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RESEARCH ARTICLE

Effect of climate on variation of oil crop production in Anbar Governorate

Bilal Muayad Abdulrahem Alalosy[1], Sulaf Taha Daood[2], Mohammed Rahim Mohamed[1], Ali Suleiman Erzik Al-Karbouli[2], Jumaa Mohammed Ahmad[1] & Emad T. Abdel Ghani[1*]

[1]Upper Euphrates Basin Developing Centre, University of Anbar, Iraq
[2]General Directorate of Anbar Education, Anbar Province, Iraq

*Email: emadabdulghani@uoanbar.edu.iq

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Abstract

The different elements of climate have an effective impact on the nature and quality of cultivated crops in any region and this effect is reflected by determining the thermal, photovoltaic, and water requirements and the time of germination and growth for each crop, The results show that there is a difference in climatic conditions in each of the study stations within Anbar Governorate, and this variation is evident in the climatic elements affecting the growth and maturity of oily crops, especially the general average temperature and the maximum and minimum temperature rates, which increased in 2022 compared to the year 2000. In the shadow of the decrease in the amounts of rain from what it was in the past, this difference was reflected in the quantities of production between those years, as the output in the year 2000 was more than the amount of production in the year 2022 for all crops, so the amount of production for the Maize crop in the year 2000 was (22620) tons, while in the year 2022 (16450) tons, while the sunflower crop was (40.6) tons, while in the year 2022 (15.1) tons, and the cotton crop in the year 2000 was (57.6) tons, while the production reached in 2022 (11.1) tons, the sesame crop in the year 2000 (1873) and in the year 2022 (210.3) tons.

Keywords

climatic requirements; ideal temperature; solar radiation; sunflower; yield

Introduction

Climate elements control the existing agricultural activity in any region and since agriculture is the main source of human food, any change in the climate of a region will be reflected directly on agriculture, so man has realized since ancient times the impact of climatic conditions on crops, which prompted him to divide them into summer and winter vegetable crops, grain crops and industrial crops that we aim to study. This division is conclusive evidence of human knowledge of the relationship between the type of agricultural crop and the time of its cultivation. There are several crops including oil crops of several types that differ in the duration of their cultivation, and the length of their growth season. The demand for their cultivation has increased due to the increased demand for their nutritional value and economic returns.

Each research has a problem that is the main engine and driving fuel for the research, so the researchers of this study formulated their problem with the following question, do the climate elements have an impact on the cultivation of oily crops and the variation of their production in Anbar Governorate between the years (2000 - 2022).

Each question has an answer, and the researchers have developed a question and aim to reach an accurate answer through the different stages of research. To ascertain the problem of research and investigation to prove its validity, the researchers of this study formulated an answer showing their initial vision, which is that the elements of climate have an influential role in the productivity of oily crops in Anbar province between the years 2000-2022. The researchers adopted a descriptive inductive and analytical approach to develop basic rules in the interpretation of climate variables and their relationship to each other, and their impact on the productivity of the studied oily crops, using modern techniques and programs such as (SPSS), sensing technologies and (10.4 Arc GIS). The study aims to find out the extent of variation in the amount of production of oily crops (Maize, sunflower, cotton, and sesame). It also aims to investigate the extent to which the different climatic conditions between the years 2000-2022 affect the amount of production.

Importance of the study

The study of the impact of climate with its various elements on agriculture is very important to determine the best areas for the cultivation of this crop and not others, as well as the possibility of determining the planting season of each crop accurately to reach the highest level of production. This is what led the researchers to go to such a study and reveal the temporal and spatial variations of the impact of climate on oily crops because of their great importance in food and feasible economic value if used as vegetable oils. Due to the rapid population growth in Anbar province, it is necessary to increase the production of foodstuffs in general and oily crops in particular to meet the growing needs of the population.

The boundaries of the study

1- Spatial boundaries: The geographical location is of great importance in climate studies, where the latitude and longitude of all climatic elements control the site. The study area is located astronomically between longitude (39° - 44.4°) east and two latitudes (30.38° – 35.6°) north as it is within the desert area with a dry climate (Fig. 1).

2- Time boundaries: The study relied on the data of the Iraqi General Authority for Meteorology and Seismic Monitoring for the period (2000-2022), as for the crops yellow maize, cotton, sesame, and sunflower the study was according to what was available from agricultural data in the Statistical Planning Department.

The climatic requirements of oily crops

Agricultural production is affected in quantity and quality in any region by the natural and human factors prevailing in it, as each plant has requirements that must be met to continue its growth, and temperature, sunlight, rain, and wind are among the most important elements related to agriculture.

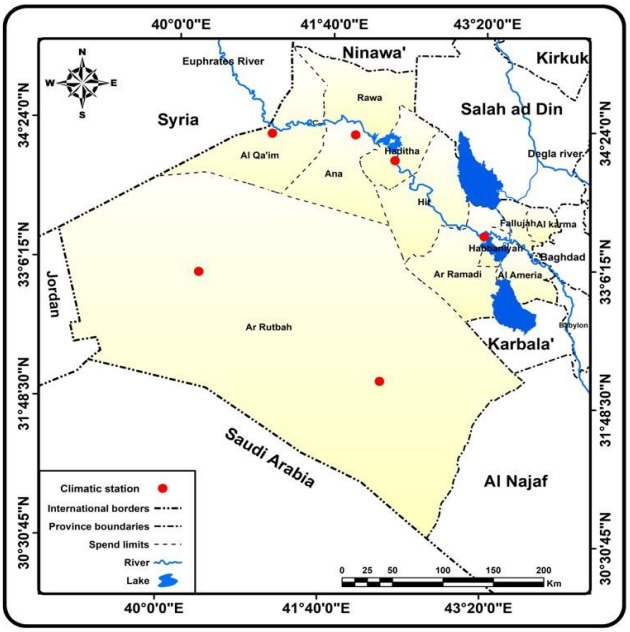

Fig 1. Map of the Locations of climatic stations approved in the study taken from General Authority for Survey, administrative map of Iraq, scales 1: 100,000 for the year 2000.

Photo requirement

Sunlight has a direct role in photosynthesis and the formation of green pigment (chlorophyll). Studies have proven that the best form for plant growth and development requires lighting of 8-20 kilolux, a light unit equivalent to one photon per m^2. Lutein is a unit of luminous flux estimated at candles per unit of time. As this light value gives the optimal limit of fruiting, the light requirements of the studied crops can be indicated as follows:

1. Maize: This crop is classified as having a short day, but it needs intense solar lighting, especially in the early stages of growth, so it is preferable to plant it in places where solar radiation reaches without obstacles (1). It is clear from Table 1 that the ideal photovo;taic requirement for the maize crop is 12-14 hrs. and if the photovoltaic hours increase beyond 14, this may damage the plant,

2. Sunflower crop: Needs a high number of light hours, meaning its cultivation succeeds in areas with little cloudiness (2), From Table (1), it is clear that the minimum hours of sunlight required by this crop is 8-10 hours per day, while the upper limits for the number of hours in which radiation reaches this crop are 14 hours, and from this rate and above, the effects are negative on the crop, while the ideal number of light hours for the requirements of this crop is 10-12 hours.

3. Cotton: The table shows that the cotton crop requires a minimum of 8 hours and 10-12 as an ideal time for the success of the crop and should not exceed the maximum of 14 hours.

4. Sesame: It is classified among the crops of the tropics, meaning that it is one of the crops with a need for long

periods of solar radiation and is affected by the photoperiod (3). The length of time in which sunlight reaches the crop lies of the utmost importance in the vegetative growth period, while it does not need the same time in the stage of maturity, sunlight works to damage the fruits if the period is long (4). Table 1 states that 8 hours is the minimum number of light hours needed by this crop, while the ideal number of light hours is 8 to 10 hours and damage to the crop begins when it exceeds this period, and the upper limits are considered 14 hours.

Thermal requirements

Heat is one of the energy sources for the plant, and it has a clear effect on most physiological processes such as photosynthesis, water absorption and nutrients, evaporation - transpiration, respiration, flower formation, and fruit set (5). The plant grows within certain thermal limits, and these limits naturally vary from one plant species to another, as each plant has a minimum temperature suitable for its growth called the minimum temperature or zero growth, and each plant has an upper limit for the temperature necessary for its growth, in addition to the minimum and upper limit, there is also the most appropriate temperature suitable for plant growth, which is the ideal temperature. The thermal requirements of the studied crops can be indicated as follows:

1. Maize crop: Many researchers have found that the crop cannot be successfully cultivated under a temperature of 5˚C, which is the minimum degree, but for (Soot and Farl R.leng)) says that the most suitable for germination of the crop is 10 ˚C as for maturity, it needs high heat, if the daily rate is 28 m, this helps to mature well (6). It is clear from Table 2 that the minimum thermal requirements for this crop are 10˚C, while the ideal degree is 32-35˚C for the growth and maturity of the crop, and the upper limits are 43˚C.

Table 1. Photovoltaic requirements for oily crops included in the study

Crop	Minimum photovoltaics	Ideal photovoltaics	Upper photovoltaics
Maize	8-10	12 – 14	More than 14
Sunflower	8-10	12	16
Cotton	8	10 -12	14
Sesame	8	8-10	12

Source: - Sahar Jaber Kazim, Climate and its impact on the spatial variation of the cultivation of industrial crops in Iraq for the period (1981-2012), Master Thesis, College of Education for Human Sciences, University of Babylon,

Table 2. Thermal requirements for oil crops

The crop	Minimum temperature	Optimum temperature	Upper temperature
Maize	10	32-35	43
Sunflower	8-10	25-30	35-40
Cotton	16	32-35	41
Sesame	21	27	41

Source: Hamid Hassan Taher, Climate and its relationship to the cultivation of oil crops, sunflower, flax, sesame, yellow maize in the Iraqi country, Master's thesis (UP.), College of Education, University of Baghdad,

2. Sunflower crop: This crop is characterized by growth even in conditions where temperatures drop, as it endures up to -5˚C in the first days of germination, but after a certain period in which the plant reaches the eighth leaf, the decrease becomes very harmful to the plant (Table 2). It is clear that the minimum need for this crop temperature, which are 8-10˚C, while the ideal degree is 25 -30˚C suitable for the growth and maturity of the crop and tolerates the rise in temperature up to a certain limit known as the upper limit 35-40^0 C.

3. Cotton: The cotton crop needs relatively high temperatures and it is clear from Table 2 that the cultivation of the crop requires a temperature of 16˚C as a minimum and 31-35℃ as an ideal degree for the growth and maturity of the crop, but the upper limits should not exceed 41˚C.

4. Sesame: Since this crop appeared in the tropics, this means that it is one of the crops that need relatively high temperatures, so it should not be grown in areas where the temperature is lower than 16˚C, the minimum yield in terms of temperature is 21˚C, while the ideal requirements for crop growth and maturity are 27^0 C, as for the upper limits 41˚C.

Hydraulic requirements

1. Maize: One of the crops that need abundant water, especially at the time of flowering, and in general, the need for the crop is estimated at 500-800 mm.

2. Sunflower: The sunflower crop cannot succeed in less than 400 mm and if it exceeds 900 mm, it will be harmful to the crop.

3. Cotton: The need for this crop in water varies according to the stage of the plant, in the germination stage needs a moderate amount to avoid root rot, but the peak of what it needs in the flowering stage, while the least needs for water is in the stage of maturity and in general, it needs 600-800 mm.

4. Sesame: The basic need for this crop for water at the time of germination as well as the growth stage and needs 100-400 mm and up to (10) irrigation divided during the growth period and cut-off water at the end of August for fruit ripening.

The climatic characteristics in the study area

Solar radiation

Energy from the Sun reaches the Earth's surface in waves of varying lengths (7). It is clear from Table 3 that a clear difference between the stations of the study area for the annual and monthly rate of solar radiation reaching the surface of the earth, as the highest annual rate was recorded at the Nukhayb station and amounted to (451.1 calories/cm^2/ day), while the station recorded the lowest rate in the study area and amounted to (420.8 calories/cm ^{2}/day).

It is also clear that this variation is not limited to the annual rate only, but there is a variation from time to time and from place to place, as the Nukhayeb station recorded the highest monthly rate among the stations during June (651.1 calories/cm^2/day) and that the lowest monthly rate

Table 3. Monthly rates of total solar radiation reaching Anbar Governorate stations (Calorie/cm^2/Day) for the Period (1990 - 2022)

Station	Januar y	Februar y	March	April	May	June	July	Augus t	Septe mber	Octob er	Nove mber	Dece mber	avera ge
Ramadi	229.8	320.5	417.8	499.5	568.4	639.6	629.5	6.8.6	506.4	364.8	274.1	226.3	440.4
Haditha	225.6	309.2	411.5	491.3	553.6	630.2	619.5	601.7	500.3	355.1	267.5	218.1	433.2
Anah	215.4	300.2	403.7	480.5	538.8	619.5	609.7	587.3	480.2	346.6	258.1	209.6	420.8
Qaim	220.3	304.6	408.9	486.7	547.4	626.7	616.4	596.1	492.6	351.4	263.3	213.2	427.2
Rutba	232.6	3.29.2	420.2	507.3	577.2	647.4	638.6	613.2	511.7	367.9	279.7	230.5	446.2
Nukhaib	236.4	335.7	423.3	514.4	580.1	651.1	640.1	618.7	514.6	378.4	287.5	233.2	451.1

Source: Republic of Iraq, Iraqi General Authority for Meteorology and Seismology, Climate Section, unpublished data.

of solar radiation was recorded in December at the station and amounted to (209.6 calories/cm^2/day). The reason for the obvious variation is due to the difference in astronomical position, especially since the study area is wide and the apparent movement of the sun between orbits, as well as the difference in the angle at which solar radiation reaches the surface within the studied area.

Speculative effulgence

It is the total hours from sunrise to sunset (8), that is the number of hours in which solar radiation is assumed, regardless of the factors that prevent the arrival of radiation (9). From Table 4, it is clear that Al-Nukhayb station recorded the highest annual rate (9:55 hours), followed by Rutba, then Ramadi, Haditha, and Al-Qaim (9:54, 9:53, and 9:51 hours). While the number of actual hours that reach the surface of the earth can be recorded on measuring devices such as Campbell Stokes, and weather phenomena such as clouds and dust affect the number of hours of actual brightness the lowest annual average was recorded in the study area, specifically at Anah station (9:46 hours).

As for the monthly average, Al-Nukhayb station recorded (14:30) hours, which is the highest rate among the stations, then wet and grey (14:29, 14:28 hours), and the lowest rate was also recorded in the station about it (14:22 hours).

Actual effulgence

The number of actual hours that reach the surface of the earth can be recorded on measuring devices such as Campbell Stokes, and weather phenomena such as clouds and dust affect the number of hours of actual effulgence (10). This rate lags from one region to another and also from time to time according to the astronomical position, the clarity of the sky, and the angle of incidence of the rays. From Table 5, it is clear that the stations of Rutba and Al-Nukhayb recorded the highest rate equally, which is 9.3 hours, followed by Al-Ramadi and Haditha stations (9.2, 8.9 hours), while the station recorded about 8.7 hours, which is the lowest rate recorded within the study area.

As for the monthly level, Al-Nukhayb station recorded the highest rate per month (12.4 hours), followed by Rutba and Ramadi (12.3, 12.2 hours), but the lowest rate is in a station about it (12 hours).

Table 4. The average length of day (hour) in governorate stations for the period (1990-2022)

Station	January	February	March	April	May	June	July	August	Septem ber	October	Novem ber	Decem ber
Ramadi	10:7	11:1	12:1	13:4	14:3	14:28	14:12	13:22	12:20	11:19	10:25	9:53
Haditha	10:4	10:58	12:5	13:2	14:00	14:25	14:10	13:19	12:18	11:16	10:23	9:51
Anah	10:2	10:55	12:00	13:00	13:56	14:22	14:6	13:15	12:16	11:12	10:20	9:46
Qaim	10:3	10:57	12:4	13:1	13:58	14:24	14:8	13:17	12:17	11:15	10:22	9:50
Rutba	10:8	11:2	12:2	13:5	14:4	14:29	14:13	14:23	12:21	11:20	10:26	9:54
Nukhaib	10:10	11:4	12:3	13:6	14:6	14:30	14:14	13:24	12:22	11:21	11:27	9:55

Source: Republic of Iraq, Iraqi General Authority for Meteorology and Seismology, Climate Section, unpublished data.

Table 5. Monthly and annual average of actual solar brightness hours in Anbar Governorate Stations for the period (1990-2022)

Station	January	February	March	April	May	June	July	August	Septe mber	Octobe r	Novem ber	Decem ber	Rate
Ramadi	6.9	7.5	8.3	8.3	9.7	12.2	12	11.8	11.7	8.7	7.4	6.3	9.2
Haditha	5.9	7.3	8.3	8.2	9.7	12	12	11.8	10.7	8.7	7.2	5.9	8.9
Anah	5.5	7.1	8.1	8.2	9.2	12	11.8	11.7	10.6	8.6	7	5.7	8.7
Qaim	6	7.2	8.2	8.3	9.7	12.1	11.8	11.5	10.7	8.7	7.2	5.8	8.9
Rutba	6.9	7.7	8.3	8.5	9.6	12.3	12.8	11.8	10.6	8.7	7.5	6.4	9.3
Nukhaib	7	7.8	8.4	8.4	9.6	12.4	12.6	11.8	10.5	8.9	7.6	6.7	9.3

Source: Republic of Iraq, Iraqi General Authority for Meteorology and Seismology, unpublished data

Temperature

The resultant of terrestrial and solar radiation is the element most associated with all climatic elements and makes things warmer (11). The heating elements affects industrial and agricultural activities, each of which has certain requirements, whether high or low, for the success of any activity.

It is clear from Table 6 that the highest annual rate was recorded in Al-Nukhayb station (22.4) [S5] and then Ramadi station (22.1)[S5], while Al-Rutba station recorded the lowest annual rate (19.4) [S5] due to the height above sea level and the intensity of the impact of air masses, while the monthly rates show that the highest rate is in Al-Nukhayb station (33.8°C), while Al-Rutba station recorded the lowest monthly rate of (33.8°C).

Maximum temperature

This term is given to the highest degree recorded in the daytime, where the net radiation is positive from the beginning of sunrise until the afternoon (12), it is recorded at two o'clock in the afternoon because at that time the amount of what it loses is equal to the solar radiation gained by the earth. Table 7 shows that the maximum annual rate was (29.4°C) at Ramadi station followed by Nukhayb and Haditha (29.2 and 28.9°C) stations, whereas the minimum rate was (26.9°C) at Rutba station. As for the lowest monthly average in the study area, it is in Al-Qaim station (12.8°C) in January. Then followed by Anah and Haditha (13.5 and 13.3°C), while the maximum monthly average was (41.8 °C) at Ramadi station in August.

Minimum temperature

The lowest degree is recorded when the net radiation turns negative (13). This degree is recorded at a time when the earth gains is equivalent to the radiation it loses (14).

Table 8 shows the lowest annual rate recorded in Al -Rutba station (12.5°C) and its distance (12.8°C) and the highest annual rate recorded In Ramadi station (14.9°C) while the highest monthly average was recorded in Nukhayb station (25.9°C) in July, while the lowest rate is 2°C at the Rutba station.

Wind

Air movement is parallel to the surface of the Earth (15). Al-Nukhayb station recorded the highest annual average wind speed (3.8) m/s. While Al-Qaim station recorded the lowest annual rate (2.5) m/s. The highest monthly average

Table 6. Monthly and annual average temperatures (°C) in study area stations for the period (1990-2022)

Station	January	Februar y	March	April	May	June	July	Augu st	Septe mber	October	Novem ber	Decem ber	rate
Ramadi	9.4	11.7	15.5	22.2	27.2	31.8	33.6	33.1	29.7	24.5	16.3	11.3	22.1
Haditha	8.4	10.6	14.7	20.8	26.9	31.1	33.4	32.8	29.3	22.8	15.2	9.5	21.2
Anah	7.9	10.1	13.8	20.6	26	30.4	32.9	32.4	28.5	22.5	14.5	9.4	20.7
Qaim	7.8	9.6	14.2	20.4	25.6	30.8	32.4	32.1	28.3	22.5	14.3	9.1	20.5
Rutba	7.7	9.4	13.1	18.3	24.6	28.2	30.9	30.5	27.4	21.3	13.6	8.7	19.4
Nukhayb	9.7	12.5	15.4	22.5	27.8	31.5	33.8	33.4	30.5	24.5	16.9	11.4	22.4

Source: Republic of Iraq, Iraqi General Authority for Meteorology and Seismic Monitoring, unpublished data.

Table 7. Monthly and annual average minimum temperatures (°C) in Anbar governorate stations for the period (1990-2022)

Station	Januar y	Febru ary	March	April	May	June	July	August	Septe mber	Octobe r	Novem ber	Decem ber	rate
Ramadi	14.6	17.7	22	30.1	35.2	40	41.8	41.7	38.4	32.7	22.7	16.9	29.4
Haditha	13.5	16.7	21.3	28.2	34.9	39.7	41.6	41.4	38.2	31.0	22.1	15.0	28.9
Anah	13.3	16.5	21.1	28.5	34.6	39.4	41.7	41.3	37.7	30.8	21.6	15.3	28.5
Qaim	12.8	15.6	21.2	27.9	33.6	38.4	40.3	40	37.1	30.5	21.5	14.7	27.8
Rutba	14.0	15.7	19.5	26.4	32.2	36.4	38.8	38.2	36.1	29.5	21.2	15.3	26.9
Nukhayb	15.2	17.9	23.3	29.7	34.7	39.5	40.7	40.9	37.8	31.9	22.3	16.9	29.2

Source: Republic of Iraq, Iraqi General Authority for Meteorology and Seismology, unpublished data,

Table 8. Monthly and annual average of maximum temperatures (C) in Anbar governorate stations for the period (1990-2022)

Station	January	Febru ary	March	April	May	June	July	August	Septe mber	October	Nove mber	Dece mber	rate
Ramadi	4.2	5.8	9.1	14.3	19.2	23.5	25‹4	24‹5	21	16‹3	9‹8	5‹7	14‹9
Haditha	3.3	4.5	8.1	13.4	18.8	22.5	25.2	24.2	20.4	14.6	8.3	4.1	14
Anah	2.4	3.6	6.5	12.7	17.3	21.2	24.1	23.5	19.3	12.9	7.4	3.5	12.8
Qaim	2.3	3.8	7.9	13.1	17.5	21.6	24.5	23.6	19.7	13.2	7.9	4.2	13.2
Rutba	2	3.3	6.1	12.3	16.8	20.4	23.6	25	18.9	11.7	8.5	3.4	12.5
Nukhayb	3.8	3.4	8.9	12.7	19.8	23.1	25.9	23.2	21.4	15.9	9.5	3.5	14.4

wind speed was recorded in Haditha station (5.5) in July, while Al-Qaim station recorded the lowest monthly average of 1.8- m/s.

Rainfall

The amount of rain varies from season to season and from time to time, as Table 9 and 10 shows that the highest annual rain rate of 146.8 mm was recorded in the study area in Al-Rutba station, followed by (146.8) mm. The lowest annual rate in the study area is in Ramadi station at 116.2 mm, while at the level of monthly rates, the highest rate is in Al-Qaim station at 24.4 mm, and the lowest monthly average rainfall was recorded at Al-Nukhayb and Ramadi stations equally of 0.4 mm.

Relative humidity

It does not differ from the previous elements in spatial and temporal variations, so it is clear from Table 11 that the Ramadi station recorded the highest rate of relative humidity of 49.7%. As for the lowest annual rate of humidity, it was recorded in Al-Nukhayb station (38.6%), followed by Al-Rutba station (41.2%), while in terms of monthly rates, the highest rate was recorded in Anah station (73.8%), then Al-Qaim station (73.3%), while Al-Nukhayb station recorded the lowest rate (20.4%).

Results and Discussion

The impact of climatic elements on oil crop production (2000-2022)

It is clear that there is a variation in the annual climatic parameters in terms of time and place, as this left an impact on the variation in the production of oil crops in Anbar province and will be addressed as follows:

Maize

1. Light

It is clear from Table 12 that the study stations recorded a slightly lower average light hour than what the studied crops need. The lowest rate recorded was in Al-Qaim stations by 13.1 and for the years 2000-2022, while the highest rate recorded was for the stations of Al-Rutba and Al-Nukhayb by 13.9. This means that all study stations recorded rates very close to the ideal rates needed by each crop, and after analyzing the data, it turned out that the effect of light clocks in the variation of the production of oil crops (yellow corn, sunflower, cotton, sesame) within the geographical area and the specific time is almost negligible because the length of the day does not differ much, whether at the level of months or years, but the impact on this is the processes to which radiation is exposed and prevents it from reaching the surface of the earth.

Table 9. Monthly and annual average wind Speed (m/s) in Anbar Governorate Stations

Station	Januar y	Februa ry	March	April	May	June	July	August	Septe mber	Octob er	Nove mber	Decem ber	rate
Ramadi	2	2٫4	2٫6	2٫5	2٫7	2٫9	3	2٫4	2	1٫6	1٫7	1٫9	2٫3
Haditha	2٫4	3	3٫3	3٫4	3٫8	4٫8	5٫5	4٫4	3٫2	2٫4	2٫1	2٫4	3٫3
Anah	2٫2	3٫2	3٫4	3٫5	3٫8	5٫2	5٫4	4٫3	2٫8	2٫2	1٫8	2٫3	3٫4
Qaim	2٫1	2٫5	2٫6	2٫7	3	3٫3	3٫7	3	2٫1	1٫7	1٫9	1٫8	2٫5
Rutba	2٫9	3٫5	3٫7	3٫8	3٫4	3٫6	3٫8	3٫1	2٫3	2٫3	2٫2	2٫6	3٫1
Nukhayb	3٫5	3٫7	4٫7	4٫2	4٫7	4٫8	4٫8	4٫2	3٫1	3	2٫7	2٫7	3٫8

Source: Republic of Iraq, Iraqi General Authority for Meteorology and Seismology, unpublished data

Table 10. Monthly and annual averages of the amount of rainfall in Anbar Governorate for the period (1990 - 2022)

Station	Januar y	Februa ry	March	April	May	June	July	Augu st	Septe mber	October	Novem ber	Decem ber	rate
Ramadi	19.7	20.2	15.7	12.4	4.6	-	-	-	0.4	9	16.5	17.7	116.2
Haditha	23.4	22.2	22.9	20	7.1	-	-	-	0.9	7.3	18.7	20.4	142.9
Anah	23	23	22.7	14.5	7.2	-	-	-	0.2	13.2	19.8	20.9	144.5
Qaim	24.4	23.2	23.8	15.2	6.0	-	-	-	0.8	9.2	20.9	19.5	143
Rutba	23.8	22.6	23.4	17.8	5.8	-	-	-	0.5	8٫6	21.7	22.5	146.8
Nukhayb	16.4	14.3	15.7	10.3	5	-	-	-	0.4	7.0	14.6	15.8	99.5

Source: Republic of Iraq, Iraqi General Authority for Meteorology and Seismology, unpublished data

Table 11. Monthly and annual rates of relative humidity in Anbar governorate stations for the period (1990-2022)

Station	January	Februa ry	March	April	May	June	July	August	Septe mber	October	Nove mber	Decem ber	rate
Ramadi	71.9	62.6	54.1	48	39.4	32.8	30.9	33.6	38.3	49.6	62.6	72.6	49.7
Haditha	71.9	61.8	55.9	42.3	31.2	22.2	21.8	23.5	26.6	38.3	54.6	71.2	43.4
Anah	73.8	62.3	52.5	42.8	31.3	25.5	25.1	25.9	29.4	42.5	60.0	72.8	45.3
Qaim	73.3	63.2	54.9	45	35.3	29.7	28.4	30.6	36.2	45.6	60.7	71.8	47.8
Rutba	67.2	57.1	47.3	40.1	29.5	22.8	24.7	24.5	27.6	39.2	49.4	63.1	41.2
Nukhayb	63.1	53.8	46.6	39.1	28.6	21.4	20.4	22.6	23.7	37.4	46.9	60.2	38.6

Source: Republic of Iraq, Iraqi General Authority for Meteorology and Seismology, unpublished data.

Table 12. Comparison of photovoltaic requirements of oily crops with climate characteristics in study stations for the years (2000 -2022)

Crops	Optimal photo. Requirements	Qaim		Anah		Haditha		Ramadi		Rutba		Nukhayb	
		2000	2022	2000	2022	2000	2022	2000	2022	2000	2022	2000	2022
Maize	14-12	13,4	13,6	13,5	13,3	13,5	13,3	13,7	13,8	13,9	13,9	13,8	13,9
Sunflower	12	13,4	13,2	13,3	13,1	13,4	13,5	13,7	13,8	13,9	13,5	13,2	13,8
Cotton	12-10	13,1	13,3	13	13,2	13,3	13,1	13,5	13,3	13,7	13,6	13,3	13,3
Sesame	10-8	13,4	13,3	13,2	13,1	13,3	13,1	13,5	13,3	13,7	13,6	13,6	13,5

The table prepared by the author depends on:

-Majeed Al-Ansari, et al., Principles of Field Crops, 5th Edition, Dar Al-Maarifa, Baghdad, 1980, p. 59.

-Republic of Iraq, Ministry of Transport and Communications, Iraqi General Authority for Meteorology and Seismic Monitoring, Climate Section, unpublished data

2. Temperature

The thermal requirements of oil crops vary from one crop to another, the different months in which crops grow and mature, as it requires the crop of yellow corn (32-35˚C). It is clear from Table 13 that the study stations did not achieve the ideal rates for growing this crop. Rather, it came close to it, as the Nukhayb station was recorded in 2022 (30.2˚C) and (28.8˚C) in the year 2000 for the same station, and the lowest rate for the year 2022 the station (26.1˚C), while in the year 2000, the same station was recorded (25.5˚C).

The table prepared by the author depends on:

Majeed Al-Ansari, et al., Principles of Field Crops, 5th Edition, Dar Al-Maarifa, Baghdad, 1980, p. 59.

Republic of Iraq, Ministry of Transport and Communications, Iraqi General Authority for Meteorology and Seismic Monitoring, Climate Section, unpublished data.

2.1 Minimum temperature

The minimum temperature that this crop can tolerate is 10°C. It is clear from Table 14 that the rates were within the limits required for the crop in the year 2000, as the lowest rate was recorded at Anah and Haditha stations. It reached 11.1°C which was above the limit. Ramadi station recorded the highest rate, reaching 13.2°C for the same year. Most of the stations recorded rates that were very close to the minimum crop growth rate in 2022. These rates are considered harmful to the crop, as the Ramadi station recorded at 9.7°C, Al-Nukhayb station (9.8°C), and Haditha station (10°C). The climatic conditions in terms of minimum temperature in 2000 were more suitable for the crop.

2.2 Maximum temperature

It is clear from Table 15 that most of the study stations recorded rates that match the requirements of the yellow corn crop in the year 2000, where the Nukhayb station recorded the highest temperature of 41.9°C. While the other stations recorded rates not exceeding 39.5°C for each of Haditha, Anah, and Al-Qaim, however, in 2022, these parameters differed, three stations recorded higher than the highest rate borne by the crop in each of the Nukhayb stations (43.8°C) m, Rutba (43.5°C) and Ramadi (43.5°C) m, and therefore the climatic conditions in terms of the maximum temperature that the crop tolerates, the year 2000 is more suitable for the growth and maturity of the crop than the year 2022.

Table 13. Average temperature of oil crops in study stations for the years (2000, 2022)

Crops	Optimal thermal. requirements	Qaim		Anah		Haditha		Ramadi		Rutba		Nukhayb	
		2000	2022	2000	2022	2000	2022	2000	2022	2000	2022	2000	2022
Maize	14–12	24.2	26.5	25.5	26.1	26.6	27.4	26.8	28.6	24.8	25.9	28.6	30.2
Sunflower	12	22.9	25.4	22.6	25.1	22.6	25.3	22.8	25.9	22.2	24.4	22.6	25.7
Cotton	12–10	25.4	26,3	25.2	26,1	25.3	26,1	26.8	28,5	24.9	25.4	25.1	27,1
Sesame	10–8	28.1	29.1	29.5	29.7	30.7	31.5	29.7	31.2	28.7	30.1	31.6	32.9

Table 14. Comparison of the minimum temperature for oil crops with the temperatures recorded by the study stations for the years (2000, and 2022)

Crop	Minimum Temperature	Qaim		Anah		Haditha		Ramadi		Rutba		Nukhayb	
		2000	2022	2000	2022	2000	2022	2000	2022	2000	2022	2000	2022
Maize	10	11.3	10.8	11.1	10.1	11.1	10	13.2	9.7	11.6	10.2	11.7	9.8
Sunflower	10-8	7.8	7.6	7.9	7.1	7.9	8	8.3	8.1	8.5	8.6	8.8	9.2
Cotton	16	14.1	13.9	14.1	14.1	14.3	14.4	15.2	14.9	15.4	15.1	15.8	15.2
Sesame	21	9.5	9.1	9.1	9.4	9.7	9.9	9.4	10.2	10.1	10.9	10.4	11.1

Source: Republic of Iraq, Ministry of Transport and Communications, Iraqi General Authority for Meteorology and Seismic Monitoring, Climate Department, unpublished data.

Table 15. Comparison of the maximum temperature of oil crops with the reality of study stations for the years (2000, 2022)

Crops	Maximum temperature	Qaim		Anah		Haditha		Ramadi		Rutba		Nukhayb	
		2000	2022	2000	2022	2000	2022	2000	2022	2000	2022	2000	2022
Maize	43	39.5	41.3	39.1	41.5	39.3	42.1	41.1	43.6	41.7	43.5	41.9	43.8
Sunflower	40-35	38.3	41.3	38.3	41.1	38.3	42.4	40.3	43.5	41.9	43.2	39.8	42.9
Cotton	41	39.7	41.8	39.5	41.5	38.9	40.8	40.1	42.9	40.7	42.7	40.9	42.1
Sesame	41	39.5	41.5	38.3	41.3	39.7	41.8	40.1	42.4	41.1	43.2	41.4	42.9

Source: Republic of Iraq, Ministry of Transport and Communications, Iraqi General Authority for Meteorology and Seismic Monitoring, Climate Section, unpublished data

2.3 Cumulative temperature

The accumulated heat required by this crop is (1500-2000) thermal units and is shown in Table 16. Most of the study stations recorded a total higher than the optimal limits for crop requirements, as the Al-Nukhayb station for the year 2022 (2215℃) recorded a thermal unit and the Ramadi station (2143℃) thermal units, while the same stations for the year 2000 (1991℃) were recorded in Al-Nukhayb station, and the Ramadi station (1950℃) and Al-Qaim (1876℃) recorded a thermal unit, meaning that it is within the optimal limits, and thus it becomes clear that the year 2000 is more suitable in terms of the accumulated temperature necessary for the growth of the crop.

3. Rainfall

Rainfall is concentrated in a certain season in the study area and the cultivation of oil crops is outside the limits of the rainy season, so all stations recorded very low rates in both years that do not suit the requirements of crops ranging between (30-46.2 mm) while water requirements range from (400 - 1000 mm) from Table (17) and the above extrapolation of climatic conditions, it is clear that there is a difference in the amount of corn production in Anbar province between the year 2000 and the year 2022, where The total production in 2000 was 22,620 tons, which is higher than the total production in 2022, which amounted to 16,450 tons.

Sunflower

1. Light

This crop requires an average of ideal light hours ranging from 12-14 hours/day during the growing season, and it is noted from Table 12 that all study stations recorded ideal rates of the crop, and Al-Nukhayb station recorded 2022 the highest rate of 13.9 hours, followed by the stations of Al-Rutba (13.9 hours) and Ramadi (13.8 hours), and Al-Rutba station recorded the highest rate for the year 2000 amounting to (13.9 hours), then Al-Nukhayb and Al-Ramadi station (13.7-13.8 hours).

Table 16. Comparison of the accumulated heat of oil crops with the reality of study stations for the years (2000, 2022)

Crops	Temperature	Qaim		Anah		Haditha		Ramadi		Rutba		Nukhayb	
		2000	2022	2000	2022	2000	2022	2000	2022	2000	2022	2000	2022
Maize	-2000 1500	1876	1950	1653	1770	1868	2000	1950	2143	1842	1940	1991	2215
Sun-flower	1500	2120	2163	2127	2179	2187	2234	2242	2297	2287	2319	2307	2373
Cotton	-3000 2400	2439	2520	2453	2541	2481	2583	2516	2621	2530.1	2639	2573	2693
Sesame	2500	2470	2575	2411	2440	2436	2588	2527	2613	2398	2430	2603	2805

Source: Republic of Iraq, Ministry of Transport and Communications, Iraqi General Authority for Meteorology and Seismic Monitoring, Climate Section, unpublished data.

Table 17. Rain requirements for oil crops with the reality of study stations for the years (2000, 2022)

Crops	Hydraulic requirements	Qaim		Anah		Haditha		Ramadi		Rutba		Nukhayb	
		2000	2022	2000	2022	2000	2022	2000	2022	2000	2022	2000	2022
Maize	800-500	54,9	46,1	56,1	49,5	58,7	50,6	48,2	39,2	58,4	46,1	45,6	37,8
Sunflower	900-400	51,9	42,6	49,3	40,2	50,2	41,1	44,5	36,3	51,1	44,1	39,8	33,2
Cotton	800-600	44,3	35,8	42,1	37,1	44,5	36,7	42,7	34,6	48,3	39,9	43,1	36,5
Sesame	400-1000	30,5	23,1	33,7	42,4	43,9	33,1	41,6	30,8	46,2	37,3	40,6	32,9

Source: Republic of Iraq, Ministry of Transport and Communications, Iraqi General Authority for Meteorology and Seismic Monitoring, Climate Section, unpublished data.

Temperature

The sunflower crop requires an ideal temperature (25-30° C), and it is clear from Table 13 that the Ramadi station recorded the highest temperature rate in 2022 (25.9℃), then followed by the Nukhayb station and the same year (25.7 °C), and the lowest rate for the same year was 25.1 °C, while for the year 2000, the Ramadi station recorded the highest rate (22.9 °C), followed by him, Haditha and Al-Nukhayb, respectively, at a rate of 22.6 °C, so the year 2022 is closer to the suitability of the crop in terms of ideal temperature.

2.1 Minimum temperature

This crop needs 8-10°C and it is clear from Table 14 that the highest rate recorded was in Al-Nukhayb station and reached 9.2°C in 2022 and the lowest rate for the same year in a station of about 7.1°C, while the year 2000, the highest rate was recorded in Al-Nukhayb station (8.8°C), while Al-Qaim station had the lowest rate of 7.8°C.

2.2 Maximum temperature

This crop requires maximum temperatures of 35 - 40°C. It is noticed from Table 15 that the Ramadi station recorded the highest rate of (43.5 ℃), followed by the wet (43.2°C), then the Nukhayb (42.9 °C) and then Haditha (42.2 °C) in 2022, and these rates are higher than the upper limit that the crop bears, but in the year 2000, the Rutba station recorded an average of 41.9 m, followed by the Ramadi station (40.3 °C), while the existing and about him and Haditha (38.3°C) were recorded equally for the same year. It turns out that the requirements in terms of maximum temperature in the year 2000 are more favorable for crop growth than in 2022.

2.3 Cumulated temperature

This crop requires 1500 thermal units throughout the stages of crop growth, and it is clear from Table 16 that the highest total was recorded in Al-Nukhayb station in 2022 and amounted to 2373 thermal units, then Al-Rutba station 2319 thermal units, then Ramadi station 2297 thermal units, and the lowest rate for the same year in Al-Qaim station (2163), followed by the wet station 2287 thermal units and then about 2127 thermal units while recorded station based 2120 thermal units, which is the lowest total in the year and it is clear from the above that the year 2000 is the closest in terms of suitability of the crop because the more heat collected from its limit played a negative role on the crop.

3. Rainfall

The crop requires 400-900 mm, and this quantity was not available in any of the study stations, as it was the highest rate in the year 2000 in the Al-Qaim station (51.9 mm) and the lowest rate in the Al-Nukhayb station for the year 2022.

Cotton

1. Light

Crop requires a light of 10-12 hours. It is clear from Table 12 that the Rutba station in the year 2000 recorded the highest rate of 13.9 hours, followed by the Ramadi station 13.7 hours and the lowest rate is in the station about 13 hours, while in the year 2022, the Rutba station recorded the highest rate of 13.6 hours, then each of the Ramadi station and Al-Nukhayb equally 13.3 hours and the lowest rate is in the station about 13.2 hours, and it is clear that the light data is suitable for the crop in both years.

2. Temperature

The crop requires temperature range of 32 - 35°C and it is clear from Table 13 that the Ramadi station recorded 2022 the highest rate 27.1°C, then a modern station (25.8°C) and the lowest rate (24.3°C) in the Rutba station, while in the year 2000, the Ramadi station recorded the highest rate (26.8°C), then the Qaim station (25.4°C), while the lowest rate in the Rutba station (24.9°C). From here, it turns out that the temperature rates for the year 2022 are closer to the suitability of the crop.

2.1 Minimum temperature

The highest minimum limit temperature for this crop is 16° C. It is clear from Table 14 that the highest rate is in Al-Nukhayb station in 2000 reaching (15.8°C), then the Rutba station comes at a rate of (15.4°C) and the lowest rate for the same year in both Haditha station and Al-Qaim equally (14.1°C). In 2022, the highest rate was in Al-Nukhayb station (15.2°C), then Ramadi station (14.9°C), and the lowest rate in Al-Qaim station (13.9°C), and therefore the rates in the year 2000 is closer to meeting the crop requirements than 2022.

2.2 Maximum temperature

This crop requires 40^0 C, and it was found that the highest rate is in the Rutba station reached 42.7 °C for the year 2022, and the lowest rate for the same year is in a station about 40.5^0 C, but in the year 2000, the highest rate is in Al-Nukhayb station 40.9°C, while the lowest rate is in a modern station for the same year and amounted to 38.9°C, from that, it is clear that the rate in the year 2022 is better for the plant in terms of thermal requirements.

2.3 Accumulated temperature

The crop needs (2400-3000 °C) over the months of growth and maturity of the crop. It is clear from Table (17) that Al-Nukhayb station recorded 2022 the highest total and reached 2693°C, followed by Al-Rutba station (2639°C) and the lowest rate in Al-Qaim station (2520 °C), while in the year 2000, the highest total was recorded in Al-Nukhayb station (2573°C) and then Al-Rutba station (2530.1 °C).

3. Rainfall

This crop needs (600-800 mm) and this quantity was not available in any of the study stations for both the years 2000 and 2022, where the highest rate was in 2000 in the Rutba station (48.3 mm) and the lowest rate in 2022 in the Nukhayb station (36.5 mm).

Sesame

1. Light

This crop requires 8-10 hours of light and it is clear from Table 12 that the highest rate was recorded in the Rutba station in the year 2000 and amounted to (13.7) hours, then Al-Nukhayb station (13.6 hours) and the lowest rate for the same year in the Anah station (13.2 hours). In 2022,

Al-Rutba station recorded the highest rate of (13.6 hours), then Al-Nukhayb station (13.5 hours), while Haditha station recorded the lowest rate of (13.1) hours, and the entire study area is suitable for the crop in both years.

2 Temperature

It requires a temperature rate of 28°C as an ideal degree, and it is clear from Table 13 that the highest rate recorded in 2022 is in Al-Nukhayb station (32.9°C), followed by Al-Ramadi station (31.5°C), while the lowest rate for the same year is in Al-Qaim station (29.1°C). In 2000, the highest rate was recorded at Al-Nukhayb station (31.6°C) and then Haditha station (30.7°C). While the lowest rate was recorded at the Al-Qaim station (28.1°C), it is clear that the heat rates for the year 2000 are closer to the ideal requirements than in 2022.

2.1 Minimum temperature

Crop requires 21°C. It is noted from Table 14 that the highest rate recorded is in 2022 in Al-Nukhayb station (11.1°C) and the lowest rate for the same year in Al-Qaim station (9.19°C), while in the year 2000, it was found that the highest rate was in Al-Nukhayb station (10.4°C), while the lowest rate was recorded in Al-Nukhayb station (9.1°C).

2.2 Maximum temperature

The crop bears a maximum (of 41°C) and it is clear from Table 15 that the rates in 2022 exceeded the upper limit, and the highest rate was recorded at Al-Nukhayb station (43.2°C) and then Al-Rutba station (42.9°C), while the lowest rate for the same year was at Anah station (41.3°C). In the year 2000, the highest rate was in Al-Nukhayb station (41.4°C) and then Al-Rutba station (41.1°C), while the lowest rate was recorded (38.3°C), so the rates for the maximum temperature in the year 2000 are closer to crop suitability than in 2022.

2.3 Accumulated temperature

This crop requires an accumulated temperature of 2500°C and it is clear from Table 16 that the highest rate in the year 2022 in the Nukhayb station (2805°C) and then the Ramadi station (2613 ° C) and the lowest rate for the same year is in the station about (2440°C) thermal units. In the year 2000, the highest rate reached (2603°C) thermal units in the Nukhayb station, followed by the Ramadi station (227°C), while the station recorded the lowest rate (2411° C), so the year 2022 provided the accumulated heat required by the crop more than in the year 2000.

3 Rainfall

This crop requires 400-1000 mm of rainfall, however, this quantity was not available in the study area, as the highest recorded rainfall was 46.2 mm in the Rutba station in the year 2000 and the lowest in the Ramadi station was 30.1 mm in the year 2000.

As a result of the variation of climatic conditions resulting from the increase in high temperatures, lack of rain, increase in heat waves and cold waves, as well as the increase in the frequency of dust storms and the prevalence of drought, which led to a discrepancy in the requirements necessary for the growth and maturity of oil crops (yellow corn, sunflower, cotton, sesame) in Anbar Governorate and a comparison between the years (2000-2022) as shown in the table:

1. The total production of maize in Anbar province reached 22,620 tons in the year 2000 (Table 18), thus it is more than the total production in 2022, which amounted to 16,450 tons. This is because of the difference in climatic conditions between the years (2000, 2022) in the study area, where it was found that the minimum temperature and the maximum temperature, as well as the collected temperature, were more suitable for the requirements of the crop in the year 2000, which led to the success and high amount of production.
2. The total production of the sunflower crop in Anbar province was 40.6 tons in the year 2000, which is more than in 2022 when the total production reached 15.1 tons. The reason for the variation in the amount of production is that the temperature gathered in which the success of the crop cultivation stands was in the year 2000 more appropriate, as well as the maximum temperature in that year within the ideal limits.
3. The total production of the cotton crop reached 57.6 tons in Anbar province for the year 2000, which is higher than the amount of production for the same crop in 2022, in which the total production reached 11.1 tons, due to suitability of the average for the minimum and maximum temperatures in the year 2000, more than in 2022.
4. The total production of the sesame crop reached 1873 tons in Anbar province in the year 2000, which is higher than the amount of production for this crop in the year 2022, as the production in that year reached 210.3 tons, and the reason for this is the availability of the requirement in terms of the accumulated temperature and temperature rates, as well as the maximum temperature.

Table 18. Production of oil crops in Anbar Governorate for the year 2000

Station	Qaim		Anah		Haditha		Ramadi		Rutba		Nukhayb		Qaim	
Year	2000	2022	2000	2022	2000	2022	2000	2022	2000	2022	2000	2022	2000	2022
Maize	3700	4000	280	200	550	165	10730	11585	620	-	6740	500	22620	16450
Sunflower	7	5	3	2	5	3	20	5	5.1	0.1	0.4	-	40.6	15,1
Cotton	0,2	0,1	-	-	-	5	57	5	0.3	1	0.1	-	57.6	11,1
Sesame	520	90	30	20	43	30	970	70	290	0.2	20	0,1	1873	210,3

Source: The work of the researcher based on the Ministry of Agriculture, Anbar Directorate of Agriculture, unpublished data, 2000

Conclusion

It is concluded that climatic conditions varied clearly in the stations of the study area between the years 2000-2022, where it was found that there was a rise in temperature, maximum temperature, and minimum temperature, a decrease in rainfall amounts, and an increase in drought. Also, the variation in the production quantities of oil crops between the two years of the study, as the year 2000 recorded production quantities for all studied crops more than what was recorded for production in 2022. Finally, the accumulated temperature and the upper limit of the maximum temperature have a clear effect on the variation of production.

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Authors' contributions

BMAA studied climatic characteristics and collected and analyzed climatic data to understand their implications. STD focused on studying agricultural water resources and their effect on crop production. MRM investigated the specific climatic requirements for each crop. ASEA organized and streamlined ideas of research. JMA participated in creating and designing detailed maps. ETAG was responsible for providing crop data and its analysis and interpretations. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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