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# A Study on Precipitation Change and its Impact on Wheat Cultivation in Sulaimaniyah Region, Iraq

**Akram M. AbdulRahman[1], Jawhar H. Khalid[2] & Zana M. Majeed[1]**

[1]Directory of Agricultural Research, Sulaimaniyah, Iraq
[2]Directorate of Meteorology and Seismology, Sulaimaniyah, Iraq

*Corresponding author: absrh2010@gmail.com

**Abstract:** Using a production function method and district-level data from 1941 to 2020, this study examines the influence of climate change on wheat cropped area in Sulaimaniyah. The data for these time periods provide evidence of an increase in mean rainfall. Since the quantity of rain that fell on Sulaimaniyah during the 79-year research period is averaged out, it comes to 679 mm, which is a good rate for fulfilling agricultural irrigation demands in this location, especially when an essential crop like wheat requires about 450 mm for adequate output. Only nine years, out of the 79 years analyzed, had less than 450 mm of rain, while the rest had more than 450 mm. During the research period, variations in rainfall quantities had an impact on the farmed areas. Season 2019-2020 cultivated about 39250 hectares in Sulaimaniyah Region, with precipitation of 746 mm, while the season before that was one of the wettest, with 1317 mm rain. For the rainy years, which allow greater areas for cultivation, the visual distribution of cultivated areas across the study years reveals a semi-organized pattern. Seasons 2006-2007, 2007-2008 and 2008-2009 were three of the driest seasons, with agricultural areas reduced to bare minimums despite acceptable rainfall levels, although those years were not drought years, since a drought year is defined as a year with less than 300 mm of rain.

**Keywords:** Climate change, Rainfall, cultivating area, Wheat cultivation

## Introduction

One of the most critical elements influencing the overall impact of climate change will be changes in precipitation. Although precipitation is more difficult to forecast than temperature, scientists can make certain predictions with confidence about the future (Schlenker & Roberts, 2008; Dell et al., 2014). Warmer air can contain more moisture, and global water vapor increases by 7% for every degree Celsius of warming. It's less obvious how this will translate into changes in global precipitation, although overall precipitation volume is anticipated to rise by 1-2% for each degree of warming (Feng et al., 2013). There is evidence that regions that are currently wet are more likely to grow wetter, but details regarding how much moisture and the consequences will be at the local scale are difficult to predict. The subtropical dry lands are expected to get drier and move towards the poles. Winters

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are anticipated to be wet over much of Europe, while summers in central and southern Europe will be dryer. (Hundecha & Bardossy, 2005; Fisher et al., 2012).

Changes in weather patterns that make it harder to anticipate precipitation, while many climate models agree on future warming on a global scale, there is less consensus at a technical level when it comes to predict how these changes will impact weather and hence precipitation (Ward et al., 1993). In warmer climates, heavy precipitation is expected to increase, resulting in fewer, but more severe occurrences. This might result in prolonged droughts and a higher danger of floods (Okpara, 2006). So far, any impact of climate change on regional precipitation has been indistinguishable from natural fluctuations. However, a signal began to develop in some specific situations.

According to a new research, man-made climate change increased the likelihood of disastrous floods in England and Wales in the fall of 2000 and Germany in 2021. Increases in severe rainfall throughout the winter may begin to emerge in the UK in the 1920s of twentieth century, according to current thinking (Mearns et al., 2001). According to global warming data, the average global temperature has risen by roughly 1.5 °C since the Industrial Revolution began. According to a separate research, the tendency is increasing, with average temperatures rising by 0.2 °C per decade as global temperatures rise and precipitation patterns shift locally (Tamiotti et al., 2009).

According to the Global Discussion Forum of the United Nations Framework Convention on Climate Change (UNFCCC), rising global temperatures are anticipated to enhance agricultural productivity in temperate zones while reducing yields in tropical regions. Climate change is described by the United Nations Environment Program (UNEP) as severe weather events that have negative consequences for agriculture, water resources, human health, plant cover, soil, ozone layer depletion and carbon dioxide doubling in the ecological environment (Ofori-Boateng, 2014). Climate change has an impact on all natural and human systems, and it may jeopardize human progress as well as social, political and economic existence. Most droughts in arid and semi-arid regions are linked to a late beginning of the rainy season and an early cessation of rainfall, resulting in a significant reduction in the length of the rainy season (Stern, 2008).

## Rainfall as a Critical Variable in Climate Change

Agro-meteorology is the study of the impact of numerous meteorological conditions on agriculture (Salami et al., 2010). Climate variables have a direct influence on agricultural productivity and are used as a basis for agricultural production forecasts. Changes in air temperature and precipitation fluctuations can be used to track climate change. Due to disruptions in the socio-economic system caused by drought or floods, climate change has piqued public attention, particularly in connection to the unpredictability of precipitation over time. On the social and economic side, the impact of climate change is expressed in the amount of surface water in the valley and the volume of groundwater recharge (Ajayi, 1998). Climate fluctuation has a limited influence on power supply (for heating, cooling, irrigation and lighting), coastal cattle husbandry and agriculture, the presence of some disease vectors (valley fever), flood water devastation and tourist and business curtailment (Sivakumar, 1992).

The findings revealed that the frequency of distinct rainfall events, as well as related seasonal and yearly rainfall, in the Kurdistan Region/ Iraq is geographically and seasonally heterogeneous, with the highest rainfall in the northeast and decreasing rainfall in the south. Unsurprisingly, it was discovered through seasonal research that there was a favorable association between agricultural productivity and rainfall in the region. This connection indicates rain-fed agriculture's dominance in the region (Al-Quraishi et al., 2021).

All humid events in Central Europe rose throughout the second half of the twentieth century (1946-1999), despite limited geographical coherence in the trend and evidence of too high changes in extremes relative to the yearly average (KleinTank & Können, 2003). The annual precipitation fraction index rose in the station where the quantity of yearly precipitation increased, leading to particularly wet days with disproportionately significant swings in precipitation extremes (Giannini et al., 2003). There is no obvious reaction to extremes in places with lower annual rainfall. Maximum precipitation patterns in Europe during the last century (1901-2000) indicated regional variations in seasonality (Mottet et al., 2006).

Ahmad et al. (2017) conducted an experiment in Kurdistan Region/ Iraq on the effect of drought on some wheat cultivars and found that wheat yield decreased significantly with the effect of drought and a decrease in rainfall, especially in critical months. Germination percentages of all cultivars used in this experiment were greater in the control treatment and began to decline with increasing amount of water stress.

Opoku-Ankomah & Amisigo (1998) used a time series spectral analysis to determine the importance of weekly, monthly and yearly rainfall in agriculture, water and environmental projects. The most notable feature of precipitation in Central and Western Europe is a considerable rise in winter precipitation, both in terms of average intensity and in the occurrence of quite intense occurrences. There is no indication that summer precipitation indices have changed much (Bozzola et al., 2012).

Osborn et al. (2000) identified a tendency towards wetter circumstances in winter and drier conditions in summer for the United Kingdom, based on a comprehensive data network over the second half of the twentieth century. Intensive heavy rainfall in the winter and transitional seasons grew severe in magnitude and frequency in Western Germany over the same time period. Unlike in the winter, however, the summer tendency in severe rainfall is less dramatic. Climate variability may impact the availability of ground and surface water resources in the long run (Chebil & Frija, 2016). To establish the nature of this restriction, more study is required. Precipitation, an important component of the hydrological cycle, has a high value, both spatially and temporally (between annual and inter annual) and the change in high precipitation has been analyzed, in part, for each of the individual European countries and stations, and to a lesser extent, for Europe as a whole, based on these indicators. (Ghosh et al., 2009).

Changes in precipitation can be regarded as a reaction to external influences or feedback mechanisms in the climate system (Finan et al., 2002). Rainfall is the most significant meteorological element that controls agriculture since it provides the water required for the soil and plant atmosphere systems to function. Precipitation fluctuates greatly, although other time and spatial factors are quite conservative. Precipitation is defined by a numerous asymmetric cycle of abnormalities of various magnitude; these findings corroborate prior findings (Hulme et al., 2001).

Naylor et al. (2007) stated that the findings of rainfall studies in any location can aid decision-makers in the management of water, agricultural, environmental, and other water-related initiatives. While precipitation variability is a prominent characteristic of the climate, the region's average annual precipitation has significantly decreased since 1969.

Due to the intense and severe years of drought that affected Iraq, which resulted in decreased agricultural land areas, large losses in the area of vegetation in Kurdistan Region/ Iraq were noted from 2000 to 2008. The severe drought periods that affected Iraq, particularly the Kurdistan Region/ Iraq in 2000 and 2008, among other variables, as well as a considerable reduction in rainfall averages, are mostly to blame for this loss (Gaznayee et al., 2022).

## Methodology

The mathematical programming technique is used in this work for two reasons. Extensive assessment of economic studies on climate and agriculture is the first reason (Olayide et al., 2016). Using economically estimated fixed-effects dashboard data models, the most notable pair of traditional issues with models based on cross-section data, such as inconsistent and unobservable estimates of climate-related variables, may be minimized. This needs at least two years of observations and data collection, and is based on a single year of original data from farmers.

The other reason is that mathematical optimization provides for a more detailed depiction of the physical limitations that actual farmers confront when selecting what to plant and when to plant it. Because various rainfall schedules specify a distinct set of limitations experienced by farmers, accurate characterization of these constraints is critical to the present study (Rodrigues et al., 2012). Because the present unit of observation and the relevant data are at the farmer level, the crop and farmer-specific production functions may be parameterized without resorting to maximum entropy approaches to disaggregate production characteristics from coarser to finer particular scales, such as the farmer level (Obioha, 2008). The hydrological component employs a mass-balance model to estimate the monthly, seasonal and annual water available for irrigation to farmers in the watershed (Nicholson et al., 2012). The physical restrictions on water and rainfall utilized in the economic component were determined using this information. Following that, these two components are progressively coupled to allow for the assessment of the impacts of changes in rainfall and the volume of stored water in tiny reservoirs on agricultural revenue at various model time resolutions (Mills, 2007).

## Location Study

Sulaimaniyah is a province in northern Iraq. It is distinguished by the overall appearance of its surface. It is hilly, with valleys and tiny plains surrounding it. The city (35°33′26″N 45°26′08″E) is situated at an elevation of 850 meters above sea level. From north to south, the city is bordered by many mountain ranges. Sulaimaniyah is built on a 3.5% sloping piece of ground. The city's northern end rises to 885 meters above sea level, while the southern end rises to 800 meters. The city's climate may be classified as temperate, or the Mediterranean climate of the mountain, based on climate classifications conducted by researchers and professionals in this field. It's most important climatic features included the average annual temperature of 18.74 °C, the predominant winds (locally known as rashaba, which in Kurdish language means strong winds) are northeast and usually very fast and the rainy season is primarily in the winter and spring, with little rain in the summer. In 2018, more annual rain was reported; totaling 1273.80 mm. solar radiations hitting the Sulaimaniyah station on a daily basis averages 989.4 kcal/cm$^2$/day. Due to the heavy clouds and relative humidity, it is reasonable to state that solar radiation is moderated in the northern area in general and in Sulaimaniyah in particular. Daily vertical radiation rate of 5-6 kWh/m$^2$ in the northern area, and 6-6.5 kWh/m$^2$ in the middle and southern regions. Wheat is the most significant crop in the study region, accounting for more than half of the total land area (Mazid, 2015).

## Result and Discussion

Figure 1 depicts the time spans from 1945 to 1951, then 1952 to 1957, 1959 to 1962, and so on through 2019. The line rises and falls in a semi-regular pattern during all of these times. During the 79-year research period, there were at least 21 rises and falls. It did not exceed the periods when rainfall dropped for four seasons in a row, such as the years 1948 to 1951. When the amount of rain that fell on Sulaimaniyah Rgion over the study period, is averaged out, it comes to 679 mm, which is an excellent rate for meeting agricultural irrigation needs in this region, especially when an important crop like wheat requires approximately 450 mm for adequate production. Table 1 displays the yearly rainfall trend. Based on the results of research and studies conducted at stations affiliated with the Agricultural Research Department in Sulaimaniyah Province, the amounts of rainfall were classified into three main divisions according to the needs of the irrigated wheat plant, which were estimated to be around 400 mm. (Dell et al., 2014).

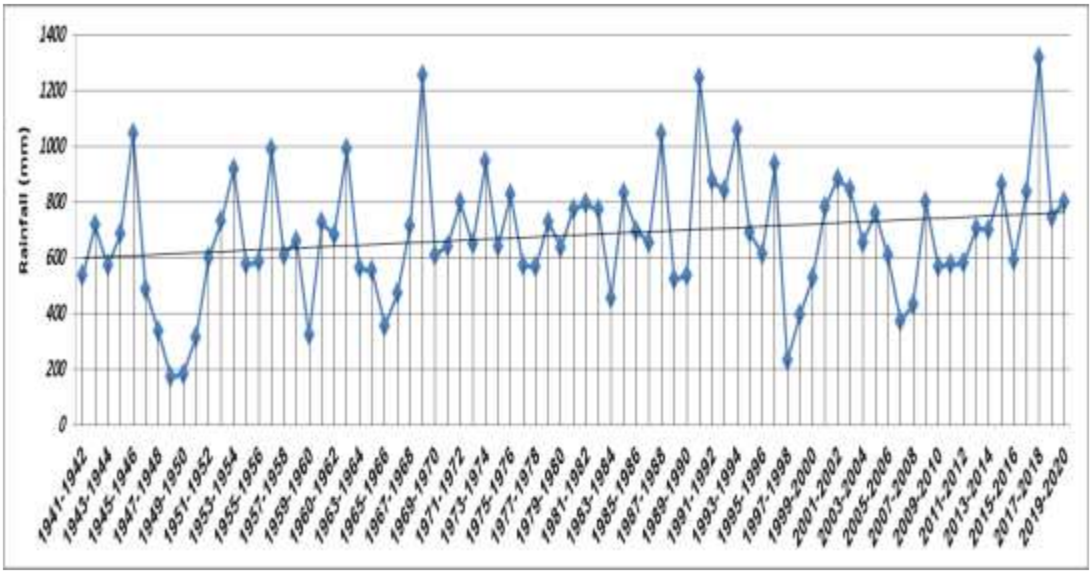


Figure 1: Data of rainfall for Sulaimaniyah Region based on the compositing of 79 annual analyses from the newly developed 1941 to 2019. Source: Directorate of Meteorology and Earthquakes in Sulaimaniyah, Iraq.

There were only nine seasons in which the amounts of rain were less than the critical limit or the first division, which was calculated at less than 400 mm, which is a small fraction compared to the 78 years in the research period. In terms of the second class of rain quantities, it was a fair quantity, estimated at more than 450 mm, with 21 seasons in which the amount of rain was between 400 and 650 mm. The plant gets its needs from the amount of rain water at these percentages. The number of seasons covered in the third group grew to 41, with heavy years defined as those with more than 650 mm of rain. As a results for data's in table 1, it is clear that if the wheat crop depends in its growth and production on the amounts of rain, then the percentage of rain is good and is considered good to give the best production in the event of a good distribution of this rain (Tošić & Unkašević, 2005; Aggarwal, 2008).

As indicated in Table 2, total rainfall in eight decades has grown. Of course, this increase is dispersed across the years of these decades in various years and months, but it appears that the rates of rainfall have increased with time (Lobell et al., 2011).

Because the bulk of seeds, planted in November, the germination of these seeds is dependent on the amount of rain. November is one of the most significant months for the culture of wheat.

Table 1: The state of rain during the period from 1941 to 2019.

| Rainfall state | Years | Number of years | Rainfall amounts |
|---|---|---|---|
| Low | 1948-1949, 1949-1950, 1998-1999<br>1950-1951, 1959-1960, 1947-1948<br>1965-1966, 2007-2008, 1999-2000 | 9 | Lower than 400 mm |
| Moderate | 2008-2009, 1983-1984, 1966-1967<br>1946-1947, 1988-1989, 2000-2001<br>1941-1942, 1989-1990, 1964-1965<br>1963-1964, 1977-1978, 2010-2011<br>1943-1944, 1976-1977, 2011-2012<br>1954-1955, 2012-2013, 1955-1956<br>2016-2017, 1951-1952, 2006-2007<br>1957-1958, 1969-1970, 1996-1997<br>1979-1980, 1974-1975, 1970-1971<br>1972-1973 | 29 | 400-650 mm |
| High | 2004-2005, 1986-1987, 1958-1959<br>1961-1962, 1944-1945, 1995-1996<br>1985-1986, 2014-2015, 2013-2014<br>1967-1968, 1942-1943, 1960-1961<br>1978-1979, 1952-1953, 2019-2020<br>2005-2006, 1982-1983, 1980-1981<br>2001-2002, 1981-1982, 1971-1972<br>2009-2010, 1975-1976, 1984-1985<br>2017-2018, 1993-1994, 2003-2004<br>2015-2016, 1992-1993, 2002-2003<br>1953-1954, 1997-1998, 1973-1974<br>1962-1963, 1956-1957, 1987-1988<br>1945-1946, 1994-1995, 1991-1992<br>1968-1969, 2018-2019. | 41 | More than 650 mm |

Source: Directorate of Meteorology and Earthquakes in Sulaymaniyah, Iraq.

Table 2: Changes in rainfall amounts for specific months over decades since 1941.

| Years (1941-2020) | Rainfall amount | Rainfall amount for November* | | Rainfall amount for March* | | Rainfall amount for April* | |
|---|---|---|---|---|---|---|---|
| | | Mm | % | mm | % | Mm | % |
| Decade 1 (1941-1950) | 5031.6 | 528.9 | 10.51 | 901.1 | 17.9 | 543.6 | 10.80 |
| Decade 2 (1951-1960) | 6701.6 | 829.5 | 12.37 | 1262 | 18.83 | 1136.3 | 16.95 |
| Decade 3 (1961-1970) | 6819.7 | 634.0 | 9.29 | 914 | 13.4 | 1394.9 | 20.45 |
| Decade 4 (1971-1980) | 7123.1 | 536.9 | 7.53 | 1455.8 | 20.43 | 872.1 | 12.24 |
| Decade 5 (1981-1990) | 6894.6 | 1086.9 | 15.76 | 1008.2 | 14.62 | 725.7 | 10.52 |
| Decade 6 (1991-2000) | 6873.5 | 1012.5 | 17.64 | 1105.0 | 16.07 | 916.4 | 13.33 |
| Decade 7 (2001-2010) | 6647.7 | 578.8 | 8.7 | 797.6 | 11.99 | 1030.8 | 15.50 |
| Decade 8 (2011-2019) | 7474.0 | 982.3 | 13.14 | 1267.2 | 16.95 | 628.9 | 8.41 |

Source: directorate of Meteorology and Earthquakes in Sulaimaniyah, Iraq.
* Since November, March and April are critical months for wheat growth.

Table 3 shows that the quantity of rain varied by season and decade over the research period, but in general, most of the seasons had good quantities of rain until the seeds germinated, which surpassed the 10% of November rainfall. This month is important for the growth of wheat plants since the absence of ground moisture during this phase leads to a loss of fertilization and seed storage, therefore plants should not be thirsty during this phase.

The ovary progressively comes up to maturity in this month, as well as a process of pollination and fertilization in wheat flowers. The most essential activities that occur in this month are the transfer of nutrients, water and organic elements, necessary for growth, from stems and leaves to grains. A pollination and fertilization procedures are also carried out throughout April. After pollination and fertilization in the wheat flower, starch storage occurs in the grains, and the weight of the grains rises linearly throughout this month depending on rainfall quantities, temperature, organic matter and nutrients, and then progressively follows the stage of grain maturity (Moberg & Jones, 2005).

Table 3: Effect of long term of rainfall on changing sowing wheat date.

| Decades (1941-2020) | Sowing in September | Sowing in October | Sowing in November | Sowing in December | Sowing in January |
|---|---|---|---|---|---|
| Decade 1 (1941-1950) | Non | 3 Seasons | 6 Seasons | Non | 1 Season |
| Decade 2 (1951-1960) | Non | 1 Season | 5 Seasons | 4 Seasons | Non |
| Decade 3 (1961-1970) | Non | Non | 5 Seasons | 4 Seasons | 1 Season |
| Decade 4 (1971-1980) | Non | 1 Season | 4 Seasons | 5 Seasons | Non |
| Decade 5 (1981-1990) | Non | 2 Seasons | 7 Seasons | 1 Season | Non |
| Decade 6 (1991-2000) | Non | 3 Seasons | 7 Seasons | Non | Non |
| Decade 7 (2001-2010) | Non | 3 Seasons | 4 Seasons | 3 Seasons | Non |
| Decade 8 (2011-2019) | Non | 4 Seasons | 5 Seasons | Non | Non |

Sources: Directorate of Meteorology and Earthquakes in Sulaimaniyah, Iraq and General Directorate for Agriculture in Sulaimaniyah, Iraq.

Climate change, particularly changes in the critical and important months for the germination of crops, particularly the crop under study, has had an impact on the field study conducted and the information received that the dates of planting the wheat crop have changed as the dates of rainfall have changed.

Table 3 shows that the planting season has shifted between October and November in the recent decade. They used to plant their crops in October at the start of the decade, but as rainy season dates changed, farmers had to wait planting until November to ensure that the seeds of their crops germinated, as this month became more guarantees for planting and seed germination (Dai et al., 2004).

Table 4 shows the steady rise in temperature rates as in the months under investigation, which is clearly seen, especially in the crucial and essential months for wheat cultivation, such as October and November. The average temperatures for October and November in the 1940s were 25 and 16.7, respectively. In following study period, average temperatures reached 28.9 and 20.3, respectively in the first decade of this century. Although this rise in temperatures was accompanied by a rise in the rates of rain, the dates of the fall of these rains were not in the interest of some field crops, especially the crop under study.

According to Figure 2, differences in rainfall amounts had an effect on the cultivated areas during the study period. The largest cultivation areas reordered were in season 2019-2020, which cultivated nearly 157 000 dunam (also spelled as donum) in Sulaimaniyah Region. In this season, the precipitation was 746 mm, but the season before that was one of the wettest, with 1317 mm rain (Parry et al., 2004).

Table 4: Relationship between rainfall and temperatures.

| Decades (1941-2020) | Rainfall Average | Average Temp. in Sep. | Average Temp. in Oct. | Average Temp. in Nov. | Average Temp. in Dec. | Average Temp. in Jan. |
|---|---|---|---|---|---|---|
| Decade 1 (1941-1950) | 503.16 | 32.6 | 25.0 | 16.76 | 10.75 | 7.25 |
| Decade 2 (1951-1960) | 670.16 | 33.4 | 26.10 | 17.07 | 10.95 | 7.3 |
| Decade 3 (1961-1970) | 681.97 | 34.9 | 26.70 | 17.8 | 11.32 | 7.5 |
| Decade 4 (1971-1980) | 712.31 | 35.03 | 27.25 | 18.42 | 11.63 | 7.77 |
| Decade 5 (1981-1990) | 689.46 | 35.62 | 27.78 | 18.57 | 12.41 | 8.4 |
| Decade 6 (1991-2000) | 687.35 | 36.2 | 28.5 | 19.2 | 13.35 | 9.0 |
| Decade 7 (2001-2010) | 664.77 | 36.5 | 28.6 | 19.8 | 12.5 | 10.4 |
| Decade 8 (2011-2020) | 830.44 | 34.76 | 28.9 | 20.3 | 13.17 | 10.6 |

Sources: Directorate of Meteorology and Earthquakes in Sulaimaniyah, Iraq and General Directorate for Agriculture in Sulaimaniyah, Iraq.

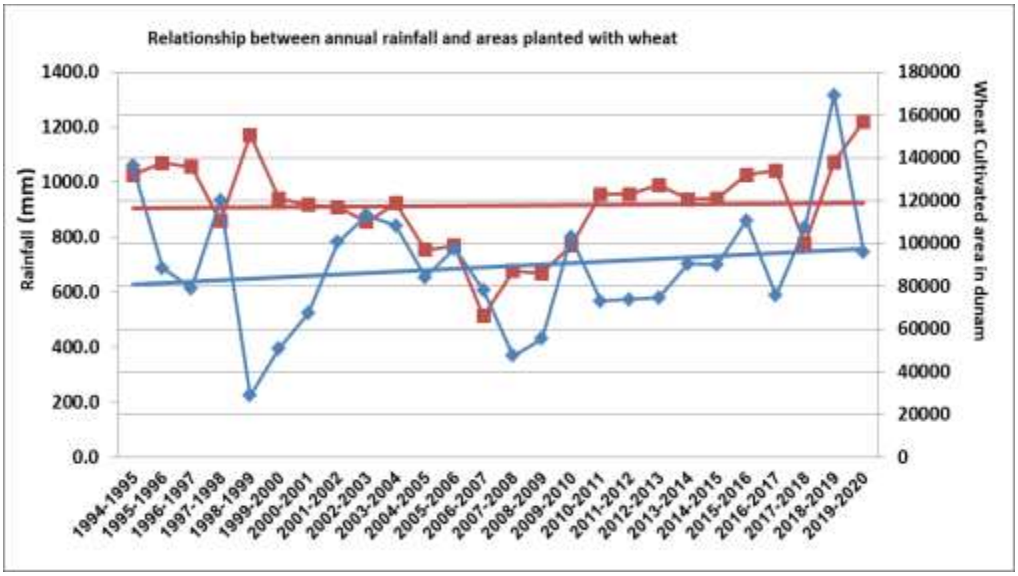


Figure 2: Relationship between the areas cultivated with wheat (in dunam which is 2500 $m^2$) and the amount of rain in Sulaimaniyah. Sources: General Directorate for Agriculture in Sulaimaniyah, Iraq and Directorate of Meteorology and Earthquakes in Sulaimaniyah, Iraq.

The graphic distribution of cultivated areas over the study years (Figure 2), shows a semi-organized pattern for the wet years, which provided larger areas for cultivation, such as the seasons1994-1995, 1997-1998, 2001-2002, 2002-2003, 2003-2004, 2004-2005, 2005-2006, 2006-2007, 2007-2008, 2008-2009, 2009-2010, 2015-2016, 2017-2018 and 2018-2019 which were one of the very dry seasons in which farmed lands were reduced to the bare minimums, despite the fact that rainfall levels were within permissible standards, and those years were not drought years, since a drought year is defined as a year with less than 300 mm of rain.

When comparing the cultivated areas in successive years from 1994 to 2020 (Figure 3), one can see that there is a change in the cultivated areas, particularly during 1994, 2006 and 2019. As a result, the quantities of wheat produced will change annually, affecting the output and economic return for farmers. When looking at the cultivated areas from 1997-98, when about 934 dunam were planted, it is clear that there has been a reduction in the cultivated lands, peaking in 2006-2007. After the 2006-2007 seasons, wheat planting areas increased until they reached their greatest level in 2016 season, when they reached around 870 dunam. When drawing a trend line for these data in the graph, one can notice that the areas planted with wheat in the years under consideration have been rather stable (Singh et al., 2013).

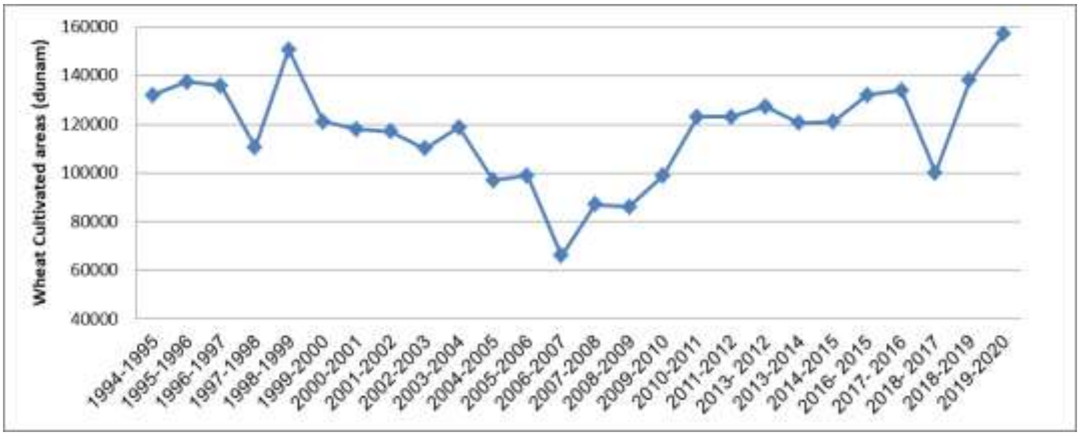


Figure 3: Impact of rainfall amounts changes on cultivated area in Sulaimaniyah Region (One dunam= 2500 m$^2$). Sources: General Directorate for Agriculture in Sulaimaniyah, Iraq and Directorate of Meteorology and Earthquakes in Sulaimaniyah, Iraq.

The adoption of most regions is one of the causes for output fluctuations from year to year. The impact of cultivated wheat on rainfall quantities and dispersion, in addition to other variables, such as the development of rust infections, epidemic in a number of wet years before maturity, during the planting season (Zolina et al., 2005).

Because of the dramatic variations in rain amounts and distribution, as well as the dramatic increase and fall in temperatures, officials may be compelled to re-examine some of the fundamentals of wheat production, such as selecting better planting dates in response to climatic changes. Researching and developing long-term solutions, at the very least, to the impact of climate change on agriculture in general, including meetings between scientists, government officials and incorporating farmers through a series of interconnected workshops are needed. The work of specialized committees between the Ministry of Agriculture and meteorologists is needed to create simulation programs for the next 30 years and to find sports models. The Aqua Crop program has shown to be crucial in determining how people may be impacted by climate change in the near future. Every year that goes by, without the program being implemented, is an irreversible loss in terms of studying the consequences of climate change on agriculture and developing more effective policies.

## References

Aggarwal, P.K. (2008). Global climate change and Indian agriculture: Impacts, adaptation and mitigation. Indian J. Agric. Sci., 78(10): 911-919.

Ahmad, N.S.; Kareem, S.H.S.; Mustafa, K.M. & Ahmad, D.A. (2017). Early screening of some Kurdistan wheat (*Triticum aestivum* L.) cultivars under drought stress. J. Agric. Sci., 9(2): 88-103. DOI:10.5539/jas.v9n2p88.

Ajayi, A.E. (1998). Agrostatistical analysis of rainfall data for the humid and sub humid stations of Nigeria. M. Eng. Thesis, School of Postgraduate Studies, Federal University of Technology, Akure, Nigeria: 73 pp.

Al-Quraishi, A.M.F.; Gaznayee, H.A.A. & Messina, J.P. (2021). Drought severity trend analysis based on the landsat time-series dataset of 1998-2017 in the Iraqi Kurdistan Region. In: IOP Conf. Ser.: Earth Environ. Sci., 779(1): 012083. IOP Publishing.

Bozzola, M.; Massetti, E.; Mendelsohn, R. & Capitanio, F. (2012). A Ricardian analysis of the impact of climate change on Italian agriculture. In: Bosello, F. (ed.). Climate change: Economic impacts and adaptation. Note di Lavoro, Fondazione eni Enrico Mattei, 23: 47 pp.

Chebil, A. & Frija, A. (2016). Impact of improving water use efficiency on its valuation: The case of irrigated wheat production in Tunisia. Afr. J. Agric. Resour. Econ., 11(2): 131-140. https://hdl.handle.net/20.500.11766/5904.

Dai, A.; Lamb, P.J.; Trenberth, K.E.; Hulme, M.; Jones, P.D. & Xie, P. (2004). The recent Sahel drought is real. Int. J. Climatol., 24(11): 1323-1331.

Dell, M.; Jones, B.F. & Olken, B.A. (2014). What do we learn from the weather? The new climate-economy literatures. J. Econ. Lit., 52(3): 740-798. DOI: 10.1257/jel.52.3.740.

Feng, X.; Porporato, A. & Rodriguez-Iturbe, I. (2013). Changes in rainfall seasonality in the tropics. Nat. Clim. Change, 3: 811-815. DOI:10.1038/nclimate1907.

Finan, T.J.; Austin, D. & McGuire, T.R. (2002). Processes of adaptation to climate variability: A case study from the US Southwest. Clim. Res., 21(3): 299-310. DOI:10.3354/cr021299.

Fisher, A.C.; Hanemann, W.M. & Roberts, M.J. & Schlenker, W. (2012). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. Am. Econ. Rev., 102(7): 3749-3760. DOI: 10.1257/aer.102.7.3749.

Gaznayee, H.A.A.; Al-Quraishi, A.M.F.; Mahdi, K. & Ritsema, C.J. (2022). A geospatial approach for analysis of drought impacts on vegetation cover and land surface temperature in the Kurdistan Region of Iraq. Water, 14(6), 927: 29 pp. DOI:10.3390/w14060927.

Ghosh, S.; Luniya, V. & Gupta, A. (2009). Trend analysis of Indian summer monsoon rainfall at different spatial scales. Atmos. Sci. Lett., 10(4): 285-290. DOI:10.1002/asl.235.

Giannini, A.; Saravanan, R. & Change, P. (2003). Ocean forcing of Sahel rainfall on inter-annual to inter-decadal time scales. Science, 302: 1027-1030.

Hulme, M.; Doherty, R.M.; Ngara, T.N.M.; New, M.G. & Lister, D. (2001). African climate change: 1900-2100. Clim. Res., 17(2): 145-168. DOI: 10.3354/cr017145.

Hundecha, Y. & Bárdossy, A. (2005). Trends in daily precipitation and temperature extremes across western Germany in the second half of the 20th century. Int. J. Climatol., 25(9): 1189-1202. DOI:10.1002/joc.1182.

KleinTank, A.M.G. & Können, G.P. (2003). Trends in indices of daily temperature and precipitation extremes in Europe, 1946-99. J. Clim., 22(16): 3665-3680. DOI:10.1175/1520-0442(2003)016<3665:TIIODT>2.0.CO;2.

Lobell, D.B.; Schlenker, W. & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. Science, 333(6042): 616-620. DOI:10.1126/ science.1204531.

Mazid, A. (2015). The project for wheat productivity improvement towards food self-sufficiency. Baseline Survey Analysis. Status of wheat production in Kurdistan Region of Iraq: Results of baseline survey. Japan International Cooperation Agency (JICA) and International Center for Agricultural Research in Dry Area (ICARDA): 40 pp.

Mearns, L.O.; Easterling, W.E.; Hays, C. & Marx, D. (2001). Comparison of agricultural impacts of climate change calculated from high and low resolution climate change scenarios: Part I. The uncertainty due to spatial scale. Clim. Change, 51(2): 131-172. DOI:10.1023/A:1012297314857.

Mills, E. (2007). From risk to opportunity: 2007 Insurer’s responses to climate change. A. Ceres Report, Boston: 44 pp.

Moberg, A. & Jones, P.D. (2005). Trends in indices for extremes in daily temperature and precipitation in Central and Western Europe, 1901-99. Int. J. Climatol., 25(9): 1149-1171. DOI:10.1002/joc.1163.

Mottet, A.; Ladet, S.; Coqué, N. & Gibon, A. (2006). Agricultural land-use change and its drivers in mountain landscapes: A case study in the Pyrenees. Agric. Ecosyst. Environ., 114(2-4): 296-310. DOI:10.1016/j.agee.2005.11.017.

Naylor, R.L.; Battisti, D.S.; Vimont, D.J.; Falcon, W.P. & Burke, M.B. (2007). Assessing risks of climate variability and climate change for Indonesian rice agriculture. Proc. Natl. Acad. Sci. U.S.A., 104(19): 7752-7757. DOI:10.1073/ pnas.0701825104.

Nicholson, S.E.; Klotter, D. & Dezfuli, A.K. (2012). Spatial reconstruction of semi-quantitative precipitation fields over Africa during the nineteenth century from documentary evidence and gauge data. Quat. Res., 78(1): 13-23. DOI: 10.1016/j.yqres.2012.03.012.

Obioha, E.E. (2008). Climate change, population drift and violent conflict over land resources in Northeastern Nigeria. J. Human Ecol., 23(4): 311-324. DOI: 10.1080/09709274.2008.11906084.

Ofori-Boateng, K. (2014). The impact of climate change and cocoa production in West Africa. Int. J. Clim. Change Strategies Manag., 6(3): 296-314. DOI: 10.1108/IJCCSM-01-2013-0007.

Okpara, E.P. (2003). Complementarily between densification and climate change conventions responses to unpredictable rainfall patterns in Nigeria, Dry Belt. NEST Forum: No. 19: 7-8.

Olayide, O.E.; Tetteh, I.K. & Popoola, L. (2016). Differential impacts of rainfall and irrigation on agricultural production in Nigeria: Any lessons for climate-smart agriculture? Agric. Water Manag., 178: 30-36. DOI:10.1016/ j.agwat.2016.08.034.

Opoku-Ankomah, Y. & Amisigo, B.A. (1998). Rainfall and runoff variability in the southwestern river system of Ghana. In: Servat, E.; Hughes, D.; Fritsch, J.-M.; Hulme, M. (eds.). Water resources variability in Africa during the XXth century. Proc. Abidjan' 98 Conf., IAHS Publ. No. 252: 307-314.

Osborn, T.J.; Hulme, M.; Jones, P.D. & Basnett, T.A. (2000). Observed trends in the daily intensity of United Kingdom precipitation. Int. J. Climatol., 20(4): 347-364. DOI:10.1002/(SICI)1097-0088(20000330)20:4<347::AID-JOC475 >3.0.CO;2-C.

Parry, M.L.; Rosenzweig, C.; Iglesias, A.; Livermore, M. & Fischer, G. (2004). Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Glob. Environ. Change, A, 14: 54-67. DOI: 10.1016/j.gloenvcha.2003.10.008.

Rodrigues, L.N.; Sano, E.E.; Steenhuis, T.S. & Passo, D.P. (2012). Estimation of small reservoir storage capacities with remote sensing in the Brazilian Savannah Region. Water Resour. Manag., 26(4): 873-882. DOI:10.1007/ s11269-011-9941-8.

Salami, A.; Kamara, A.B. & Brixiova, Z. (2010). Smallholder agriculture in East Africa: Trends, constraints and opportunities. African Development Bank, Tunis, Tunisia, Working Paper Series No. 105: 52 pp.

Schlenker, W. & Roberts, M. (2008). Estimating the impact of climate change on crop yields: The importance of non-linear temperature effects. National Bureau of Economic Research (NBER) Working Paper No. 13799: 35 pp.

Sivakumar, M.V.K. (1992). Climate change and implications for agriculture in Niger. Clim. Change, 20: 297-312.

Singh, N.P.; Byjesh, K.; Ranganathan, C.R. & Bantilan, C. (2013). Quantifying economic impact of climate change on rice in semiarid tropics of India: Using Ricardian approach for the state of Andhra Pradesh. Asia Pac. J. Environ. Dev., 20: 41-55.

Stern, N. (2008). The economics of climate change. Am. Econ. Rev., 98(2): 1-37. DOI:10.1257/aer.98.2.1.

Tamiotti, L.; Teh, R.; Kulaçoğlu, V.; Olhoff, A.; Simmons, B. & Abaza, H. (2009). Trade and climate change. WTO-UNEP Rep. Secretariat, Switzerland: xxii + 166 pp. ISBN: 978-92-870-3522-6.

Tošić, I. & Unkašević, M. (2005). Analysis of precipitation series for Belgrade. Theor. Appl. Climatol., 80: 67-77. DOI:10.1007/s00704-004-0076-1.

Ward, M.N.; Folland, C.K.; Maskell, K.; Colman, A.W.; Rowell, D.P. & Lane, K.B. (1993). Experimental seasonal forecasting of tropical rainfall at the UK meteorological office. In: Shukla, J. (Ed.). Prediction of interannual Climate Variations. NATO ASI Ser., 6: 197-216.

Zolina, O.; Simmer, C.; Kapala, A. & Gulev, S. (2005). On the robustness of the estimates of centennial-scale variability in heavy precipitation from station data over Europe. Geophys. Res. Lett., 32(14): 5 pp. DOI:10.1029/ 2005GL023231.