dhouk	43.00	36.87	498.7	171.3	237.3	909.7	0.344
Rabiah	42.10	36.80	345.8	104.6	168.3	586.1	0.303
Salahaddin	44.20	36.38	471.6	240.3	63.3	927.1	0.509
Telafer	42.48	36.37	313.8	107.3	166.3	614.4	0.342
Sinjar	41.83	36.32	342.1	124.6	158.2	663.0	0.364
Mosul	43.15	36.31	362.1	132.2	146.9	639.9	0.365
Arbil	44.00	36.15	404.5	122.2	168.8	676.3	0.302
Ducan	44.95	35.95	644.1	228.2	237.3	1080.2	0.354
Makhmoor	43.60	35.75	296.6	108.8	133.2	596.1	0.367
Sulamaniya	45.45	35.53	619.5	266.2	49.1	1052.1	0.43
Kirkuk	44.35	35.47	346.7	122.2	134.9	669.4	0.353
Biji	43.53	34.90	200.1	67.7	93.1	376.7	0.339
Tuz	44.65	34.88	274.9	98.7	130.3	478.2	0.359
Tikrit	43.70	34.57	164.5	72.9	17.0	304.6	0.443
Qaim	41.02	34.38	120.3	52.9	50.2	240.7	0.44
Anah	41.95	34.37	126.4	49.9	60.6	297.1	0.395
Kanaqin	45.38	34.35	296.4	92.0	144.2	492.1	0.31
samaraa	43.88	34.18	157.5	65.5	57.3	315.4	0.416
Hadithah	42.35	34.13	118.5	52.6	42.2	221.8	0.444
Khalis	44.53	33.83	174.1	61.0	86.2	300.8	0.35
Heet	42.75	33.63	112.1	57.0	40.8	244.1	0.508
Ramadi	43.32	33.45	109.2	46.5	47.5	241.1	0.426
Baghdad	44.40	33.30	122.0	56.3	49.9	296.7	0.462
Rutba	40.28	33.03	108.4	55.2	21.8	263.8	0.509
Karbala	44.05	32.57	90.1	35.0	26.4	200.4	0.388
Kut	45.75	32.49	137.9	53.6	65.5	369.1	0.389
Hila	44.45	32.45	106.4	40.6	41.0	198.0	0.381
AlHai	46.03	32.13	131.7	57.0	43.5	305.6	0.432
Nukhaeb	42.28	32.03	77.3	40.4	21.1	200.2	0.522
Diwaniya	44.95	31.95	102.3	43.3	29.7	223.4	0.423
Najaf	44.32	31.95	94.5	45.3	12.8	190.7	0.479
Amara	47.17	31.83	175.8	81.4	60.1	352.9	0.463
Samawa	45.27	31.27	99.9	51.4	26.2	247.9	0.514
Nasiriya	46.23	31.02	121.0	58.1	33.1	245.8	0.48
Basra	47.78	30.52	130.2	57.5	31.9	296.6	0.442
Fao	48.50	29.98	130.3	59.0	10.6	242.1	0.453

RESULTS AND DISCUSSION

Temporal distribution of rainfall in Iraq

Figure (2), shows the temporal distribution of annual rainfall for Iraq from 1908-2020. The annual rainfall showed a significant negative trend during the study period. The stronger annual rainfall major dip was 109.3 mm in 2017, while highest value of annual rainfall

was 369.3 mm were during 1988 and 1994. Also, it clear that the rainfall in Iraq is characterized by fluctuation and irregularity, and it is unstable in the amount of rain from year to year, and the characteristic of fluctuation is one of the characteristics of Iraqi rain in general. It is evident from graph that the confidence level of 95% for the results are shown in the shaded region around fitted curve (red dash line).

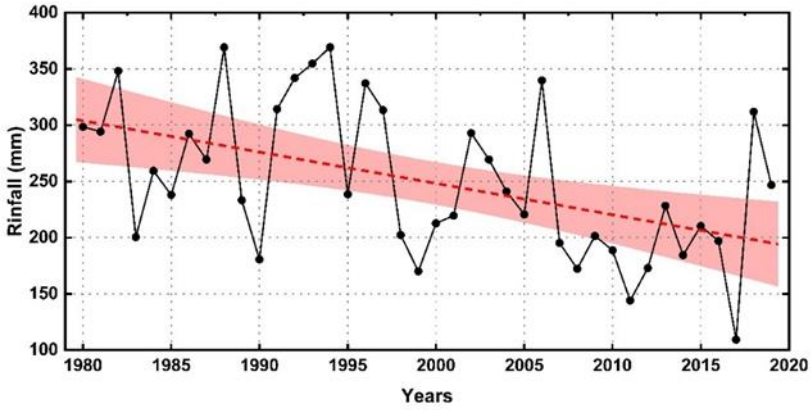

Figure 2. Temporal distribution of annual rainfall during 1980-2020

Spatial distribution of rainfall in Iraq

The results of spatial Pattern and classification of annual rainfall can be noted from Figure (3 A and B) which shows that the southwest region of Iraq is low rainfall area, where rainfall amounts below 100 mm. If one moves towards the center and the northeast of Iraq, high rainfall area can be identified where rainfall reach up to 600mm. The atmospheric depression, topography, and masses of air blowing from the neighboring areas play an important role in the change in annual values of rainfall in these areas (25). Data on the short-term mean annual rainfall (1980–2020) shows a range of 150 mm to 659 mm. This indicates a great degree of spatial variability in the region's rainfall. The research area's northern regions had the greatest rainfall values. Conversely, the southern and western regions of Iraq had the lowest amounts of precipitation. The findings indicate that there are six classes of rainfall distribution on the yearly rainfall map, ranging from 150 to 659 mm.

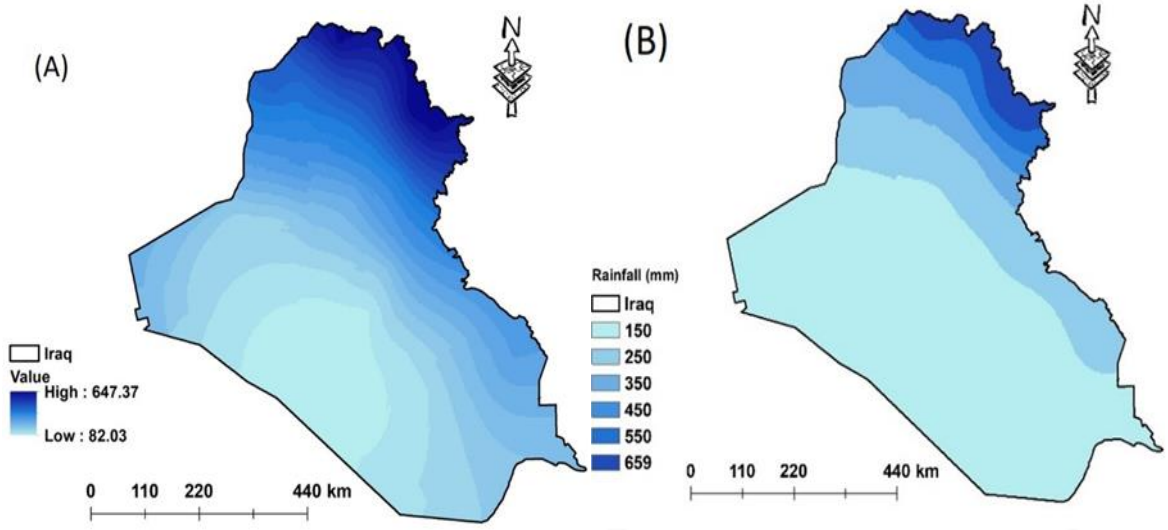

Figure 3. Annual rainfall of Iraq, (A) spatial distribution, (B) classification of annual rainfall all over Iraq during 1980-2020

Figure (4), shows a map published in the book Atlas of Modern Iraq by Dr. Ahmed Sousa, public survey directory presses in 1953. It can be seen that Iraq was located between the 100 mm rainfall line in the south and southwest, and the 1000 mm rainfall line in the northeast of Iraq.

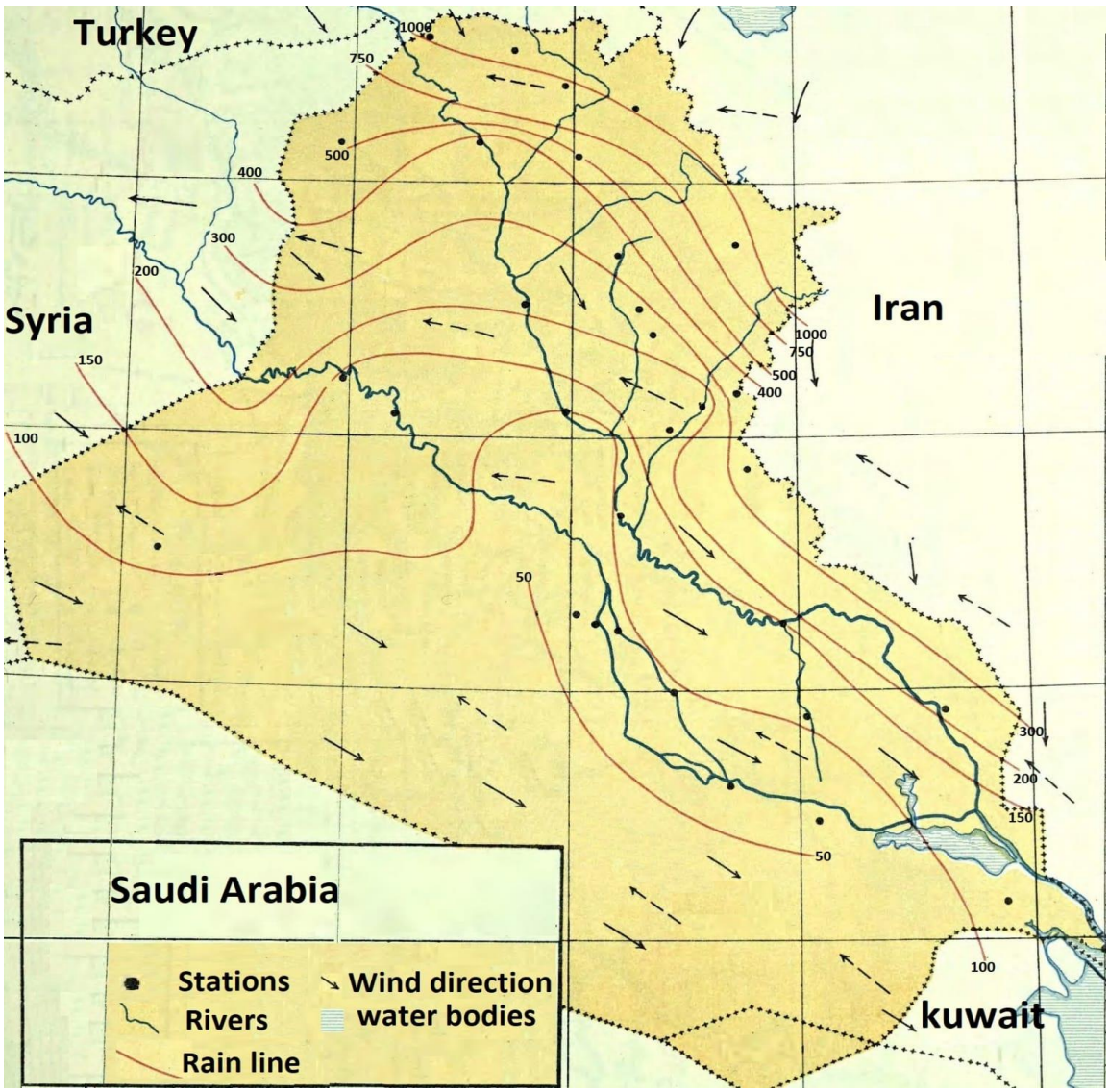

Figure 4. Spatial distribution of annual rainfall in Iraq during the decade of forties (26).

The period of this study has been divided into four periods, each representing a short climatic cycle. The climate periods included the first, second, third, and fourth decades, which represent the years (1980–1990), (1990–2000), (2000–2010), and (2010–2020), respectively. The rain distribution maps were made for the research periods before drawing rain-fed lines. Figure (5), shows the maps of the geographical distribution of rainfall distribution all over Iraq. During the first, second, and third decades of the study, noticed that Iraq became located between the rain lines (150–850), (150–820), and (150–780) mm, respectively. From Figure(5), showed that there was a significant difference in the equal rain lines. Also, it can be seen that the rained line of 1000 mm was founded on the map in Figure 5, moved inland into the high mountainous region, and was subjected to an advance towards the northeastern tip, near the Iraqi borders with both Iran and Turkey. The difference was the disappearance of the 1000-mm rain line in the northeastern part of the mountainous region of Iraq.

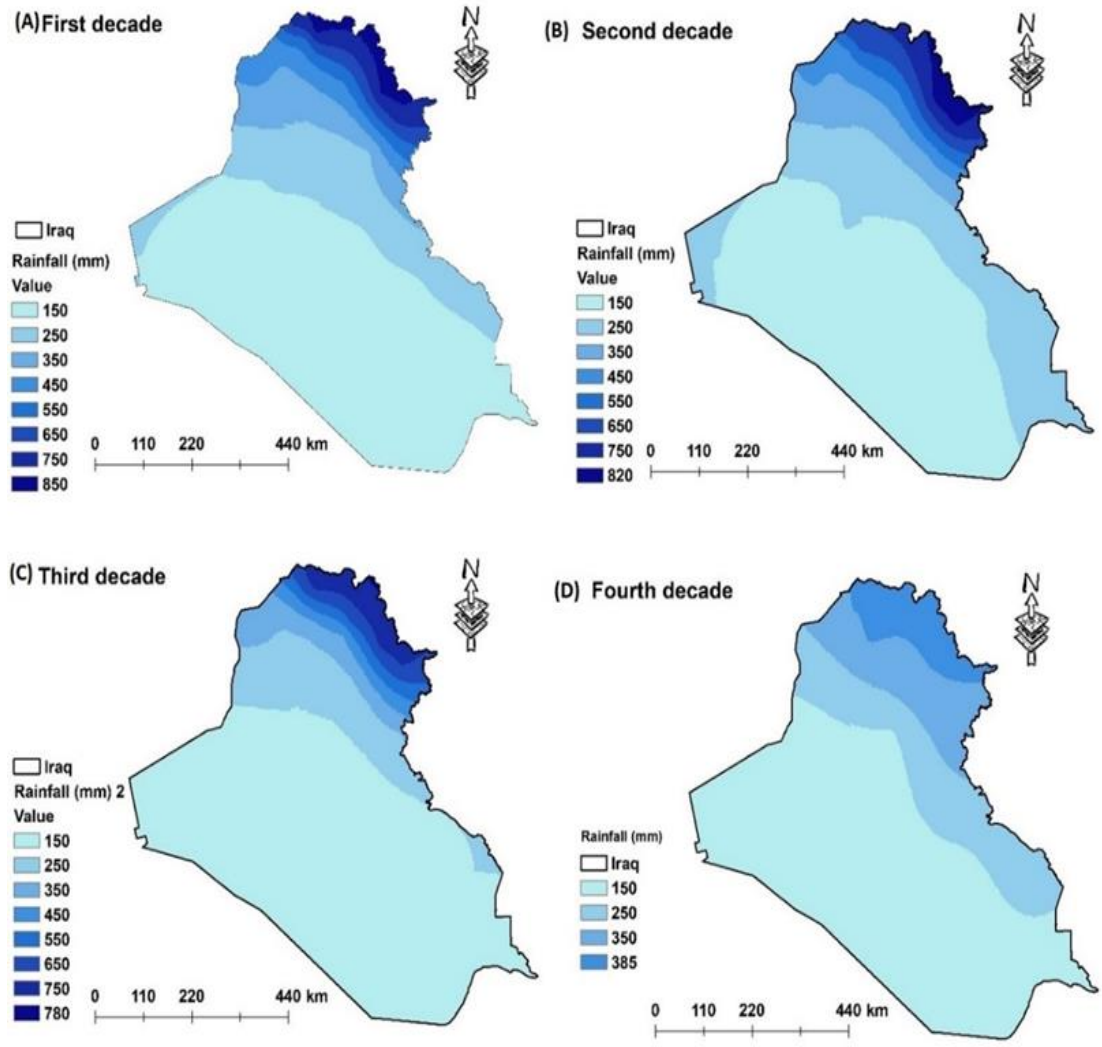

Figure 5. Spatial distribution of annual rainfall in Iraq during the four decades

The results of the comparison of a rainfed line of 250mm between the map in Figure (4) and the map in Figure (6), which included the first period (1980–1990), the second period (1990–2000), the third period (2000–2010), and the fourth period (2010–2020), show the following: During the first climatic period (1980–1990), it was shown that there was a trend towards decreasing annual rainfall; the rainfall contour line of 250 mm shifted to the north along the Iraqi border with Syria and Iran. Also, during the second climatic period (1990–2000), it was observed that there was a decreases in annual rainfall amounts, specifically the 250 mm rain line, which moved towards the north of Iraq. There was a significant correspondence in the behavior of the 250 mm rain line in the first and second periods, especially in the area located north of Baiji station and descending towards the southeast, reaching the Iraqi-Iranian border. Annual rainfall amounts decreased during the third climatic period (2000–2010). There was a greater movement of the rainfed line towards the north than in the previous two periods. Makhmour and Khanaqin stations became within the distribution of the 250 mm rain line after they had been on the 350 mm rain line. In the fourth climatic period (2010–2020), it became clear from the comparison that there was a trend towards a decreases in the annual rainfall amounts and continued to move the rainfed line 250 mm towards northern Iraq. Where the rainfall line of 250 mm reached Sinjar station in Nineveh Governorate, which was on the 500 mm rain line in the forties.

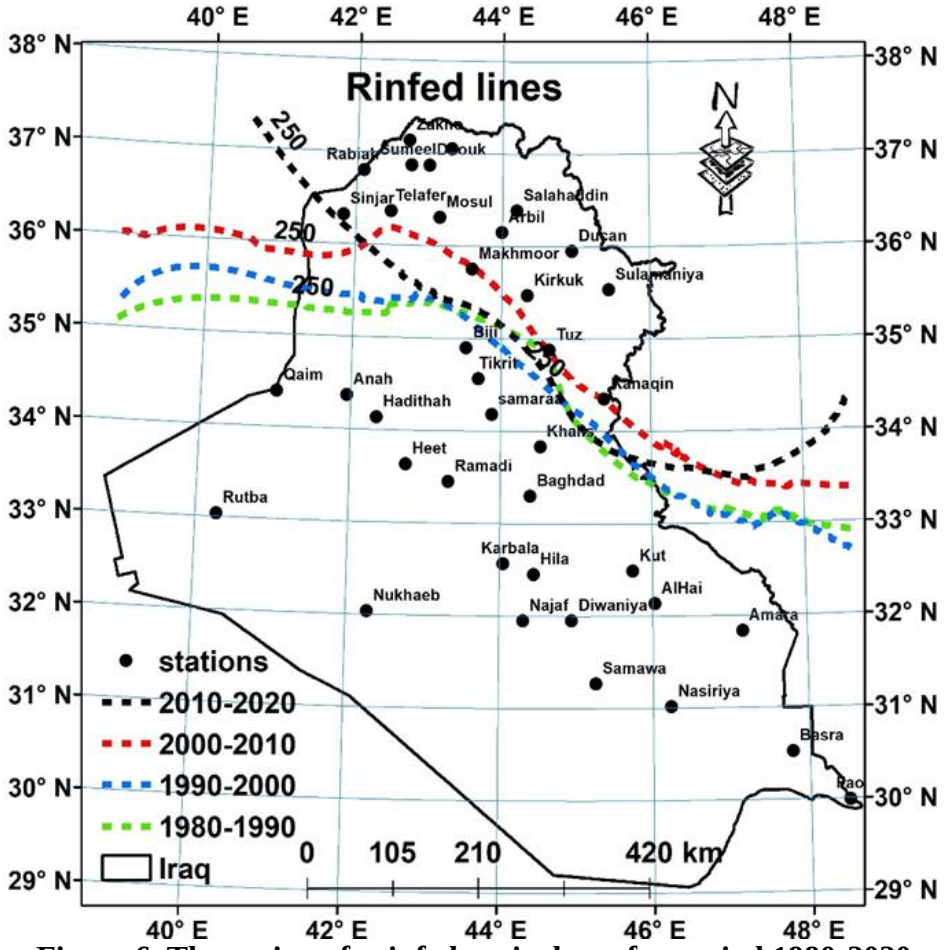

Figure 6. The region of rainfed agriculture for period 1980-2020

Figure (7) shows, the rainfed agriculture region, which depends on a 250 mm rainfall line during the four study periods. During the first time period (1980–1990), the average rainfall throughout Iraq was 280.3 mm, and the rainfall value within this region ranged from 249.8 mm at Tuz station to 771.1mm at Emadiyah station. It can be noted that the stations that can be included within this region are: Zakho, Emadiyah, Sumeel, Dhouk, Rabiah, Salahaddin,Telafer, Sinjar, Mosul,Arbil, Ducan, Makhmoor, Sulamaniya, Kirkuk, Tuz,and Kanaqin. The amount of rain in Iraq during the second time period (1990–2000) was 282.2 mm, which is approximately equal to the amount of rain in the previous period. The rainfall ranged between 282.2mm and 778.4mm at Kanaqin and Ducan stations, respectively. The stations included in this period are the same stations as in the previous period. During the third time period (2000–2010), the area of the rainy region decreased towards the southeast and north of Iraq, and the amount of rain ranged between 236.5mm and 706.2mm at Telafer and Emadiyah stations, respectively. Makhmur and Khanaqin stations left the rainy region, while Touz station was located on the rainy line for 250 mm during this period. During the fourth period (2010 -2020), the general average rainfall was 200.5 mm, and the rain ranged between 141.5 and 383.6 mm at Salahaddin and Emadiyah stations,respectively. The stations that can be included within this region are: Zakho, Emadiyah, Sumeel, Dhouk, Rabiah, Salahaddin,Telafer, Sinjar, Mosul,Arbil, Ducan, Makhmoor, Sulamaniya, Kirkuk, Tuz,and Kanaqin. These stations are distinguished by their height, which ranges between 1236m and 202m above sea level, with Emadiyah station as the highest station and Kanaqin station as the lowest altitude. During the four time periods, the area of the rainfed region amounted to 20.38%, 20.17%, 14.91%, and 17.01%. In general, the area of the region decreased in the southeast and north during the first, second, and third time periods and then expanded slightly during the fourth time period.

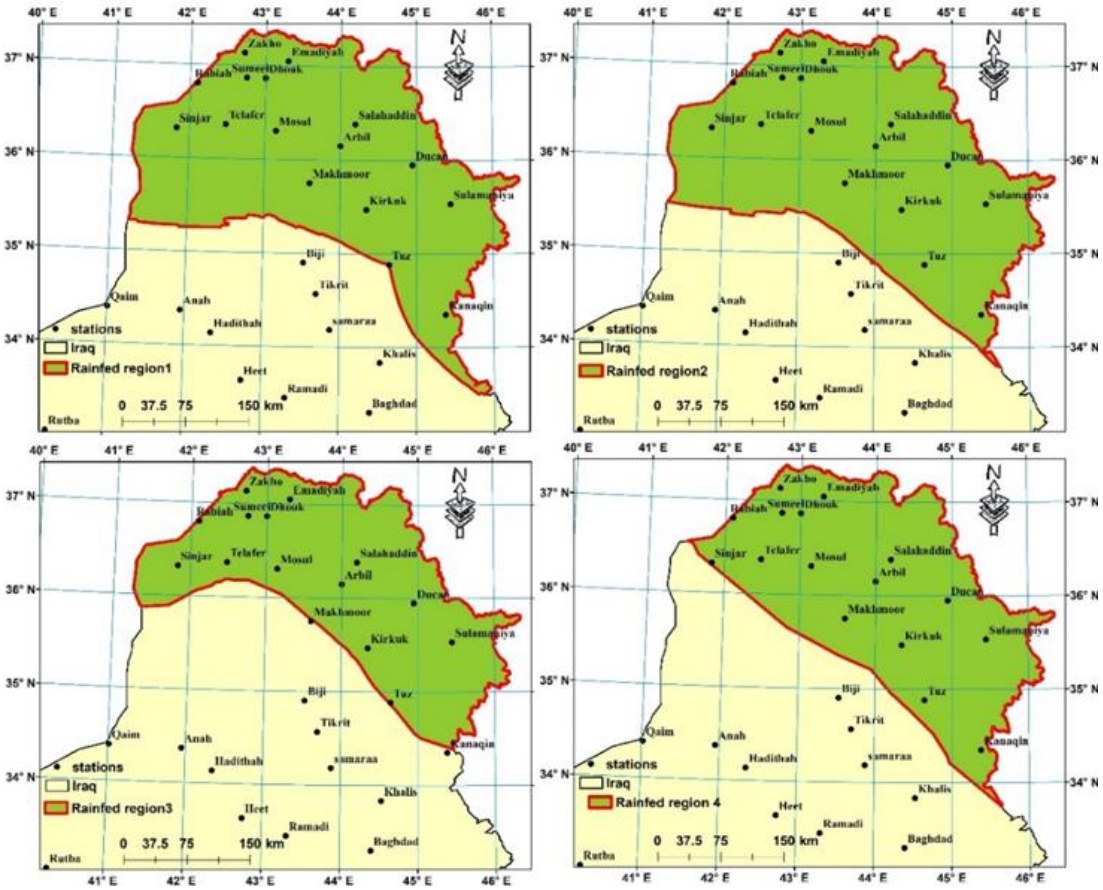

Figure 7. The regions of rainfed agriculture during the study periods

It was revealed that the rain-fed region can be identified in the high mountainous region, the semi-mountainous region, and part of the eastern sections of the alluvial plain. It can also be noted that the geographical distribution of rain-fed agricultural regions in the country is not spatially fixed. Also, the rain-fed agricultural regions are subjected to sharp changes from one period to another, and this is due to the variation in rainfall in Iraq from one season to another.

CONCLUSION

Rainfall in Iraq is a complex and critical aspect of the country's climate, impacting various sectors, including agriculture, water supply, and overall socio-economic well-being. As Iraq grapples with the challenges of water scarcity, understanding and adapting to the variability in rainfall patterns become imperative. By implementing sustainable water management practices and fostering regional cooperation, Iraq could be work towards building resilience in the face of a changing climate and ensuring a stable and secure water future. Rainfall in Iraq is characterized by an unorganized distribution of both spatial and temporal. The annual mean rainfall varies considerably with the years. Therefore, It was find that the rain lines vary from one season to another. There is a difference in determining the permanent agricultural line in Iraq due to the temperatures that Iraq is exposed to during the seasons of the year, which work to reduce the value of effective.

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