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Prospects of Agriculture in Iraq in the Confrontation of Climate Changes: a Review

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ABSTRACT

In the Middle East, Iraq is one of the countries most influenced by the effects of climate change. In recent years, Iraq has witnessed major climate changes, including a sharp rise in temperatures to 52 °C in some areas and a decline in water levels and rainfall rates. In 2023, the Haditha station recorded a rainfall rate of 14.45 mm in November. Statistics show that the rainfall rate at Ramadi station in November was 9.6 mm, which is less than the average rainfall rate for 1988–2019, as recorded at the terminal station of the Upper Euphrates Basin Development Center. This situation is also the case in most areas of Iraq and the Middle East, especially in recent years, and is considered a dangerous indicator. The lack of rainfall and scarcity of water have led to a decrease in vegetation cover. This effect, in turn, has led to the increased desertification of lands and elevated concentrations of greenhouse gases, especially CO_2, consequently resulting in aggravated global warming. Climate change is one of the most important issues of our time due to its remarkable effects on living organisms. The plant production sector in Iraq faces multiple challenges that are exacerbated by increasing drought periods, irregular rainfall, environmental changes, and increased demand for agricultural products. As a result of increasing population growth and declining self-sufficiency, the contribution of the agricultural sector to the gross domestic product of Iraq has declined to low levels. Therefore, the national government has been forced to rely on importing food from abroad to cover deficits, placing a heavy burden on the Iraqi economy and resulting in increased disadvantages. Therefore, countries and the world must confront the challenges of climate change and its danger to the world and find appropriate solutions for the future of humanity.

Introduction

The issue of climate change is among the important and novel topics that have gained the attention of numerous researchers in the past few decades of the last and current centuries. It is accompanied with serious future effects that threaten humanity, its future activities, the surrounding environment, and the expected destructive damages in the coming years if not addressed by humans by reducing activities that increase its severity [1, 3].

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Climate is a major factor affecting various environmental variables through its direct contribution to the scarcity and abundance of water, which is the primary source for agriculture [3]. Additionally, it influences temperature, evaporation percentage, relative humidity, atmospheric pressure, winds, dust storms, and other climatic elements. These factors have a direct and indirect effect on agricultural production. Therefore, climate studies in agriculture that effectively determine the compatibility between climate elements and the climatic requirements of plants are necessary [4, 5].

Iraq has a total area of approximately 174.8 million donum and is characterized by a semiequatorial continental climate. Arable land in Iraq constitutes approximately 28 million dunam, accounting for approximately 16.1% of the country's total area.

Agriculture is the second-largest contributor to the country's gross domestic product, accounting for approximately 5%, and serves as an important livelihood source for 25% of the population. In Iraq, agriculture is characterized by small farms, with many in the north regions relying on rainwater and those in other regions on irrigation [6]. Rainfed areas account for approximately 38.1% of the total cultivated land and are predominantly located in the northern and northeastern regions of Iraq. Irrigated land constitutes 61.9% of the total cultivated land and is concentrated in central and southern regions [7]. Iraq heavily relies on neighboring countries, such as Turkey, Syria, and Iran, for freshwater sources, which can negatively affect water quantities in reservoirs, lakes, and rivers. Previous studies have indicated substantial water waste in the agricultural sector due to the use of outdated and traditional irrigation methods. The overall efficiency of irrigation in the agricultural sector is between 30% and 40%, with an estimated loss of 30% during transportation and field losses of 30%–40% [8].

Agriculture is extremely sensitive to climate change given that even a 2 °C increase in global temperature averages will disrupt the stability of current agricultural systems. Climate change has the potential to alter the patterns of food production, crop productivity, livestock breeding systems, and aquaculture and reshape food distribution, markets, and access [9, 11].

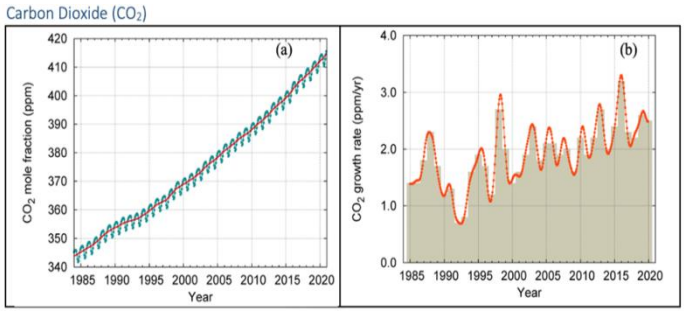
Therefore, the climate changes that are currently occurring and those anticipated to occur in the future are expected to have far-reaching negative effects on millions of people who already face challenges in securing food. This situation may pose the greatest challenges to humanity, with efforts being underway to secure the nutrition of over nine billion people by the year 2050 [12, 14].

According to the latest research, climate change could force 216 million people to migrate within their countries by the year 2050, and subsequently, its influence and exacerbation are expected to intensify. Climate change may reduce crop yields, especially in regions already grappling with food insecurity. At the same time, agricultural practices, agroforestry systems, and changes in land use contribute to approximately 25% of greenhouse gas emissions [15, 61]. As long as emissions continue, global temperatures will keep rising. Alongside temperature increases, this situation implies increased occurrences of extreme weather events, including changes in rainfall patterns, ice melting, rising sea levels, and ocean acidification, with associated long-term social and economic consequences.

Human activities are a factor that has led to the rise in the Earth's temperature. The concentration of CO_2, one of the gases directly responsible for the greenhouse effect and global warming, has increased by 35% since 1970. Approximately 70% of this increase can be attributed to the burning and consumption of various types of fossil fuels. Climate change is originally a natural phenomenon that occurs every few thousand years. However, due to increasing human activities, its occurrence has accelerated [16, 17].

Agriculture contributes to gas emissions through land use in four ways: emission of CO_2 gas associated with deforestation processes; emission of CH_4 gas from rice paddies; emission of CH_4 gas through enteric fermentation in livestock; and emission of N_2O due to fertilizer use [18, 19].

These processes constitute approximately 54% of the total CH_4 emissions and 80% of N_2O emissions, presumptively including all CO_2 emissions associated with land use. Deforestation, especially in temperate regions, may affect carbon sequestration processes, resulting in an increase in CO_2 concentrations. Livestock and related activities, such as the expansion of field operations relying on fuel combustion, are responsible for 18% of human-induced greenhouse gas emissions, including 9% of global CO_2 emissions, 35%–40% of global CH_4 emissions, and 64% of global N_2O emissions [20, 21].



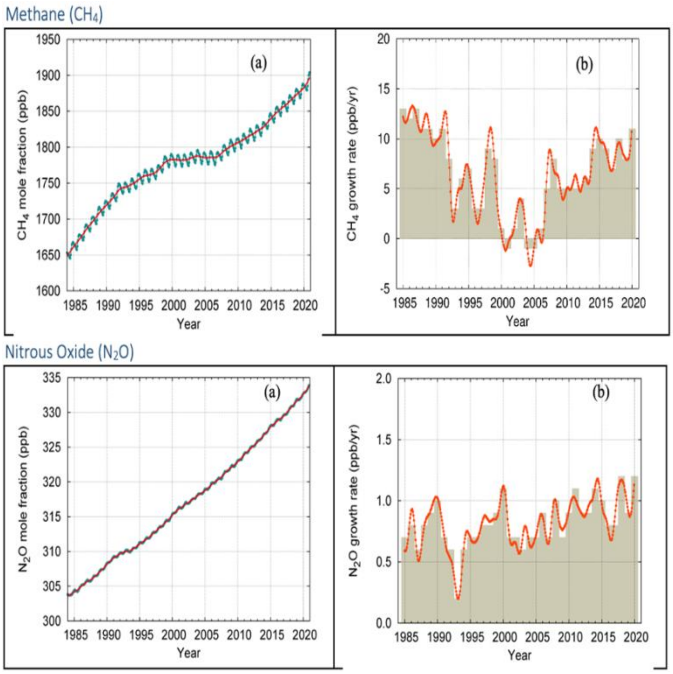


Figure 1. Global average concentrations of CO_2, CH_4, and N_2O, represented by symbols (a) for mole fractions and (b) for their growth rates from 1984 to 2020, where gas concentration changes were statistically calculated. Fractional mole fractions are indicated by the letter (a), and (b) depicts their growth rates. The increases in successive annual averages are shown as shaded bars in (b). The red line in (a) represents the monthly average after removing seasonal variations; the blue dots and line in (a) depict monthly averages. Observations from 138 stations were used for this analysis and reveal the increases that occurred with the rise in the proportion of greenhouse gases during this period and thus the increase in global warming as a result of the increase in these gases [22, 23].

Iraq and climate change

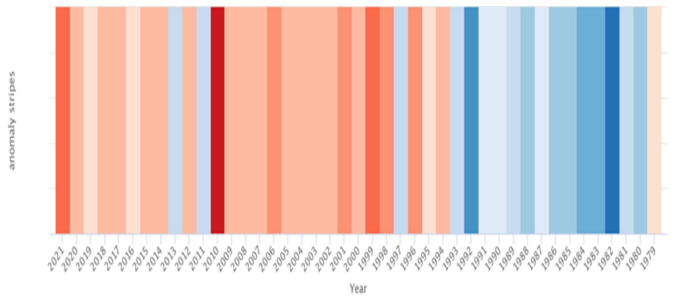
Iraq is one of the countries most affected by climate change. It is classified as one of the most vulnerable countries in the Middle East and North African region. In recent years, Iraq has experienced clear and tangible climate changes, with marked increases in temperatures, decreased rainfall, increased drought conditions, water resource interruptions, and exacerbated desertification. Additionally, Iraq has witnessed an increase in CO_2 concentrations and other highly impactful phenomena. These climate changes have had adverse effects on human health and critical sectors, such as water and agriculture, aggravating problems of food insecurity and hindering efforts to reduce poverty and enhance common welfare. Regarding temperature, heatwaves have intensified, surpassing 50 °C during the summer season, exerting devastating effects on food and water security, and threatening the livelihoods of many individuals [24, 25]. Climate change can affect Iraq and the Anbar Governorate specifically through the following factors:

Rising temperatures: Temperatures are expected to increase in arid regions, including the Anbar Governorate, leading to high evaporation rates and negatively affecting water resources.

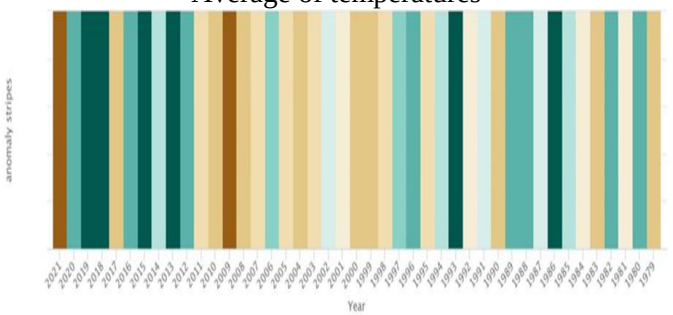
Water scarcity: Climate change can alter rainfall patterns, potentially causing seasonal droughts or reducing the available water quantity. This situation affects agriculture and the water supply for the population.

Increase in extreme weather events: Climate change may increase the frequency and intensity of extreme weather events, such as droughts, sandstorms, and floods, resulting in negative effects on infrastructure and communities.

Effects on agriculture and economy: Farmers may need to adapt their agricultural practices to changing weather conditions, affecting crop production and the local economy [26].



Average of temperatures



Average rainfall

Figure 2. Average temperatures and rainfall in Iraq from 1979–2021 [26].

The chart displays temperature anomaly lines. Each colored bar represents the average temperature for a year, with blue indicating cool years and red indicating warm years. A remarkable drop below the average is observed in 1997 and another decline is observed between 2011 and 2013, with an increase above the average occurring in 1999. Figure 2 shows precipitation lines for average rainfall. Each colored bar represents the total rainfall for a year, with green indicating the wettest years and brown indicating the driest years. Clear dry periods are noted between 2003 and 2005; another dry period is observed between 2007 and 2011; and a severe drought occurred in 2021 [26].

Climate change and its effect on agriculture: Despite technological and scientific advancements in agriculture, weather remains the primary factor influencing agricultural production, along with the quantity and quality of available natural resources, such as fertile soil suitable for cultivation and fresh water for irrigation [23]. In this regard, Iraq faces challenges due to its geographical location, which experiences high temperatures and relatively scarce rainfall, leading to limited water resources and heavy reliance on the Tigris and Euphrates Rivers, whose levels may be affected by variations in annual flood rates. The agricultural sector is one of the highest water consumers in Iraq, accounting for 85% of water consumption. Given the use of open and outdated irrigation channels, weak water resource management, deteriorating infrastructure, and the application of traditional irrigation techniques (surface irrigation) along with traditional farming practices, irrigation water quantities have exceeded the allocated water quotas over time, resulting in rising groundwater levels, soil leaching, and salinization. The continued decline in water resources will substantially affect land use, causing numerous farmers to lose their land, as well as changes in the distribution and spread of crops and livestock. An increase in water requirements for agricultural crops is expected due to rising temperatures resulting from climate change, putting pressure on available water resources to meet the irrigation needs of crops [27].

Given the limited nature of these resources, an annual decrease in cultivated land to compensate for the increased water requirements of crops is the expected effect of using the same varieties of agricultural crops and continuing to use outdated agricultural technologies without development. This situation may lead to the loss of the cultivation of some agricultural crops in currently productive regions, naturally resulting in a decrease in the food production necessary to meet dietary needs [28]. Furthermore, climate change will negatively and directly affect the production of agricultural crops due to rising temperatures. It will indirectly affect crops by increasing their water requirements, with plant water needs projected to increase by approximately 6%–16% by 2100 [29, 30]. For example, crops, such as wheat, sunflower, and rice, will be affected by existing drought conditions in various regions. High temperatures and drought can lead to a decrease in crop yields due to their effect on the physiological processes of plants [29]. For example, the drought in 2008 and 2009 caused massive crop losses in northern Iraq, damaging approximately 50% of agricultural land productivity [31].

As a result of increased evaporation and limited water resources, drought and salinity-sensitive crops are likely to suffer from decreased productivity and a reduction in their agricultural areas. Additionally, some crops may face quality issues rather than a reduction in quantity due to climate variability, resulting in soil damage and the spread of pests. The shortage and poor quality of water resources make agricultural crops less nutritious, susceptible to damage, and prone to diseases, especially during storage and transportation, leading to a decrease in their market value. Climate change in the future may also affect animal production in Iraq through its effect on the emergence and transmission of livestock diseases through various pathways. Feed quantities will decrease, and the agricultural land allocated for fodder will decrease due to increased competition for water resources between forage and grain crops [32, 33].

The climate has considerable effects on plant cover and soil, and it is a major factor in local variations within the environment due to its connection to the life activities of living organisms. Consequently, plants have adapted in various ways to survive in different environments [34, 36]. Various plants mutate and adapt

on the basis of differences in these environments. For example, plants, whether trees, shrubs, herbaceous, or perennial, that can withstand conditions of drought and high temperatures can be seen in arid regions. On the other hand, different plants have adapted to live in areas with sedimentary, saline, or prairie soils, and others have adapted to survive in mountainous regions with mild temperatures and high rainfall. Other plants have adapted to live in marshes and lowlands [37, 38].

Relationship between climate change and the water crisis in Iraq

Iraq relies on the Tigris and Euphrates Rivers to meet its water needs. Over the years, both rivers have witnessed high levels of water stress and environmental degradation, leading to increased water scarcity and a direct effect on the countries depending on them [39, 40]. The spread of drought increases in terms of duration and severity under the influence of climate change. Desertification also intensifies with the increased frequency of sandstorms and rapid floods, affecting agricultural crops [41, 42].

Water scarcity affects the agricultural sector harshly, especially during the summer months when rainfall is scarce, and farmers face water shortages [43]. The scarcity, poor quality, and salinity of water resources negatively influence crop production, either through direct damage to crops or a decline in the efficiency of irrigation systems, which are already influenced by drought conditions [44]. Prolonged drought periods have become increasingly frequent and damaging to rainfed crop production, even though they are less severe than the droughts affecting central and southern Iraq. In the 2008–2009 seasons, droughts affected approximately 50% of agricultural land [45]. Despite the increasing use of efficient irrigation methods (such as sprinkler or drip irrigation), especially by vegetable producers (tomatoes, cucumbers, eggplants, and peppers), one in four farmers still uses traditional surface irrigation methods. This practice results in substantial water wastage and has adverse consequences for vegetable productivity. However, it remains prevalent in areas near rivers in Ninawa and Al-Hamdaniya Districts. Despite the prevalence of projects combining crop cultivation and livestock breeding to enhance diversification and resilience against climate shocks, vegetable fields are poorly irrigated. In wheat and barley cultivation projects, a few farmers (11%) practice crop rotation, and none use continuous cultivation for consecutive seasons, making the systems highly vulnerable to catastrophic losses due to severe weather conditions [46, 47].

According to Iraq's National Strategy for Water and Land Resources for the period of 2015–2035, freshwater resources per capita are expected to decrease to 1000 m^3 annually by 2030. By 2050, a 10% decrease in precipitation and a 1 °C temperature increase are anticipated to result in a 20% reduction in the availability of freshwater. This situation indicates that nearly one-third of irrigated land in Iraq will not have water by that date [48]. Regarding water supplies, priority is always given to public water consumption and other vital sectors, such as agriculture. With the increasing population and growing demand for food, the agricultural sector has become the largest consumer of water [49, 52].

In addition to biological risks, environmental factors may have direct effects on the occurrence of genetic variations that negatively affect the quantity and quality of production [52, 54].

Several prospects and opportunities can be leveraged to enhance the sustainability of the agricultural sector in Iraq in the face of the challenges of climate change. Some anticipated challenges and potential solutions for future agriculture in Iraq based on current environmental and climatic trends include the following [54, 64]:

Water scarcity: With continuing low rainfall and declining levels of the Tigris and Euphrates Rivers, water scarcity for agricultural irrigation will intensity. This situation may lead to a reduction in cultivated areas and the adoption of dry farming practices [65, 68].

Water resource management: Iraq needs to improve water management in agriculture, including enhancing irrigation and drainage systems to conserve water and reduce evaporation. Additionally, improving the quality of water used for irrigation and minimizing water pollution are crucial.

Land aridity: In the future, increased aridity is expected to affect soil quality and reduce the productivity of agricultural land.

Land salinity: Growing land salinity can be a considerable challenge for agriculture, affecting plant growth and rendering soil unsuitable for cultivation.

Crop changes: Farmers may need to shift to cultivating different crops that are suited to changing climatic conditions. This necessity presents a challenge in achieving agricultural diversity by supporting farmers in cultivating new crops that are less water intensive than currently cultivated crops.

Adoption of advanced agricultural technologies: The need to adopt advanced agricultural technologies, such as drip irrigation and organic fertilizers, to enhance water use efficiency and increase land productivity will increase.

Sustainable agricultural techniques: Iraq can benefit from developing and adopting sustainable agricultural techniques, such as drip irrigation and organic farming methods. These techniques help conserve water, improve crop productivity, and reduce the influence of climate change.

Promotion of education and agricultural research: Promoting education and agricultural research is essential to ensure the provision of knowledge and modern techniques to farmers. Research can contribute to developing crops resistant to climate change.

Disaster preparedness: Strategies must be developed to address climate-related disasters, such as droughts and floods. They include securing food supplies, storing agricultural resources, and providing agricultural insurance.

Regional cooperation: Iraq can enhance regional cooperation with neighboring countries in climate change and sustainable agriculture to share experiences and resources. Improving agriculture in Iraq amid climate change requires collaborative efforts among the government, farmers, research institutions, and the international community. Sustainable and intelligent actions can enhance Iraq's ability to adapt to climate challenges and ensure the sustainability of the agricultural sector [12].

2. Conclusions

Climate change has currently become an important challenge facing the global economy, posing an obstacle to achieving sustainable development goals. Iraq is one of the countries most affected by this challenge. In recent years, Iraq has experienced severe climatic shifts, such as drought, agricultural insecurity, declining water levels, and increased salinity due to the rising water evaporation rate.

The quantitative and qualitative changes in available water resources (whether surface or groundwater) are among the most affected factors. They contribute to water scarcity in some agriculturally suitable regions and, consequently, the loss of a massive portion of arable land. Climate change also leads to a decline in agricultural crop production and vegetation cover and the expansion of desert areas due to decreased rainfall and increased drought.

In light of the above phenomena, governments and local communities must seriously address the above challenges through the implementation of appropriate strategies, including the following:

- Improving and developing agricultural practices to enhance adaptation to climate change.
- Working to reduce the degradation of agricultural land, preserving vegetation cover, and implementing programs to rehabilitate damaged lands.
- Developing and disseminating high-yielding agricultural varieties resistant to drought, heat, and increased soil salinity.
- Promoting the cultivation of short-cycle crop varieties to achieve water savings and increase agricultural productivity.
- Focusing on genetic modification to improve water use efficiency in agriculture.
- Adopting sustainable agricultural practices that consider environmental factors, such as soil, climate, and water.
- Providing accurate and sequential data on the environment and climate for different agricultural periods in various regions of Iraq, enabling researchers and stakeholders in the agriculture sector to develop precise developmental strategies for each region.
- Adopting modern irrigation methods and employing

protective techniques for farmers to mitigate the consequences of climate change.

- Monitoring climate change and assessing its effect on the agricultural sector, taking necessary measures to adapt to this phenomenon.

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آفاق الزراعة في العراق في مواجهة التغيرات المناخية -: مراجعة

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الخلاصة:

في منطقة الشرق الأوسط، يعد العراق من أكثر البلدان تأثراً بتأثيرات التغير المناخي، فقد شهد العراق خلال السنوات الأخيرة تغيرات مناخية كبيرة، منها ارتفاع حاد في درجات الحرارة لتصل إلى 52 درجة مئوية في بعض مناطق العراق، وانخفاض مناسيب المياه، وانخفاض معدلات هطول الأمطار، حيث سجلت محطة حديثة في عام 2023 معدل هطول أمطار بلغ 14.45 ملم في شهر نوفمبر/تشرين الثاني. وأظهرت الإحصائيات أن معدل هطول الأمطار في محطة الرمادي في شهر نوفمبر/تشرين الثاني بلغ 9.6 ملم، وهو أقل من متوسط معدل هطول الأمطار للفترة (1988–2019)، (المحطة الطرفية لمركز تنمية حوض أعالي الفرات). وهذا هو الحال أيضاً في معظم مناطق العراق والشرق الأوسط، وهذا يعتبر مؤشراً خطيراً، وخاصة في السنوات الأخيرة. ان قلة الامطار وندرة المياه ادى الى تناقص الغطاء النباتي وبالتالي زيادة التصحر في الاراضي وزيادة تركيزات الغازات الدفيئة وخاصة ثاني اكسيد الكربون وبالتالي زيادة الاحتباس الحراري لذلك تعتبر ظاهرة التغير المناخي من اهم قضايا عصرنا نظرا لتأثيرها الكبير على الكائنات الحية. وبالتالي على الانتاج النباتي حيث يواجه قطاع الانتاج النباتي في العراق تحديات متعددة تفاقمت بسبب زيادة فترات الجفاف وعدم انتظام هطول الامطار والتغيرات البيئية وارتفاع الطلب على المنتجات الزراعية ونتيجة لزيادة النمو السكاني وانخفاض الاكتفاء الذاتي تراجعت مساهمة القطاع الزراعي في الناتج المحلي الاجمالي الى مستويات متدنية. ونتيجة لذلك اضطرت الحكومة إلى الاعتماد على استيراد المزيد من الغذاء من الخارج لتغطية العجز، الأمر الذي ألقى بأعباء ثقيلة على الاقتصاد العراقي، وبالتالي تزايدت المساوئ، لذا يتوجب على الدول والعالم مواجهة تحديات التغير المناخي وخطورته على العالم وإيجاد الحلول المناسبة لمستقبل البشرية.

الكلمات المفتاحية :التغيرات المناخية، الغطاء النباتي، التصحر ندرة المياه، الغازات الدفيئة