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Original Article

The effect of climate change on agricultural production in Iran

O efeito das alterações climáticas na produção agrícola no Irão

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Abstract

The issue of climate change caused by global warming has become a major concern and challenge around the world, requiring comprehensive countermeasures. Agriculture is the most affected part of climate change and Iran's agriculture economy is at risk because of hot and dry and damages due global climate changes. This study investigates the effects of climatic variables temperature, such as precipitation, carbon and dioxide emission on total crop production in Iran from 1971 to 2020 using a fully modified conventional least squares econometric model (FMOLS). Chemical fertilizer and crop area variables, as well as fixed capital in agricultural have machinery, also been used as indicators of technology. The results showed that all variables had a significant effect on production. The average annual temperature and total annual rainfall its had an inverse U-shaped relationship with production, and were significant. Fertilizer and crop area variables had a positive effect, while CO2 had a negative relationship on total crop production in Iran. The findings of this study can be used to provide strategic plans for policymakers in the face of climate change. It is suggested that the government invest more in the mechanization of the agricultural sector and provide facilities and credits with priority given to farmers' education and the use of temperature-resistant varieties, and also act regionally against climate change.

Keywords: climate change, Iran total crop production, agricultural economics, CO2.

Resumo

A questão das alterações climáticas causadas pelo aquecimento global tornou-se uma grande preocupação e desafio em todo o mundo, exigindo contramedidas abrangentes. A agricultura é a parte mais afectada pelas alterações climáticas e a economia agrícola do Irão está em risco devido ao calor e à seca e aos danos causados pelas alterações climáticas globais. Este estudo investiga os efeitos das variáveis climáticas temperatura, como precipitação, emissão de carbono e dióxido na produção agrícola total no Irã de 1971 a 2020, usando um modelo econométrico convencional de mínimos quadrados (FMOLS) totalmente modificado. Variáveis de fertilizantes químicos e área de cultivo, bem como capital fixo em máquinas agrícolas, também têm sido utilizadas como indicadores de tecnologia. Os resultados mostraram que todas as variáveis tiveram efeito significativo na produção. A temperatura média anual e a precipitação total anual tiveram uma relação inversa em forma de U com a produção e foram significativas. As variáveis de fertilizantes e área cultivada tiveram um efeito positivo, enquanto o CO2 teve uma relação negativa na produção total de culturas no Irã. As conclusões deste estudo podem ser utilizadas para fornecer planos estratégicos aos decisores políticos face às alterações climáticas. Sugere-se que o governo invista mais na mecanização do sector agrícola e forneça facilidades e créditos com prioridade à educação dos agricultores e à utilização de variedades resistentes à temperatura, e também actue regionalmente contra as alterações climáticas.

Palavras-chave: mudanças climáticas, produção agrícola total do Irã, economia agrícola, CO2.

1. Intoduction

Climate change is irreversible change in the average of weather conditions which occurs in a region. In other word, statistically significant changes in the average of weather conditions or its variability that continues over a long period (IPCC, 2007). Global warming can have significant impacts on agricultural economics through changes in temperature, carbon dioxide, runoff, glaciation, rainfall, and the interaction of these elements (Wani et al., 2020). Climate change can greatly alter the risk of flooding on large regional and temporal scales, and increase the risk of unpredictable events and flooding by changing the amount of precipitation and temperature, which are the most important characteristics of climate change (Guo et al., 2020). Therefore, climate change is an important global challenge that requires comprehensive and collaborative action (FAO, 2022). Over the past 50 years, on average, the world has witnessed a daily occurrence related to climate change, climate and water hazards, and the rate of disasters and natural disasters worldwide has increased fivefold.

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Climate change is already affecting all regions of the planet in many ways, including longer warm seasons and shorter cold seasons, and this trend is expected to increase in the coming decades (WMO, 2021).

The Islamic Republic of Iran has a hot and dry dominant climate and is in a state of water scarcity and water stress in many agricultural areas. The agricultural sector of Iran contributes more than 8% of its GDP (Ministry of Agricultural Jihad, 2020). Iran is more sensitive to environmental changes than other climates due to its ecological structure. Therefore, it appears that the occurrence of climate change in these areas has significant effects on agricultural production systems (Amirnejad and Asadpour Kurdi, 2017). Agriculture is an important economic component of the global community, and climate change has a profound impact on agricultural ecosystems and poses serious threats to food security, human health, and environmental protection. Almost all economic sectors are affected by climate, but agriculture is the most dependent on climate (Sivakumar, 2021). Climate change is more important in agriculture than in other sectors, as human activity peaks, greenhouse gas concentrations will increase, causing global warming and ultimately leading to massive changes in the world's climate. These changes may have positive, neutral, or even negative effects on the agricultural sector, depending on the region (Janjua et al., 2014). Persistent greenhouse gas emissions will cause more warming and changes to the climate system, posing a serious threat to food security, human and environmental health, increasing temperatures, and dates (Sivakumar, 2021). The economic effects of climate change, such as changes in yield, production, and supply of crops, have an impact on food security, as well as long-term changes in climate parameters that affect farmers' profitability and income (Amirnejad and Asadpour Kurdi, 2017).

Among climate change researchers, there is a clear consensus on two key issues. First, global climate change (GCC) has taken place, due to a rise of 0.8 degrees Celsius in the average temperature of the Earth since the early 20th century, causing natural climate-related disasters such as hurricanes, floods, droughts, and heat waves (Bandara and Cai, 2014). The second issue is that agriculture is dependent on climate change, mainly for food production, as too much heat or insufficient water can interrupt crop growth and reduce yields, and floods and droughts can cause crop loss at harvest time. Thus, the agricultural sector is vulnerable both economically and physically to changing climate factors such as temperature and precipitation (Benhin, 2008), and changes in the pattern of these two variables can reduce crop yield over harvest time (Ben Zaied, 2013). According to the Food and Agriculture Organization (FAO), demand for grain will increase by 70% by 2050, doubling in less developed and low-income countries (FAO, 2014). Climate change, on the other hand, is the biggest threat to sustainable development due to the severe damage it causes to natural resources, the environment, human health, food security, and economic activity (Rahimi et al., 2019). Therefore, considering the increasing demand trend and the necessity of achieving sustainable development in the agricultural sector, planning to implement local programs to control the impacts of climate change is necessary.

Agriculture is one of the most important sectors in the world that is directly affected by climate change, so this study seeks to answer the following questions:

Is Iran's total crop production affected by average annual temperature?

Does annual CO_2 emissions affect Iran's total crop yield?

Does annual rainfall affect Iran's total crop production?

A wide range of studies have been conducted in agronomic sciences, development economics, and agricultural economics regarding climate change and the risks it poses to agricultural production. In both internal studies and foreign publications, the impact of climate change on the agricultural sector has mostly been confined to one region (at the provincial level) using different methods such as the Ricardian method, Growth, Mathematical planning, or a combination of them, as well as the General Circulation Model (GCM) and Computable General Equilibrium (CGE) methods. In general, clustering of agroclimatic regions of Iran based on more than 50 climatic variables shows that if climate forecasts are fulfilled, the number of climatic zones of Iran will decrease from twelve regions under current conditions to nine in 2050. This will cause changes in the structure of agricultural systems and, in addition to reducing yield, will lead to the spatial displacement of crop species, the possibility of the elimination of some species, or even the introduction of new or forgotten species (Janjua, et al, 2014).

The results of Kemerodi and Bostanabad (2019) study on the effect of climate change on agricultural production in East Azerbaijan province, conducted using a panel data approach and a time series model, showed that with a 1% increase in temperature, crop production decreases by 1.84%. Additionally, with a 1% reduction in annual rainfall, food consumption decreases by 0.11% (Kemerodi and Bostanabad, 2019).

Khaleghi et al. (2015) studied the effect of climate change on agricultural production in Iran, using a social accounting matrix model and modeling temperature and precipitation data over a 40-year period (1961-2000) under 8 scenarios, and found that agricultural production decreased by -5.37% due to the predicted climate change for Iran in the period 2000-2025.

The results of Amirnejad and Asadpour Kurdi's (2017) studies showed that the effect of climate variables of annual CO_2 emissions and total annual precipitation of Iran on subculture area variables, seed consumption, and fixed capital in machinery, estimated using distributed autoregression model with a lag for a 50-year both period, were positive and significant in the short and long run. Wheat production and constant capital and seed variables were not significant in machinery. Also, the coefficients of climatic variables of CO_2 and precipitation in the long term were 0.38 and 0.21, respectively, and in the short term, 0.22 and 0.12, respectively. This means that in the long run, with an increase of 1% in climatic variables, assuming the other conditions are constant, wheat production would increase by 0.38% and 0.21%, respectively, which has the same interpretation in the short term.

Soleimaninejad et al. (2016) used seasonal data from 1992-2012 and the Extended Interruption Self-Distribution (ARDL) method to confirm that climatic variables of temperature and precipitation respectively, have negative and effects, positive on the value added of the agricultural sector.

Hosseini et al. (2013) in "Investigating the Effect of Climate Change on the Agricultural Sector with Emphasis on the Role of Adaptive Strategies" showed that by the middle of the current century, climate change will lead to a reduction of rainfall and an increase in temperature parameters in the Zayandehrud Dam basin, which will result in a reduction of surface water resources of the basin by about 3.4% and 8.1% to horizons 1420 and 1450, respectively. The results of the economic model showed that, in the worst case (failure to apply adaptive strategies), the consequences of these changes for the agricultural sector of the basin would be about an 18% and 32% reduction in gross profit for the next 30 and 60 years, respectively (Hosseini et al., 2013). Additionally, the results of the study of the effect of global climate change on agricultural climate indices of Iran for 1430 (2050 A.D.), which was evaluated by two general circulation models based on the IPCC standard scenario, showed that the average annual temperature of different regions of the country would increase between 3.5 and 4.5°C by the target year, while the average annual rainfall would decrease between 7% and 14% (Kocheki and Mahalati, 2015).

In recent years, numerous studies have been undertaken to investigate the implications of climate change on the agricultural sector. Notable contributions include research by Rajabalinejad et al. (2023), Kemerodi and Bostanabad (2019), Amirnejad and Asadpour Kurdi (2017), Soleimaninejad et al. (2016), Khaleghi et al. (2015), and Hosseini et al. (2013). Each of these studies investigated the effect of climate change on the agricultural sector, and the results showed the effect of climatic variables of temperature and precipitation on the value added in this sector. Amirnejad and Asadpour Kurdi (2017) showed that, both in the short term and in the long term, climatic variables had a positive and significant relationship with wheat, while variables of seed and fixed capital were not significant in machinery. This differs from other studies, in which total crop production is considered in a 50-year period in Iran with the main variables of temperature, precipitation, and CO2; a significant relationship between temperature and precipitation on agricultural production has been observed. Rajabalinejad (2023) utilized the "safety cube theory" to conduct a comprehensive assessment of the impact of climate change on Iran's agricultural economy over 50 years. The study offers practical solutions to mitigate the damages of climate change through dynamic and targeted diplomacy. It is recommended that Iran's climate policy adopts a comprehensive approach that considers the entire climate change system and implements a balanced and intelligent strategy to reduce its effects at the national level, while also promoting regional and international cooperation (Rajabalinejad, 2023). Also Asadpour Kordi et al. (2023)as a result of their study, recommended that governments develop their industrial development based on medium and long-term plans based on advanced industries and support for workforce innovation, which will lead to transformation in the agricultural industry and its development (Asadpour Kordi et al., 2023). Foreign studies, including Attavanich and McCarl (2011), Alam (2013), Dasgupta et al. (2013), Ben Zaied (2013), Benlloch-Gonzalez et al. (2014), Janjua et al. (2014), Onoja and Achike (2014), Alagidede et al. (2014), Khanal et al. (2014), Bandara and Cai (2014), Shuai et al. (2015), Tokunaga et al. (2015), and Linnenluecke et al. (2018) have noted that they looked at the impact of climate change on the agricultural sector. For example, Linnenluecke et al. (2018) studied the effect of climate on Australian sugarcane production. Their results showed that CO_2 emissions and temperature had a negative effect on sugarcane production.

Shuai et al. (2015) conducted a study titled "Effects of Climate Change on Agriculture" to examine the effects of climate variables, such as minimum, maximum, and average temperature, and precipitation, on soybean and maize crop production in China. The results of this study showed that there is a nonlinear, U-inverse relationship between soybean and corn production with the climatic variables.

Alam (2013) conducted a study titled "Climate Change, Agricultural Productivity and Economic Growth in India" to examine the long-term and short-term relationship between carbon dioxide emissions, agricultural productivity, and economic growth, factoring in climate change into carbon dioxide emissions. Estimates showed that there is a positive and significant relationship between agricultural production and economic growth in both the long and short term, and the effect of the gas CO_2 greenhouse on economic growth is negative and significant in the long run.

Ben Zaied (2013) studied the climatic effects of annual rainfall and temperature on agriculture using a dynamic panel method with fully modified ordinary least squares (FMOLS). He estimated the effects of temperature and precipitation on crop production and the total agricultural production of Tunisia. The results showed that in both the long-term and the short-term, annual temperature had a negative effect on both grain production and total agricultural production and annual rainfall had a positive effect on grain production and total agricultural output in both the short-term and the long-term.

Benlloch-Gonzalez et al. (2014) investigated the effect of increasing CO_2 with increasing temperature on the root system growth of two spring wheat cultivars. The results showed that increasing CO_2 concentration alone increased root and stem growth, but this positive effect was reduced when plants were grown under high temperature.

The conclusion of these studies confirms the negative effects of annual temperatures in both the long term and the short term, and shows that the impact of CO_2 on economic growth is negative and significant in the long run. The climate variable of annual precipitation has also had a positive effect on agricultural production in the short and long term. As a result, the results of this study are consistent with the findings of the aforementioned researches.

According to studies conducted both domestically and abroad, important climate variables such as been used as have variables temperature and precipitation in agriculture. In this study, these two important climatic variables, along with the important climate variable CO_2, have been used. Furthermore, most studies have focused on the climate of one or more crops that have been studied.

In this research, considering the total crop production of the country, the effects of climate will be studied over a certain period of time, so the results of this study can be helpful for policymakers' decisions.

2. Methods

In this model, a production function is selected which shows the relationship between the inputs consumed and the output produced at different levels of input consumption. The total form of the production function is the relation (Amirnejad and Asadpour Kurdi, 2017) (Equation 1):

$$Y = f\ (X_1, X_2, \ldots, X_3) \quad (1)$$

In relation to (1), Y represents the quantity of production and X the factors of production (a variety of labour, capital and materials, respectively). If, in the production of a product, in addition to managed considered production factors, unmanageable production factors are then the production function will be as follows (Equation 2):

$$Y = f\ (X_1, X_2, X_3) \quad (2)$$

In relation to Equation 2, X_1, the vector of managed production inputs such as cultivation, fertiliser, seed and other physical inputs, X_2, the vector of unmanageable production inputs such as climatic factors (temperature, rainfall, etc.), and X_3 representing the level of technology used. In this study, the relationship (Equation 2) is stated as relation (Equation 3) (Janjua et al., 2014; Amirnejad and Asadpour Kurdi, 2017).

$$Ly_t = F(Lrain_t . Lrain^2{}_t . Ltem_{it} . Ltem^2{}_t .Ly_t(-1). \\ Lfert_t . Lland_t . Ltecno_t . Lco2_t . dom \quad (3)$$

In relation to (3), Ly_t natural logarithm of total crop production, $Lrain_t$ natural logarithm of total annual rainfall, $Lrain2_t$, natural logarithm of the second power of annual rainfall, $Ltemp_t$, natural logarithm average annual temperature, $Ltemp2_t$, natural logarithm of the second power average annual temperature, $Ly_t(-1)$, production break, $Lfert_t$, natural logarithm of total chemical fertilizer consumption, $Lland_t$, natural logarithm of the cultivated surface, $Ltecno_t$, natural logarithm of gross fixed capital formation in machinery and equipment for agricultural sector at constant prices 2004 (as an indicator of technology in the agricultural sector), $Lco2_t$, is the natural logarithm of annual carbon dioxide emissions of the country.

It should be noted that in function (3), in order to show the relationship between climatic variables (temperature and precipitation) and total crop production of the country, the second power of these variables has been used to not only estimate the relationship linearly, but also to obtain a more accurate estimate.

To investigate the relationship between the production function, the completely modified ordinary least squares (FMOLS) method is used. This model is a way to investigate long-term relationships between dependent variable and model explanatory and given the definition of climate change, which is the change of climate conditions over a period of time, the use of the FMOLS[1] method can be useful in investigating this phenomenon (Ben Zaied, 2013).

This method has been proposed by Phillips and Hansen (1990) in time series data and is used by applying modifications to the ordinary least squares method. These corrections are skewness correction and endogeneity correction (Dehmardeh et al., 2010). In order to explain this method, we consider the regression equation as a relation (Equation 4):

$$t = 1 \ldots . T \\ Y_t = \alpha + \beta X_t + \varepsilon_t \quad (4)$$

In relation (Equation 4), Y is the dependent variable and X is the independent variable, assuming that the relationship between the independent variable and its interval is Equation 5.

$$X_t = X_t + u_t \quad (5)$$

Kao and Chiang (2000) define the FMOLS estimator of the regression equation of Equation 4, which corrects the endogeneity and serial correlation problem of the OLS method, as Equation 6:

$$\hat{\beta}_{FMOLS} = \left[\sum_{t=1}^{T} \left((X)_{it} - \overline{(X)}_i \right) \left((X)_{it} - \overline{(X)}_i \right)' \right]^{-1} \times \left[\sum_{t=1}^{T} \left((X)_{it} - (\bar{X}_i) \right) (Y)^{+}{}_{it} - T\hat{\Delta}^{+}_{\varepsilon\mu} \right] \quad (6)$$

In relation to (6) $\hat{\Delta}^{+}_{\varepsilon\mu}$ is the serial correlation correction component and $(Y)^{+}{}_t$ is the transformed form of Y_t to achieve endogenous correction (Kao and Chiang, 2000).

Considering that the second power of temperature and precipitation variables is used in the applied model of relation (3), therefore, relation (Equation 7) is used to calculate the elasticity and the maximum or minimum point of these variables Hosseininesab and Paikari, 2012):

$$\hat{\eta}_{ij} = \frac{\partial \mathrm{LnY}}{\partial \mathrm{LnX}} = \hat{\beta}_1 + 2\hat{\beta}_2 \mathrm{LnX} \quad (7)$$

In relation (7), $\hat{\eta}_{ij}$, Elasticity of climatic variables, Y; Dependent variable (performance of selected products), X; independent variable (climatic variables of temperature and precipitation), $\hat{\beta}_1$; LnX coefficient value, and $\hat{\beta}_2$; The coefficient value is LnX^2. Also, according to the application model of relation (Equation 3), if there are maximum or minimum points, relation (Equation 8) is used to calculate these points in the logarithmic pattern (Hosseininesab and Paikari, 2012):

$$T = \exp\left(\frac{-\alpha_1}{2\alpha_2} \right) \quad (8)$$

In relation to (8) ، the maximum or minimum point α_1 is the first power factor of climatic variables temperature or precipitation and α_2 the second power factor is the climatic variables temperature and precipitation.

[1] Long-term.

Also, according to the applied model of the relationship (Equation 3), the elasticity of production changes (dependent variable) relative to the changes in climate variables (independent variable), is obtained from the relationship (Equation 9) (Hosseininesab and Paikari, 2012):

$$\hat{\eta}_{ij} = \frac{\partial \text{LnY}}{\partial \text{LnX}} = \hat{\beta}_1 + 2\hat{\beta}_2 \text{LnX} \quad (9)$$

In relation to (9), $\hat{\eta}_{ij}$, the elasticity of climatic variables, Y, dependent variable (production), X, independent variable (climatic variables temperature and precipitation), $\hat{\beta}_1$ is the value of LnX coefficient and $\hat{\beta}_2$ is the value of LnX^2.

Data from the World Bank (annual carbon dioxide emissions, cultivated area, and total chemical fertilizer consumption), the Food and Agriculture Organization of the United Nations (FAO) (total agricultural production), the Central Bank of the Islamic Republic of Iran (formation of fixed capital in machinery), and the Iran Meteorological Organization (temperature and precipitation) were prepared, and Eviews9 software was used to estimate the model.

3. Results

To get to know the variables used in the study, Table 1 summarizes the minimum, maximum, mean, and standard deviation values of the variables.

The figures in Table 1 show that the minimum and maximum production during the period from 1971 to 2020 were 17,742,488 and 8,045,048 tons per year, respectively. The maximum cultivated area in Iran in 1998 was 64,787 hectares, while the minimum area of cultivation during 2013-2016 was 45,954 hectares. Additionally, the maximum annual average temperature of 19°C was related to 2017, and the minimum temperature of 16.1°C was related to 1982. For the variable, the maximum annual rainfall total was 721 mm, which was related to 1977, and the lowest rainfall was related to 2016 with 186.18 mm. The highest annual CO_2 emissions in the whole country were 629,290 tons in 2018, and the lowest in 1971 was 101,883 tons.

In Table 2, the average annual precipitation and temperature of the studied period are observed to have increased since 1997, with the temperature at the top of the chart.

Table 1. Statistical characteristics of variables used in the study for the total production.

Variable Name	Variable Description	At least	Maximum	Average	Standard Deviation
Y	Production (tons)	17742488	80450485	49006072/65	19301701/63
TEMP	Average annual temperature (°C)	16/1	19	17/43	0.77
RAIN	Annual rainfall total (mm)	186/18	721	405/63	140/33
LAND	Acreage area (hectares)	45954	64787	57330/02	7078/49
FERT	Total Fertilizer Consumed (kg/ha)	11/36	126/78	62/39	26/80
TECNO	Fundraising*	3/74	109365/9	13135/80	24374/15
CO_2	Annual Emissions	101883/92	629290	314975/20	178386/82
	Carbon Dioxide Percentage/hectare				

*Establishment of gross fixed capital in machinery and equipment of business in agriculture sector at fixed prices in 2005 (Billion Rials).
Source: Research Findings.

Table 2. Static results for variables at the level and first order difference.

Variable	At the level		First-order difference	
	Dickey Fuller Generalized Test		Dickey Fuller Generalized Test	
	Statistic t	Possibility	Statistic t	Possibility
LY	-1.92	0.32	-7.43***	0.000
Lrain	-1.70	0.42	-10.58***	0.000
Lrain2	-1.75	0.39	-10.67***	0.000
LtempP	-0.99	0.74	-8.78***	0.000
Ltemp2	-0.97	0.75	-8.55***	0.000
LfertT	-1.88*	0.07	-6.87***	0.000
Lland	-0.76	0.12	-6.95***	0.000
Ltecno	-0.38	0.90	-8.20***	0.000
Lco2	-0.67	0.84	-5.28***	0.000

The findings *,**, and *** were significant at the level of 10, 5, and 1 percent, respectively.

Meanwhile, the average annual rainfall in the country has been decreasing. This reduction in rainfall will be a factor in the mutual intensification of temperature and its adverse effects on the environment and agriculture. Increasing average seasonal temperatures can reduce the growth period of many crops and thus reduce yields (Mahato, 2014). In the long run, climate change can affect agriculture in several ways, such as the quantity and quality of crops in terms of productivity, growth rate, photosynthesis, and evaporation rates, moisture availability, etc. (Mahato, 2014). Before estimating the model, the stationarity of variables is first investigated by the widely used Dickey-Fuller test, which the results of are summarized in Table 2 for the logarithm of the studied variables at the surface and after the first difference.

According to the results of unit root tests in Table 2, all the variables of the pattern are non-stationary and contain a single root at the probability level of 1%, so that after the first differentiation they are stationary or I(1) at the level of 1%. Estimation of the model with unknown variables can lead to the creation of false regressions; to avoid this, there are differentiating methods and cointegration tests. Therefore, if there is co-accumulation between the unknown variables in the model, the results of the estimation of the model will be reliable. In this article, the method provided by Johanson is used to check for cointegration in the model. The null hypothesis in this test is the absence of co-accumulation or long-term relationship, the results of which are shown in Table 3.

According to Table 3, at the significance 1% level, a convergent vector exists. After proving the existence of cointegration in the model, the long-term relationship is estimated. There are various methods for estimating the long-term model, and, as previously stated, the Fully Modified Ordinary Least Squares (FMOLS) method has been used. The results of the estimation of the FMOLS model are shown in Table 4.

According to the results of the estimation shown in Table 4, the estimated coefficient of determination is 0.97, which states that 97% of the variation of the dependent variable is expressed by the explanatory variable of the model. Additionally, the results of this model indicate that the variables have a significant relationship with production. The average annual temperature climate variable has a nonlinear relationship with production, and according to the sign of the first and second power coefficients of the average annual temperature variable, this relationship is non-linear and U-inverted. In fact, the temperature climate variable has a maximum point such that before the maximum temperature increase leads to an increase in production, and then it causes a decrease in production. According to the relationship (8), the maximum annual temperature point of production is 16.78 °C.

Table 3. Johansson test results.

Probe	Critical limit 0.05	Trace	Eignvalue	Number of Integrative Equations
0.000	197.37	246.85	0.77	Zero*
0.87	159.52	179.07	0.60	A
0.197	125.61	123.48	0.57	Two
0.240	96.75	84.13	0.46	Three

*Lack of co-existence is rejected. Title: Research Findings.

Table 4. Results of the FMOLS model.

Variable	Coefficient Value	Standard Deviation	Statistic t	Probability Value
Ltemp	36.82**	14.18	2.59	(0.01)
Ltemp2	-6.53**	2.48	-2.62	(0.01)
Lrain	-0.77*	0.40	1.90	(0.06)
Lrain2	-0.06*	0.03	-1.83	(0.07)
LY(-1)	0.42***	0.04	10.23	(0.00)
Lfert	0.03**	0.01	2.60	(0.01)
Lland	0.19***	0.04	3.96	(0.00)
Ltecno	0.10***	0.007	13.77	(0.00)
Lco2	-0.127***	0.03	-3.56	(0.00)
C	-46.73**	19.91	-2.34	(0.02)
		$\bar{R}^2$= 96	R^2= 97	

The findings *,**, and *** were significant at the level of 10, 5, and 1 percent, respectively.

That is, before the temperature of 16.78 °C, the average annual temperature increase leads to an increase in yield, and after 16.78 °C temperature rise leads to a decrease in yield. Furthermore, according to the relationship (9), the average annual temperature has been estimated to be about 0.5 °C. This means that, assuming other conditions are constant, a 0.5% increase in the average annual temperature for the country in the period of 50 years leads to a 0.5% increase in the average annual crop production of the country. The effect of temperature is greater than that of precipitation on crop production. Furthermore, according to the results of the precipitation variable, temperature has a nonlinear, cohort-shaped relationship with production, which, according to the first and second power coefficients and the relationship (8), has a maximum rainfall of 614 mm.

The average annual rainfall up to 614 mm increases production and then leads to a decrease in crop production during the period studied. The tensile of precipitation variable, according to calculations, was 0.05. The physical variables of the area of cultivation, fertilizer, variable fertilizer and production interruption had a direct production, relationship with and the elasticity of these was 0.19, 0.03, and 0.42, respectively. This means that, assuming other conditions are constant, a 1% three variables increase in the area of cultivation and result in a total crop 0.03% increase in production of the will 0.19 country, respectively. The and CO_2 has also had a negative effect on the country's crop production. This means that, assuming other conditions are constant, a 0.5% increase in the average annual temperature for the country over a 50-year period leads to a 0.5% decrease in the average annual crop production of the country. The effect of temperature is greater than that precipitation on of crop production. Furthermore, according to the results, precipitation has a nonlinear, cohort-shaped relationship with production, which, according to the first and second power coefficients and the relationship (8), has a maximum rainfall of 614 mm. That is, average annual rainfall up to 614 mm increases production and then leads to a decrease in crop production during the period studied. Additionally, the elasticity of the precipitation variable, according to calculations, was 0.05. The physical variables of the area of cultivation, fertilizer, and production interruption had a direct production, relationship with and the elasticity of these three was 0.19, 0.03, and 0.42, respectively. This means that, conditions, a 1% assuming constant increase in the area of cultivation and the total crop production of the country will increase by 0.19 and 0.03%, respectively. CO_2 has also had a negative effect on the country's crop production.

4. Discussion and Conclusion

The climate change, intensified by human activities in recent decades, has increased concerns at the international level. In fact, climate change to be one of the most important environmental problems in the world, has had many drawbacks on agricultural production worldwide. As the agricultural production system in Iran is rigid due to lack of technology and capital, it has become increasingly vulnerable to climate change. In this paper, the effects of climate variables such as mean annual temperature, annual rainfall, and annual CO_2 emissions, along with chemical fertilizer variables, cultivation area, and fixed capital in machinery as an indicator for technology, have been discussed. To this end, the Fully Modified Ordinary Least Squares (FMOLS) method has been used. According to the results of the climatic variables, rainfall has not been found to have a significant relation with production, and the other variables have a significant relation with the total crop production. The average annual temperature, a climatic variable, has a nonlinear relation with production, according to the first and second power coefficients of the average annual temperature variable. This nonlinear relation has a maximum point, whereas before the maximum temperature (which is achieved according to the results of 16.78), the increase in temperature leads to an increase in production and after that, the production decreases. As a result, continuous temperature increase could lead to a decrease in production and ultimately yield of agricultural products per unit area, which has a direct effect on the model of the agricultural economy and especially food security. There is a significant relationship between temperature and precipitation on agricultural production, as evidenced by research by Linnenluecke et al. (2018), Amirnejad and Asadpour Kurdi (2017), Benlloch-Gonzalez et al. (2014), Ben Zaied (2013), Zarekani et al. (2014), Momeni and Zibaei (2013), Alijani et al. (2011), and Sultana et al. (2009).

The results also show that annual CO_2 emissions have a negative effect on production, which is consistent with scientific theories and the results of Rehman et al. (2022), Linnenluecke et al. (2018), Amirnejad and Asadpour Kurdi (2017) and Attavanich and McCarl (2011). Since one of the most important factors of global warming is the increase in greenhouse gases (the most important of which is excessive CO_2 emission) which cause climate impacts and an increase in temperature, resulting in a reduction in temperature-sensitive crop production, the government should avoid over-emissions of these gases. It is recommended to use renewable energy rather than fossil fuels. Solar and wind energy are widely used in Iran, and in order to absorb more CO_2 by natural resources, prevent forest destruction and overharvest of forest trees, and implement and institutionalize tree-planting projects in the country. Another result of this study is the positive effect of fixed capital in agricultural machinery as a technology indicator. It is suggested that the government invest more in mechanization in the agricultural sector and more extensive measures such as facilities and government credits, and train farmers to use the machinery properly, which leads to an increase in the country's crop production.

In general, considering that climate change and global warming have occurred and the results of this study have confirmed the impact of production on climatic variables (temperature and precipitation), the use of temperature-resistant varieties and cultivars can be useful and effective in combating climate change.

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