The economic impact of climate and environmental changes on wheat and rice crops in Iraq for the period 2000-2023 using the Ricardo approach.

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Abstract

The study aims to analyze the economic impacts of climate and environmental changes and to determine their impact on the total revenue of wheat and rice crops in Iraq for the period (2000-2023). Using the statistical program Eviews13, the results showed that the variables average temperature, the square of the average temperature and water, the square of water, and carbon dioxide emissions were all significant and influential on the total revenue of the rice crop during the period studied, according to the Ricardian climate methodology. The sign of the average temperature, the square of water, and carbon dioxide emissions was negative, and the aforementioned variables explained 81% of the changes in the dependent factor. As for the wheat crop, the variables were balanced, with the exception of carbon dioxide emissions, because the effect of this variable may be minimal on the quantities produced from the wheat crop, and other variables, such as temperature and water, had the greatest impact on the quantity produced. The parameters of average temperature were Water has a negative sign in the model, and these changes explained 92% of the variations in the dependent factor. The study recommends developing new varieties of wheat and rice that are resistant to future climatic conditions in Iraq, in addition to cultivating genetically modified varieties that are adaptable to the climatic and environmental conditions surrounding the agricultural environment .

Key words : global warming , Green economy , Water, production function , strategic crops.
*** Post of M.Sc. thesis of 1st author**

Introduction

Agriculture is affected worldwide by climate change, and these climate changes have a greater impact on developing countries in general, due to the lack of modern capabilities and means to mitigate the impact of climate change, particularly in arid or semi-arid regions (7). Temperature changes, as the most important climatic factor, significantly affect the nature, quantity, and value of agricultural production. (9) Climate change (15) represents a serious challenge facing the world in general, and Iraq in particular. According to the United Nations classification Wheat and rice are among the most important food crops in the world and have great economic and social importance. They are the main food in the bread industry, as well as their impact on food security, support for the national economy, and an important source of income for farmers, Iraq is the fifth country at risk from climate change (8); it suffers from high temperatures in the summer, reaching 50 degrees Celsius (16), which causes a significant increase in the rate of water evaporation and loss, in addition to a decrease in rainfall rates in the winter. Changes in climate play a role in the production of field crops (wheat, rice, corn, etc.) (3). These factors are considered essential for determining the success of agriculture and

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increasing agricultural productivity, such as (temperature, humidity, rainfall, and floods) (2). In general, climate and environment play a decisive role in determining the ability of farmers to produce. Wheat and rice crops are efficiently grown, and this affects the food and economic security of Iraq (1) considering that wheat is very important because it is a main source of food for many people. Wheat production also needs a certain amount of water and sun to grow better. If the climate is dry, there will not be enough water for wheat to grow, and if it is very cold, there will not be enough sun for wheat to grow (10). Likewise, the rice crop is considered a basic and important crop and needs a warm and humid environment to grow properly, as heat and humidity affect plant growth and the speed of maturity. (4) Agro-ecosystems also contribute to the exacerbation of greenhouse gas problems. The sources of greenhouse gas emissions in the agricultural sector are emissions of NO2 (nitrogen oxide) from soil, particularly as a result of nitrogen fertilization, emissions of CH4 (methane) from internal fermentation, and emissions of CH4 and N20 from manure management (13), which significantly impacts global food production. They also contribute to the pollution of drinking water, whether with nitrates or nitrogen fertilizers, as it is believed that agricultural methods that rely on chemical fertilization contribute to increased pollution. The Ricardian method is widely used in agriculture to assess climate contributions to net farm income across broad climate zones (12). The main idea of using the Ricardian cross-sectional approach to measure the economic impact of climate change is to use the model to assess climate characteristics in terms of marginal effects on net revenue as a measure of change in farm welfare (11). The Ricardian method is a modern technique widely applied to assess the impact of climate on net farm income.(6) Climate impact is measured by regressing farm income on climatic and farm-specific variables. This method assumes that farmers continually change the use of inputs and outputs to suit the surrounding environment, and as a result, adaptation choices are made implicitly. The research aims to identify and analyze the economic impacts of climate and environmental changes, represented by temperature, water, and emissions, on the total revenue of wheat and rice crops in Iraq using the Ricardian approach.

Materials and Methods:

Data sources were obtained from official bodies represented by ministries, periodicals, and the Food and Agriculture Organization of the United Nations. As for climatic and environmental variables, they were obtained from the Ministry of Environment for the two crops. Temperatures were dealt with, taking into account that the wheat crop is a winter crop and depends on rain to some extent, and the rice crop, which depends on the traditional irrigation method, is a summer crop.

If the production function takes the following form:

$$Q_i=Q_i\ (K_{ij}.E($$

Where: Qi is the quantity of commodity production, Kij, i is the vector of production inputs j used to produce E, and Qi is the vector of external environmental factors such as temperature, rainfall, soil, and characteristics of production sites.(5)(14(

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Assuming the presence of element prices W_J, and both Q, E, and the minimization of costs for the following cost function:(2(

C_i=C_i (Q_i.W.E

Where: C_i is the cost of producing commodity W (wl.w2...wn), i is the vector of item prices, using the cost function C_i at market prices, and maximizing profits for farmers in a given location as follows: (3(

Max.π=[PiQ_i ┤-C_i (Q.W,E)-P_L ├ L_i [

Where: PL is the fixed annual cost or land rent. Under perfect competition, all profits that exceed the natural return of all production factors go to zero. (4(

P_i Q_i^*-C_i^*=(Q_i^*,W,E)-P_L L_i^*=0

If the production of commodity i is from the maximum use of land E, then the market rent of the land will equal the net annual profits from the production of the commodity. By solving for PL from the previous equation, the rent of a unit of land is equal to the net revenues per unit. (5(

P_L=(P_i Q_i^*-C_i (Q_i^*,W,E))/L_i

The present value of current and future revenue streams gives the value of the land V_L:(6(

V_L=∫_∩^∞▒P_(L^(e^(-rt)) dt) =∫_0^∞▒[(P_i Q_i^*-C_i (Q^*,W,E)/├ L_i]┤ e^(-rt) dt

The basis of the analysis is the effect of external changes in environmental variables on net economic welfare (ΔW). Net economic welfare is the change in welfare caused by environmental change from one region to another. The change in economic welfare is measured in terms of the change in the capital value of the land or alternatively in net farm income. The change in annual welfare as a result of environmental change from region A to B, which causes environmental inputs to change from EA to EB, is measured as follows:

ΔW=W(E_B)-W(E_A)=∫_0^(B^Q)▒[(P_i Q_i-C_i (Q_i,W,E_B/├ L_i]┤ e^(-rt) dQ-∫_0^(A^Q)▒[(P_i Q_i ┤ -C_i (Q_i,W,E_A)/├ L_i] e^(-rt) dQ

If the market prices did not change as a result of the change in E, then the previous equation leads to: (7(

ΔW=W(E_B)-W(E_A)=[P┤ Q_B-∑_(i=1)^n▒〖C_i (Q_i,W,├ E_B]-[P┤ 〗 Q_A-∑_(i=1)^n▒〖C_i (Q_i,W,E_A〖 [(├

P_L L=Pi〖Qi〗^*-Ci(〖Qi〗^*.W.E By substituting equation (8..(

ΔW=W(E_B)-W(E_A)=∑_(i=1)^n▒〖 (P_LB L_Bi-P_LA L_Ai〖(

"Where: both P_LA and L_A are at E_A, and both P_LB and L_B are at E_B".

The present value of the change in welfare is as follows (9:(

)^0_∫B^Q)▒〖 〖ΔWe〗^(-rt) dt=∑_(i=1)^n▒〖(V_LB 〖LB〗_Bi-V_LA L_Ai〖〖(

The Ricardo model takes either Equation (8) or Equation (9), depending on whether data are available for net annual returns or net capital returns (V_L) (Uddin et al., 2014.(

The study used the Ricardo approach, using the total net revenue of Iraq's wheat and rice crops as the dependent variable, which is sloped on the independent variables.

Results and Discussion:

Table (1) shows that the highest wheat production in Iraq during the period studied was in 2020, reaching 6,238,392 tons, enabling Iraq to achieve self-sufficiency. This is due to the good rainy season, government support for farmers, increased crop purchase prices, and other factors. The lowest production was in 2000, reaching 384,000 tons. This is attributed to economic sanctions,

which weakened Iraq's ability to import fertilizers and pesticides, the damage to agricultural infrastructure, and the severe drought between 1999 and 2000. and 2001, which negatively impacted agricultural production in general and wheat in particular. As for wheat prices, the highest price for wheat during this period reached 2942074.602 dinars per ton in 2014. This was due to a rise in global wheat prices due to drought in most countries, including Iraq, in addition to government support policies for purchasing local wheat at high prices. The lowest prices were in 2000, reaching55296 dinars per ton due to the Oil-for-Food Program and Iraq's import of large quantities, which flooded the local market and lowered prices.

Table (1) Iraq's wheat production (tons) and wheat prices in Iraq for the period (2000-2023(

years	Quantity of wheat (tons)	Wheat prices in dinars (tons)(	Total revenue (Million/ton)(
2000	384000	144000	55296
2001	903400	133000	120152.2
2002	2589000	145000	375405
2003	2329000	160000	372640
2004	1832000	175000	320600
2005	2228000	224000	499072
2006	2086000	342000	713412
2007	2202800	400000	881120
2008	1255000	458000	574790
2009	1700390	488000	829790.32
2010	2748840	600000	1649304
2011	2808900	685000	1924096.5
2012	3062312	686000	2100746.032
2013	4178379	695000	2903973.405
2014	5055111	582000	2942074.602
2015	2645061	537000	1420397.757
2016	3052939	477000	1456251.903
2017	2974136	650000	1933188.4
2018	2177885	560000	1219615.6
2019	4343473	433000	1880723.809
2020	6238392	427000	2663793.384

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2021	**4233714**	**439000**	**1858600.446**
2022	**5233053**	**452000**	**2365339.956**
2023	**5235053**	**467000**	**2444769.751**
*Highest value	**6238392**	**695000**	**2942074.602**
Lowest value	**384000**	**133000**	**55296**
Average	**3004585.76**	**430269.2**	**1403943.218**

Source: Ministry of Trade, General Company for Grain Processing.

As shown in Table (2), the highest rice production in Iraq was in 2019, reaching 574,705 tons. This was due to the lifting of the ban on rice cultivation in 2018 due to water shortages that year, and the implementation of a drip irrigation system, which contributed to increased irrigation efficiency and improved production. The lowest rice production was in 2000, reaching 60,000 tons. This was due to water scarcity and volatile climate change. As for rice prices in Iraq, the highest price was in 2007, reaching 919,103 dinars. This was due to the difficult security situation that year, the mass displacement of farmers, and the emergence of a global food crisis. This affected grain prices, particularly rice, in addition to the amount of water required, especially since the rice crop requires large quantities of water. The lowest price for rice was in 2001, reaching 423,904 dinars, due to the same reasons for the decline in wheat prices mentioned above.

Table (2) Iraq's rice production (tons) and rice prices in Iraq for the period (2000-2023(

years	**Quantity of rice (tons)**	**Local rice prices**	**Total revenue (Million/ton)**
2000	**60000**	**528582**	**31714.92**
2001	**128000**	**423904**	**54259.712**
2002	**250000**	**602407**	**150601.75**
2003	**90000**	**739970**	**66597.3**
2004	**250000**	**442126**	**110531.5**
2005	**309000**	**542876**	**167748.684**
2006	**363000**	**556172**	**201890.436**
2007	**393000**	**919103**	**361207.479**
2008	**248157**	**699606**	**173612.1261**
2009	**173074**	**678358**	**117406.1325**
2010	**155829**	**713379**	**111165.1362**
2011	**235118**	**761670**	**179082.3271**
2012	**361339**	**773058**	**279336.0047**

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2013	**451849**	**715807**	**323436.6771**
2014	**403028**	**618912**	**249438.8655**
2015	**109209**	**582920**	**63660.11028**
2016	**181320**	**602378**	**109223.179**
2017	**265852**	**612000**	**162701.424**
2018	**518196**	**623000**	**322836.108**
2019	**574705**	**800000**	**459764**
2020	**464159**	**803000**	**372719.677**
2021	**422463**	**813000**	**343462.419**
2022	**233111**	**850000**	**198144.35**
2023	**37324.3**	**863000**	**32210.8709**
*Highest value	**574705**	**919103**	**459764**
Lowest value	**60000**	**423904**	**31714.92**
Average	**285206.44**	**677239.8**	**197470**

Source: Ministry of Commerce, General Company for Grain Processing

Table (3), which estimates the parameters of the Ricardo model and wheat yield, shows that the variables explain 92% of the variations in the dependent variable. All variables were found to be significant, with the exception of carbon dioxide emissions, as these gases are expected to have a minimal impact on wheat yield, and the yield is affected by more important variables such as temperature, water scarcity, and others. The temperature variable was negative, reflecting wheat's response to low temperatures, especially since this is a winter crop that grows in moderate and ideal conditions. The water variable was positive, reflecting the importance and role of water in increasing yield through modern irrigation systems and water management to improve varieties. The carbon dioxide emissions squared was positive, due to the expected positive impact of enhancing photosynthesis, increasing plant growth, and thus increasing yield, known as the CO2 fertilization effect.

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Table (3) Parameters of the Ricardo model for the impact of climate change on the net farm income of wheat crops during (2000-2023(

Variables	Cofficient	Std.Error	t-Statistic	Prob.
Constant	0.302845	0.154898	1.955132	0.07
Average Temperature	-43319482	114691975	-3.779408	0.00
Average Temperature Squared	914635.4	243870.6	3.750495	0.00
Water	11.42E+10	4.95E+10	2.307070	0.01
Water Squared	-2.18E+08	0.62E+08	-3.576034	0.00
Carbon Dioxide Emissions	2.8442961	3.383901	0.840538	0.41
Carbon Dioxide Emissions Squared	67.4E-05	2.62E-05	2.570656	0.02

Source: Researchers' work based on (Eviews13.(

Table (4), which is concerned with estimating the parameters of the Ricardo model for the rice crop during the period (2000-2023), shows that the variables explain 81% of the changes in the dependent factor. The significance of the effect of all variables is also evident. The table also shows an inverse relationship between the average temperature and the total revenue of the rice crop. This reflects the sensitivity of the rice crop to high heat. It needs relatively moderate temperatures for the growth stages and avoids increased water evaporation and thus heat stress for the plant. The temperature square variable came with a positive sign due to the use of some rice varieties that are resistant to high heat and heat stress, such as Amber, Jasmine, and Euphrates rice. The water variable came with a positive sign that is consistent with economic logic because the rice crop is one of the crops that consume a large amount of water, and this was reflected positively on the total revenue. The water square variable came with a negative sign, but it is consistent with logic because increasing or doubling the quantities of water leads to weak growth and rapid loss of nutrients, thus affecting the quantity produced. The carbon dioxide emissions variable Carbon dioxide was negative, which is consistent with the logic that decreasing CO2 emissions increases production and, consequently, revenue, and vice versa.

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Table (4) Estimated parameters of the Ricardo model for the impact of climate change on net farm revenue for rice crops during (2000-2023(

Variables	**Cofficient**	**Std.Error**	**t-Statistic**	**Prob.**
Constant	**0.515108**	**0.149718**	**3.440527**	**0.00**
Average Temperature	**-7236060.**	**2777486.**	**-2605255**	**0.02**
Average Temperature Squared	**154769.3**	**59240.81**	**2.612546**	**0.02**
Water	**47327.67**	**11799.75**	**4.010904**	**0.00**
Water Squared	**-436.4352**	**111.9743**	**-3.897639**	**0.00**
Carbon Dioxide Emissions	**-18333270**	**6676959**	**-2.745751**	**0.01**
Carbon Dioxide Emissions Squared	**8.16E-05**	**2.71E-05**	**3.012125**	**0.01**

Source: Researchers' work using the Eviews13 program.

Table (5) Data on average temperature, carbon dioxide emissions, and water imports in Iraq for the period (2000-2023(

years	**Average temperature (degrees Celsius)**	**Carbon dioxide emissions (kilotons)**	**Water intake of the Tigris and Euphrates Rivers (billion cubic meters)**
2000	**23.008**	**87630**	**42.73**
2001	**23.213**	**97550**	**28.8**
2002	**22.85**	**91160**	**76.88**
2003	**22.903**	**81280**	**66.05**
2004	**22.84**	**88110**	**55.67**
2005	**22.82**	**85130**	**65.2**
2006	**22.978**	**82960**	**59.19**
2007	**23.065**	**76650**	**35.7**
2008	**22.993**	**88140**	**67.51**
2009	**22.9**	**94200**	**32.11**
2010	**24.643**	**108550**	**52.1**
2011	**22.435**	**113040**	**51.4**
2012	**23.388**	**129000**	**50.7**

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2013	**22.413**	**139100**	**49.8**
2014	**23.323**	**134040**	**49.1**
2015	**23.545**	**133170**	**48.4**
2016	**23.193**	**142230**	**54.75**
2017	**23.62**	**155080**	**49.33**
2018	**24.033**	**163150**	**52.73**
2019	**23.07**	**174560**	**56.29**
2020	**23.574**	**143493.3**	**47.65**
2021	**23.559**	**153486.7**	**31.41**
2022	**22.764**	**157180**	**32.9**
2023	**23.674**	**151386**	**43.6**
*Average	**23.20**	**119594.83**	**50.21**
Highest Value	**24.643**	**174560**	**76.88**
Lowest Value	**22.413**	**76650**	**28.8**

Source: Ministry of Environment / Planning and Follow-up Department.

Conclusions

.1

Average temperature and water had a significant impact on the total yield of wheat crops in Iraq, reflecting the clear role of water and temperature in the growth of this important crop.

.2There was no clear impact of carbon dioxide emissions on wheat production due to the presence of other variables that have a greater impact on crop production.

.3With regard to rice, all studied variables (temperature and water) and carbon dioxide emissions had a significant impact on rice production and, consequently, on the total yield of rice.

Recommendations

.1Encourage the cultivation of genetically modified crops to enhance their ability to adapt to future environmental and climatic changes in Iraq.

.2Emphasize the use of organic fertilizers in the cultivation of major crops instead of chemical fertilizers, which contributes to reducing environmental pollution.

.3Encourage the use of modern irrigation technologies in the cultivation of major crops, which enhances water use efficiency and reduces the loss of this vital resource, which is important to the agricultural sector.

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