

The Impact of Climate Changes in Algeria on Crop Production During the Period (1961-2021)

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Abstract: This study aims to shed light on climate change in Algeria and its impact on agricultural crop production during the period 1961-2021, in an attempt to design a model that reflects the trajectory of the crop production index according to the most important climatic factors affecting it (or rather according to the possible interactions between these factors), knowing that these effects include direct and indirect effects (intermediate effects). This research has shown that the crop production index in Algeria was subject to the influence of the following interactions: the interaction between average temperature and average precipitation; the interaction between average temperature and carbon dioxide emissions; the interaction between average temperature and the ratio of agricultural land to the total land area; and the interaction between the ratio of agricultural land to the total land area and carbon dioxide emissions. Some of these interactions had a positive and some had a negative impact on crop production.

Keywords: Climate Change; Climate Indicators in Algeria; Crop Production Index.

1. Introduction

Climate changers' huge impact on agriculture has become nowadays' most controversial issues. which has witnessed unprecedented climate fluctuations. The most controversial that these ones have both negative and positive impacts on agriculture in different areas, according to each region's physiological characteristics.

Considering that Algeria is one of the warm regions in the world, which has made it suffer from climate fluctuations, in light of the ongoing controversy over the pressures the country suffers from in the field of agriculture; It was necessary to search the relationship between climate fluctuations and agriculture in the region.

1. 1. The problem of the study

From the above, the following main problem can be raised: How will climate change shape the course of agricultural crops in Algeria during the period under study?

To address the main problem, the following sub-questions can be asked:

- Does the interaction between the average temperature and the average precipitation variables directly affect the interaction between the average temperature variable and the carbon dioxide emissions variable?

- Does the interaction between the average temperature variable and the carbon dioxide

emissions variable directly affect the interaction between the average temperature variable and the agricultural land to total land area variable?

- Does the interaction between the average temperature variable and the agricultural land to total land area variable directly affect the interaction between the agricultural land to total land area variable and the carbon dioxide emissions variable?

- Does the interaction between the average temperature variable and the carbon dioxide emissions variable directly affect the crop production index variable?

- Does the interaction between the average temperature variable and the agricultural land to total land area variable directly affect the crop production index variable?

1. 2. Study hypotheses

Based on the raised sub-questions, the following six hypotheses were formulated:

H1: The interaction between the average temperature variable and the average precipitation variable directly affects the interaction between the average temperature variable and the carbon dioxide emissions variable.

H2: The interaction between the average temperature variable and the carbon dioxide emissions variable directly affects the interaction between the average temperature variable and the variable of the ratio of agricultural land to the total land area.

H3: The interaction between the average temperature variable and the variable of the ratio of agricultural land to the total land area directly affects the interaction between the variable of the ratio of agricultural land to the total land area and the carbon dioxide emissions variable.

H4: The interaction between the average temperature variable and the carbon dioxide emissions variable directly affects the crop production index variable.

H5: The interaction between the average temperature variable and the variable of the ratio of agricultural land to the total land area directly affects the crop production index variable.

H6: The interaction between the variable of the ratio of agricultural land to the total land area and the carbon dioxide emissions variable directly affects the crop production index variable.

1. 3. Importance of the study

The importance of the study raised from the pressures that the country is experiencing in the agricultural field and food security; which has become a major concern for researchers. Searching the relationship between agriculture and climate fluctuations has made the study more valuable, which in turn has become a sensitive discussion topic on the international scene.

1. 4. Objectives of the study

The study attempts to reveal the underlying relationships between: the possible interactions of climate fluctuation factors among themselves, and the crop production index. Thought testing a model for analyzing the path of the latter according to the interaction variables in Algeria during the last 61 years.

1. 5. Study methodology

The study relied on a measurement approach by analyzing the pathway of the crop production index in Algeria during the period 1961-2021, based on the possible interactions between the most important indicators controlling climate change; using the AMOS program.

1. 6. Previous studies

There are many related studies to this topic, which were used as a guide when preparing this study. This part of the study attempts to shed light on some of these studies, each of which touched one or some of the study variables. After reviewing and carefully scanning, it was found that the previous studies have dealt in general with the impact of climate change on crops, and these two variables are treated each time from a specific angle based on different indicators. The researcher has tried to shed light on the most important of these studies and those closest to the research topic. The essence of these studies can be summarized as follows:

1. 6. 1. *Study of Martin Watts & Mathew Mpanda & Andreas Hemp & Kelvin S.-H. Peh; entitled "The potential impact of future climate change on the production of a major food and cash crop in tropical (sub) montane homegardens"*: The study's aim was to analyze warmer and drier climatic conditions effects on tree-soil-crop interactions in tropical mountain home gardens. Soil data included: Soil moisture weighting content, bulk density, exchangeable calcium, exchangeable potassium, exchangeable sodium, exchangeable magnesium, exchangeable actinium, exchangeable bases, iron concentration, aluminum concentration, boron concentration, copper concentration, manganese concentration, zinc concentration, phosphorus concentration, sulfur concentration, soil pH, soil alkalinity, total carbon content, and total nitrogen content. The tree data included: tree height, diameter, and above-ground biomass estimates. As for climate data, it included: annual rainfall, air temperature, and relative humidity. Finally, the crop data were embodied in a banana crop yield index. The study concluded that warmer climatic conditions had a direct negative effect on the soil; climate conditions also had an indirect effect on the soil through the trees; in turn, the soil affected the banana crop. In other words, it was concluded that climate change was affecting soil productivity (directly or indirectly) and hence the crop. (Watts , Mpanda, Hemp , & S.-H. Peh, 2023, p. 161263)

1. 6. 2. *Study of Crimildo T. Cassamo & David Draper & Maria M. Romeiras & Isabel Marques & Rogério Chiulele & Marisa Rodrigues & Marc Stalmans & Fábio L. Partelli & Ana Ribeiro-Barros & José C. Ramalho; entitled "Impact of climate changes in the suitable areas for Coffea arabica L. production in Mozambique: Agroforestry as an alternative management system to strengthen crop sustainability"*: The study aimed to analyze the potential impact of future climate change on the suitability of the studied areas for rainfed coffee. Regarding climate variables, the most important for coffee plant growth were temperature and rainfall; although other variables may contribute to the geographical shifts of crops. The study concluded that: Extreme temperatures associated with a lack of rainfall may lead to a decrease in the suitability of areas for coffee cultivation. It was also proven that high CO₂ may lead to important physiological effects on plants, which may reduce the negative effects of global warming. It was found that CO₂ significantly enhances coffee vigor, growth and productivity; by stimulating the process of launching protective responses against drought and above-optimal temperatures, which improves coffee's resilience to environmental constraints. (Cassamo, et al., 2023, p. 108341)

1. 6. 3. *Study of Diptimayee Mishra & Naresh Chandra Sahu; entitled "Economic Impact of Climate Change on Agriculture Sector of Coastal Odisha"*: the aim of the study was to explore the economic impact of climate change on agriculture in coastal Odisha, using the Ricardian approach; where net revenue per hectare was estimated at the farmer level in the region (taking 13 major crops in the state: rice, wheat, maize, ragi, rocket, black gram, horse, sesame, groundnut, mustard, potato, jute, sugarcane) depending on climatic changes (measured through temperature and rainfall variables), based on time series regression analysis over thirty years; with control of various geographic and economic variables (population density, adult literacy rate, number of farmers, oxen and tractors per hectare, area under highly productive seeds, percentage of area under irrigation, ...). The study concluded that: temperature increase had a significant negative impact on agriculture in the

region; while rainfall variable had no significant impact (which was positive in some seasons and negative in others). For the other control variables, population density, number of farmers, number of tractors, and percentage of irrigated area had a significant positive effect on revenues; while literacy rate had a negative relationship with net revenues (as the level of education increases, the individual moves away from agricultural activities). (Mishra & Sahu, 2014, pp. 241-245)

1. 6. 4. *Study of Minah Jung & Jiwon Kim & Eun-Yeong Kim & Chaeyoung Yoo & Dahee Ko & Hojun Lee & Yunseo Chae & Yong-Min Kim & Gbum Yi; entitled "Climate change impacts on Allium crop production: Insights from long-term observations in South Korea"*: The aim of the study was to understand the possible impacts of climate change on major crops; Growth patterns of onion and garlic were observed in more than ten different sites in South Korea, with analyzing production data over the past 40 years. The study found that yield was significantly related to temperature and precipitation; higher average winter temperatures and spatial and temporal concentration of precipitation had a significant impact on allium crop yield. noticeably, linear regression analysis showed that allium crop yield was positively affected by both temperature and precipitation; while experimental analysis showed that fluctuations in temperature and precipitation had a negative impact. (Jung, et al., 2024, p. e34749)

1. 6. 5. *Study of Areeja Syed & Taqi Raza & Talha Tufail Bhatti & Neal S. Eash; entitled "Climate Impacts on the agricultural sector of Pakistan: Risks and solutions"*: The study's aim was to highlight the impacts of climate change on the agricultural sector in Pakistan; analyze the current risks and identify minimizing potentials within flexible agricultural practices that provide food security for households. The study concluded that global climate change has had an increasingly continuous impact on agricultural crops produced in Pakistan (wheat, rice, cotton, sugarcane, maize). It has been shown that the continued rise in global temperatures leads to change the rainfall patterns and shift in the monsoon season. Hence affecting agricultural production, livelihoods and agribusiness infrastructure, which in turn leads to food insecurity and malnutrition among farming communities. (Syed, Raza, Bhatti, & Eash, 2022, p. 100433)

1. 6. 6. *Study entitled "Climate change and global warming: Impacts on crop production"*: The study's aim was to investigate the impact of climate change in general (temperature, rainfall, extreme weather phenomena) and global warming in particular, on agricultural crops productivity. Among the most prominent findings of the study is that greenhouse gas emissions (the most important of which is carbon dioxide) have an evident impact on crop productivity; however, it is difficult to attribute any response in crop productivity to rising CO₂ levels, due to the potential interactions of the latter with the other influencing climatic factors and features.

In summary, it can be said that some researchers have focused on certain climatic factors, while others have given importance to other factors that they considered more effective. This research paper has attempted to list the most important climatic indicators that researchers have monitored in previous studies, which strongly control global climate fluctuations and may severely affect crop production; represented by: average temperature, precipitation rate, CO₂ emissions level, and the ratio of agricultural land to the total land area.

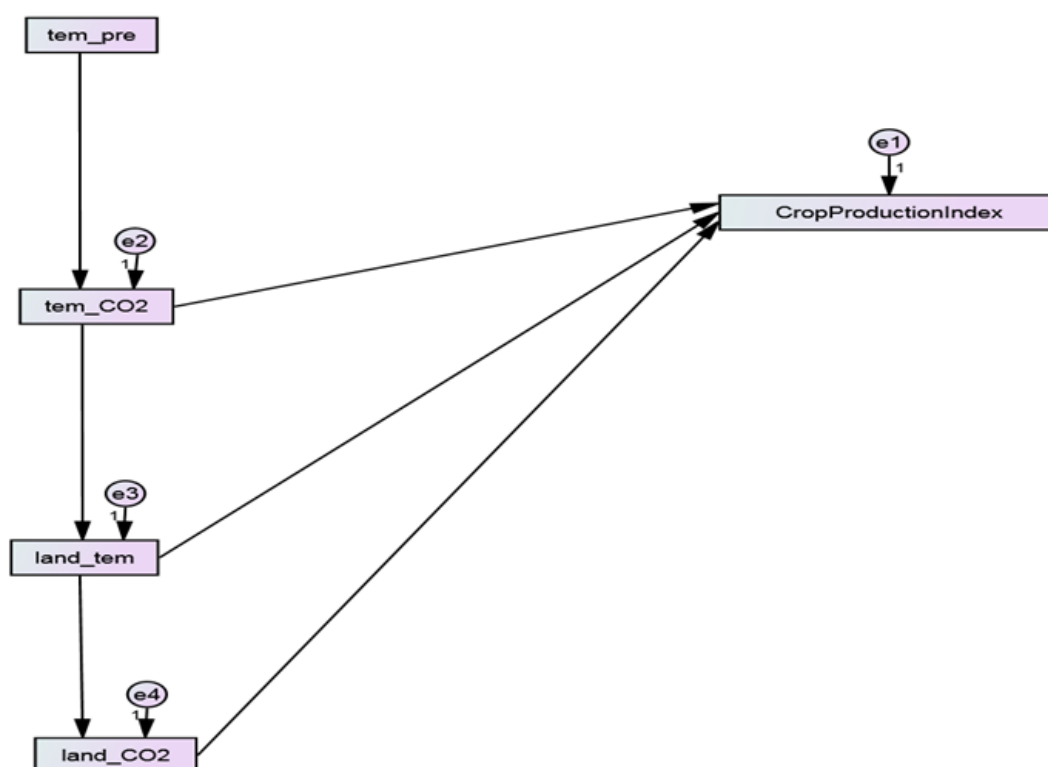
Interestingly, some of these studies have indicated that most of these factors do not affect agriculture alone, but rather the interaction between them is what drives and controls this relationship. Accordingly, a model was proposed to analyze the path of the crop production index in Algeria according to the possible interactions between the most important climate indicators; hoping that this study will be the beginning of the road to future studies in this field that may be deeper and more accurate.

2. Theoretical framework of the study

2. 1. Study Model

Figure 1 shows the model proposed by the researcher to analyze the path of the crop production index in Algeria according to the indicators that control the movement of this phenomenon, represented by the possible interactions between the most important climate variables at all; This is based on the addressed previous studies.

Figure.01. The proposed model to analyze the impact of climate change on crop production in Algeria



Source: Prepared by the researcher based on previous studies.

Clearly, the form of the model shows that there is an indirect effect of the interaction variable between average temperature and average precipitation on the crop production index variable; through the interaction variable between average temperature and carbon dioxide emissions.

There is also an indirect effect of the interaction variable between average temperature and average precipitation on the crop production index variable; carried by the variables: the interaction between average temperature and carbon dioxide emissions and the interaction between average temperature and the percentage of agricultural land to the total land area.

In addition to another indirect effect of the interaction variable between average temperature and average precipitation on the crop production index variable; carried by the following variables: the interaction between average temperature and carbon dioxide emissions and the interaction between average temperature and the percentage of agricultural land to the total land area and the interaction between the percentage of agricultural land to the total land area and carbon dioxide emissions.

2. 2. Study variables

In this model we have five basic variables, which are: the interaction between average temperature and average precipitation; the interaction between average temperature and carbon dioxide emissions; the interaction between average temperature and the percentage of agricultural land to the total land area; The interaction between the ratio of agricultural land to total land area and carbon dioxide emissions; Crop production index.

This model was based on the interactions between the basic variables controlling climate change; since most of these variables did not affect the crop production index individually, but rather their interactions clearly do affect and it is shown from the statistical program outputs.

2. 2. 1. *Average temperature (degrees Celsius)*: The daily average is calculated by taking the sum of the highest temperature (which usually occurs at 2:00 pm) and the lowest temperature (which occurs around 4:00 am), then dividing it by two. Then we calculate the monthly average by taking the sum of the daily averages during the month, then dividing it by the days number of that month. Finally, we calculate the annual average by taking the sum of the monthly averages of temperature and dividing it by twelve. (trading Economics, s.d.)

2. 2. 2. *Average precipitation (mm)*: The indicator provides the average annual precipitation over a long period (over time and space) in a country. Precipitation is defined as any type of water that falls from clouds in liquid or solid form (rain, snow, or hail). (trading Economics, s.d.)

2. 2. 3. *Proportion of agricultural land to total land area (%)*: This indicator gives the proportion of arable land under permanent crops or covered by permanent pastures. According to the FAO definition, arable land includes land under temporary crops (double-cropped areas are counted once), temporary meadows for harvesting or grazing, flower and vegetable gardens, and land in fallow. This indicator excludes land left behind due to shifting cultivation. Lands planted with permanent crops are presented in land planted with crops that cover the land for long periods and do not have to be planted after each harvest, such as cocoa, coffee, and rubber. This category includes land under flower plants, fruit trees, walnuts, and vines, with the exclusion of land planted with trees for wood production. Permanent pasture is land used for five years or more to provide fodder, including natural or cultivated crops. (trading Economics, s.d.)

2. 2. 4. *Carbon dioxide emissions (kilotonnes)*: Mainly comes from burning fossil fuels and cement manufacturing; in addition to those released during the consumption of solid, liquid and gaseous fuels and gas flaring. (Statista, s.d.)

2. 2. 5. *Crop Production Index (2014-2016=100)*: This index shows agricultural production per year relative to the base period 2014-2016; it includes all crops except forage crops. Total areas and total income groups are calculated for the purpose of FAO production indicators from core values in international dollars adjusted to correspond to the base period. (world Bank Group, s.d.)

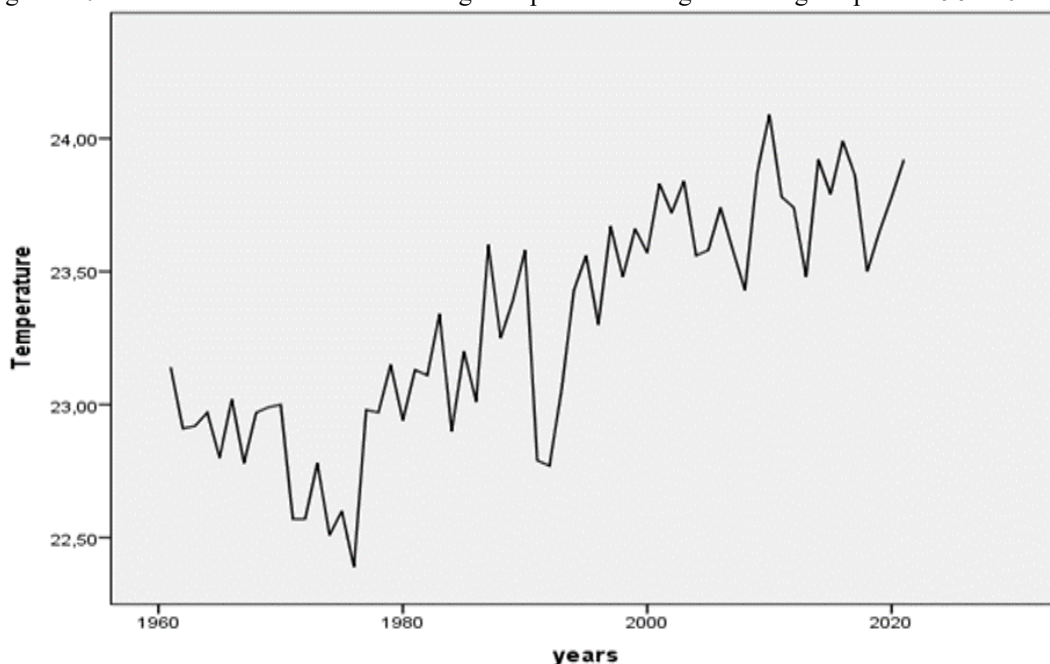
2. 3. *Study Literature:*

2. 3. 1. *Climate Change*: Climate change is defined according to the United Nations Framework Convention on Climate Change as: "A change resulting directly or indirectly from human activities that leads to a change in the composition of the global atmosphere, which is observed at similar time intervals." According to the Intergovernmental Panel on Climate Change (GIEC), it is defined as "all forms of changes that can be expressed in a statistical description, which can continue for decades, and result from human activity or from the internal interactions of the climate system components." (Rizk Allah, 2020, p. 101)

2. 3. 2. *Evolution of temperatures*: The average annual temperature in Algeria increased from

23.14 °C in 1961 to 23.92 °C in 2021, an increase of 3.37%. This illustrates an undeniable trend regarding the rise in temperatures in the region. See the figure below.

Figure.. 2. The evolution of the annual average temperature in Algeria during the period 1961-2021



Source: Prepared by the researcher based on World Bank data.

Clearly, from the figure above the annual average temperature has fluctuated significantly during the study period. With some recorded ups or downs sometimes. In fact, the highest average temperature was recorded in 2010, equivalent to 24.09 degrees Celsius.

2. 3. 3. Evolution of the precipitation rate: The average annual precipitation in Algeria decreased from 64.84 mm in 1961 to 61.96 mm in 2021; i.e. a decline rate of 4.45%. This shows the precipitation rate decrease in the region; not to mention the severe fluctuations recorded within this indicator during the study period. See the figure below.

Figure. 3. Evolution of the annual precipitation rate in Algeria during the period 1961-2021



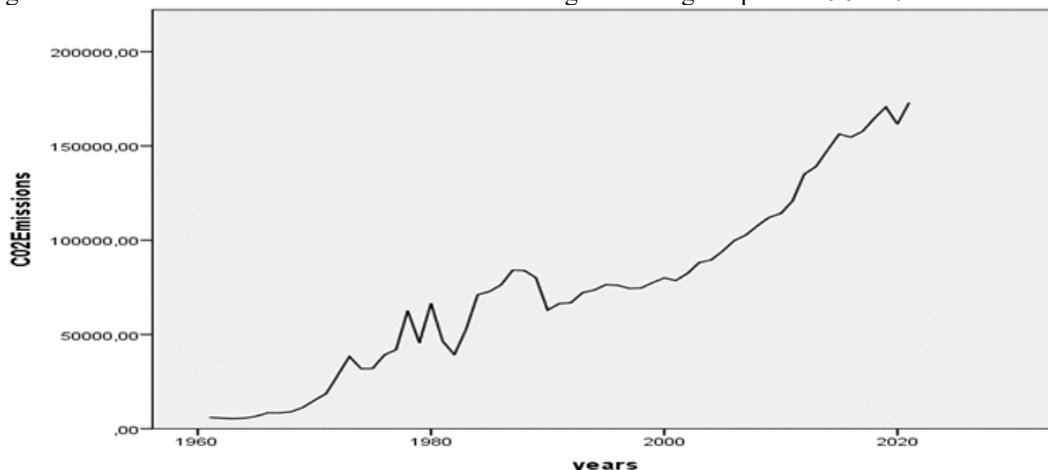
Source: Prepared by the researcher based on World Bank data.

It is clear from the figure above that the rainfall rate in Algeria has fluctuated sharply

during the study period. With many jumps from year to year, up and down. In fact, the lowest rainfall rate was recorded in 1983, equivalent to 51.68 mm; and the highest rainfall rate was recorded in 1976, amounting to 121.6 mm.

2. 3. 4. Evolution of CO₂ emissions: CO₂ emissions in Algeria have increased sharply, from 6065 kilotons in 1961 to 173000 kilotons in 2021; i.e. a very large growth rate of 2752.43%. This indicates the seriousness of the situation regarding this indicator, which is constantly increasing in an unacceptable manner. See the figure below.

Figure. 4. Evolution of carbon dioxide emissions in Algeria during the period 1961-2021



Source: Prepared by the researcher based on World Bank data.

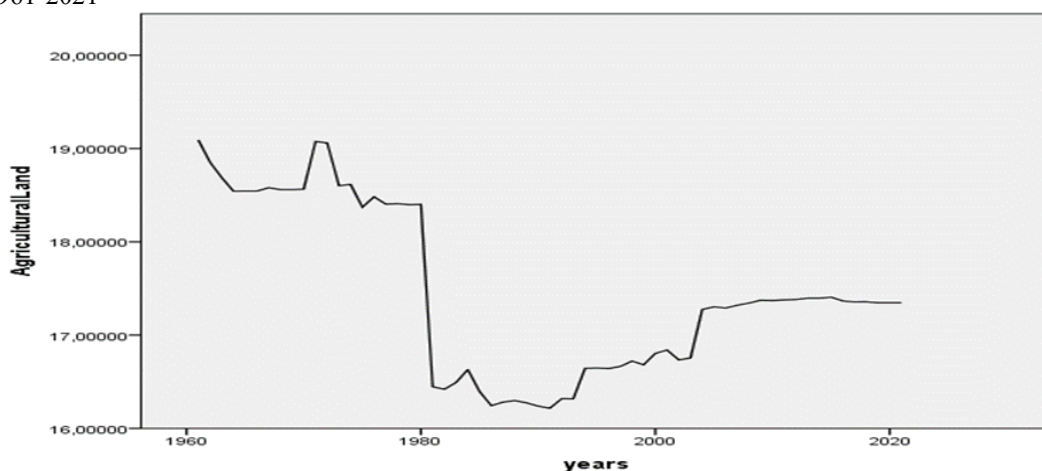
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Clearly, from the figure above CO₂ emissions in Algeria have witnessed a serious development during the study period. In fact, the highest rate was recorded in 2021, equivalent to 173,000 kilotons.

2. 3. 5. Evolution of the ratio of agricultural land to the total land area: Noticeably, the ratio of agricultural land to the total land area in Algeria has decreased, from 19.09% in 1961 to 17.35% in 2021. Unfortunately, this may negatively affect crop production. See the figure below.

Figure. 5. Evolution of the ratio of agricultural land to the total land area in Algeria during the period 1961-2021



Source: Prepared by the researcher based on World Bank data.

Clearly, from the figure above the ratio of agricultural land to the total land area in Algeria has decreased starting in 1981; to remain at the same state until 2003; then

witnessing a slight development during 2004, to remain almost constant throughout the period 2004-2021.

2. 3. 6. *The relationship between climate change and crop productivity*: Despite technological and scientific progress in the field of agriculture, weather remains the main factor affecting agricultural production; in addition to the size and quality of available natural resources such as fertile soil suitable for agriculture and fresh water for irrigation. (Arhim, 2-3-2022, p. 7)

The relationship between agriculture and climate change is two-fold. On the one hand, industrial food systems consume about 30% of the world's total energy based on fossil fuels; These systems also rely on chemical fertilizers, pesticides, herbicides and non-therapeutic antibiotics; and an important branch of agriculture, livestock farming, uses about 80% of the world's agricultural land for animal feed and grazing, which is responsible for 18% of greenhouse gas emissions. All of this contributes to the problem of climate change. In the other hand, agricultural crops are not able to withstand extreme weather events; which are becoming more violent and threatening agricultural activity and global food security. (Reza & Sabau, 2022, p. 100406)

The impact of climate change on crop production is due to the fact that each crop has a basic temperature for vegetative growth at the beginning of plant growth, as well as an optimum temperature range at which the plant develops rapidly. High temperatures also have a negative impact at the flowering stage on pollen viability, fertilization and grain filling, reducing crop production potential; over time and with rainfall variability, the impacts on agriculture may become more severe. (Al-Zuraiqat, 2022, p. 383)

3. The applied framework of the study

3. 1. Study community and sample

The five study indicators movement was monitored by adopting an annual time series for the period 1961-2021; the study sample consisted of 61 years; see Appendix No. 1.

3. 2. Study Model Test

3. 2. 1. *Determining the model*: The table below shows the model identification indicators, which are: the number of distinct sample moments; the number of distinct parameters to be estimated and the degree of freedom.

Table.1. Determining the model: Computation of degrees of freedom (Default model)

Number of distinct sample moments:	15
Number of distinct parameters to be estimated:	11
Degrees of freedom (15 - 11):	4

Source: Prepared by the researcher, based on the outputs of the AMOS program.

From the above table, it is clear that the model is highly specific (considering that the degree of freedom is greater than 0). Accordingly, we will move to the phase of model fit test.

3. 2. 2. *Model fit test*: The model fit will be tested based on the significance level χ^2 (the extent of match between the proposed model and the sample data); then the absolute fit test (the extent of match between the proposed model and the ideal model); then the relative fit test (the extent of match between the proposed model and the null model); and finally, the strict fit index test (very parsimonious).

Table.2. χ^2 test: Result (Default model)

Minimum was achieved
Chi-square = 9,493
Degrees of freedom = 4
Probability level = ,050

Source: Prepared by the researcher, based on the outputs of the AMOS program.

Unlike traditional statistic that looks for a significance level less than (5%), as for this stage of the test we look for a significance level greater than or equal to 0.05 (we want to reach that there are no differences between the covariance matrix of the proposed model and the other of the study data). It is clear here that the significance level was equal to 0.05. Accordingly, it can be judged that the study model was somewhat identical to the sample data.

Table. 3. Test of absolute and relative conformity

Category :	Indicator Name :	Index value :	Jugement :
Absolut conformity	GFI	,942	acceptable
relative (gradual) conformity	CFI	,953	good
tight conformity	CMIN/DF	2,373	acceptable

Source: Prepared by the researcher, based on the outputs of the AMOS program.

Clearly, from the table above the GFI index (which was adopted in the absolute fit test) was acceptable; as it was indicating that the study model was somewhat identical to the ideal one. The CFI index (which was used to test the relative fit) was also good; as it confirmed that the study model was far from the null model. As for the firm fit index CMIN/DF, it was acceptable, which means the acceptance of the variables and the model in general.

3. 2. 3. *Testing the direct effect hypotheses:* The table below displays the outputs of the AMOS program on testing the statistical significance of the direct relationships included in the model. This was done according to a significance level of 0.05.

Table.4. Analysis of direct effects: Regression Weights: (Group number 1 - Default model)

		Estimate	S.E.	C.R.	P	Label
tem_CO2	<--- tem_pre	-,285	,087	-3,259	,001	Statistically significant
land_tem	<--- tem_CO2	-,407	,135	-3,022	,003	Statistically significant
land_CO2	<--- land_tem	,593	,083	7,120	***	Statistically significant
CropProductionIndex	<--- tem_CO2	31,920	3,210	9,944	***	Statistically significant
CropProductionIndex	<--- land_tem	11,197	3,769	2,970	,003	Statistically significant
CropProductionIndex	<--- land_CO2	15,028	4,136	3,634	***	Statistically significant

Source: Prepared by the researcher, based on the outputs of the AMOS program.

Clearly, from the table above the six direct effects included in the model were statistically significant at a significance level of 0.05.

Table. 5. Testing the direct effect hypotheses

Hypothesis	Hypothesis text	P-Value	Judgment
H1	tem_pre has a direct impact on tem_CO2	,001	Proven
H2	tem_CO2 has a direct impact on land_tem	,003	Proven
H3	land_tem has a direct impact on land_CO2	***	Proven

H4	tem_CO2 has a direct impact on CropProductionIndex	***	Proven
H5	land_tem has a direct impact on CropProductionIndex	,003	Proven
H6	land_CO2 has a direct impact on CropProductionIndex	***	Proven

Source: Prepared by the researcher, based on the outputs of the AMOS program.

Clearly, from the table above the six hypotheses of the study, which state that there are direct relationships between the study indicators, are valid at a significance level of 0.05.

Table.6. Direct effects: Standardized Direct Effects (Group number 1 - Default model)

		R
tem_CO2	<--- tem_pre	-,388
land_tem	<--- tem_CO2	-,363
land_CO2	<--- land_tem	,677
CropProductionIndex	<--- tem_CO2	,784
CropProductionIndex	<--- land_tem	,308
CropProductionIndex	<--- land_CO2	,362

Source: Prepared by the researcher, based on the outputs of the AMOS program.

Clearly, from the table above some of the six direct effects were positive (direct relationship between the two variables under observation) and some of which were negative (inverse relationship between the two variables under observation). Some of these effects were strong and others were moderate, as shown by the correlation coefficient values.

Table.7. Indirect effects: Standardized Indirect Effects (Group number 1 - Default model)

		R
land_tem	<--- tem_pre	,141
land_CO2	<--- tem_pre	,095
CropProductionIndex	<--- tem_pre	-,226
land_CO2	<--- tem_CO2	-,246
CropProductionIndex	<--- tem_CO2	-,201
CropProductionIndex	<--- land_tem	,245

Source: Prepared by the researcher, based on the outputs of the AMOS program.

Clearly, from the table above some of the six indirect effects were positive (direct relationship between the two variables under observation) and some of which were negative (inverse relationship between the two variables under observation). Most of these effects were moderate, while some were weak, despite the stability of the significance of the correlation coefficient.

Table.8. Coefficient of determination: Squared Multiple Correlations (Group number 1-Default model)

	Estimate
Crop Production Index	,677

Source: Prepared by the researcher, based on the outputs of the AMOS program.

Clearly, from the table above the model indicators were able to explain about 67.7% of the movement of the crop production index variable; through this model.

4. Conclusion

This study has concluded that the six hypotheses that stating the existence of direct influence relationships included in the model were valid. At a significance level of 0.05. Accordingly, it can be said that crop production was mainly affected by: the interaction between average temperatures and average precipitation; the interaction between average temperatures and carbon dioxide emissions; the interaction between average temperatures

and the ratio of agricultural land to the total land area and the interaction between carbon dioxide emissions and the ratio of agricultural land to the total land area.

It is noticeable that the average temperatures were a primary catalyst for three interactions that controlled the path of the agricultural crop production index in Algeria. Knowing that some of these interactions had a positive (direct) effect and some had a negative (reverse) effect on crop production.

The study results also showed that proposed model indicators (represented by: climate changes in the form of interactions between the most important factors controlling the climate) were able to explain about 67.7% of the movement of the crop production index. Accordingly, it can be said that the proposed model to analyze the path of the crop production index in Algeria, according to the most important possible interactions between the most important factors controlling the climate; was largely acceptable.

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6. Appendices

Appendix .1. Movement of study variables During the period 1961-2021 in Algeria

Years	Precipitation	Temperature	Crop Production Index	Agricultural Land	CO2 Emissions
1961	64,84	23,14	28,93	19,09	6065
1962	98,74	22,91	30,88	18,85	5669
1963	97,82	22,92	31,39	18,69	5427
1964	86,99	22,97	27,2	18,54	5651
1965	82,39	22,8	31,35	18,54	6597
1966	82,42	23,02	19,15	18,54	8430
1967	87,52	22,78	21,36	18,58	8441
1968	78,7	22,97	28,35	18,56	9061
1969	104,59	22,99	25,54	18,56	11276
1970	63,56	23	26,33	18,56	15075
1971	95,81	22,57	27,12	19,08	18669
1972	100,82	22,57	23,7	19,06	28350
1973	87,52	22,78	21,77	18,6	38313
1974	84,18	22,51	23,53	18,61	31907
1975	87,6	22,6	26,4	18,37	32031
1976	121,6	22,39	23,68	18,48	39171
1977	73,49	22,98	17,67	18,4	41892
1978	70,64	22,97	17,85	18,41	62530
1979	103,26	23,15	20,87	18,4	45621
1980	95,82	22,94	22,93	18,4	66519
1981	61,75	23,13	23,2	16,45	46439
1982	101,37	23,11	18,67	16,42	39270
1983	51,68	23,34	19,2	16,49	52625
1984	81,73	22,9	21,27	16,63	71103
1985	84,22	23,2	28,76	16,4	72786
1986	103,99	23,01	28,9	16,24	76277
1987	79,43	23,6	27,39	16,28	84121
1988	80,26	23,25	23,85	16,3	83949
1989	71,58	23,39	27,55	16,27	80047
1990	93,99	23,58	24,79	16,24	62937
1991	87,61	22,79	33,05	16,22	66429
1992	90,88	22,77	35,92	16,32	66845
1993	65,96	23,06	32,03	16,32	72219
1994	86,58	23,43	27,54	16,64	73606
1995	83,76	23,56	33,02	16,65	76440
1996	99,31	23,3	43,26	16,64	76124

1997	94,2	23,67	30,82	16,66	74433
1998	70,55	23,48	36,34	16,72	74649
1999	98,12	23,66	39,35	16,68	77505
2000	60,79	23,57	30,95	16,8	80047
2001	68,06	23,83	36,67	16,84	78646
2002	71,21	23,72	37,64	16,73	82404
2003	107,72	23,84	49	16,75	88189
2004	97,67	23,56	54,54	17,28	89493
2005	73,31	23,58	55,85	17,3	94188
2006	93,24	23,74	59,16	17,29	99809
2007	90,24	23,58	51,52	17,32	102750
2008	83,53	23,43	52,87	17,34	107746
2009	93,89	23,87	72,36	17,37	112172
2010	95,86	24,09	74,96	17,37	114179
2011	97,61	23,78	83,53	17,38	120785
2012	86,41	23,74	88,72	17,38	134934
2013	89,82	23,48	98,82	17,4	139024
2014	77,52	23,92	94,93	17,4	147735
2015	80,02	23,79	101,74	17,41	156273
2016	69,56	23,99	103,33	17,37	154654
2017	78,31	23,86	104,4	17,36	157704
2018	95,1	23,5	115,36	17,36	164534
2019	78,64	23,65	121,01	17,35	170582
2020	60,66	23,78	120,95	17,35	161563
2021	61,96	23,92	108,76	17,35	173000

Source: <https://tradingeconomics.com>
<https://data.worldbank.org>
<https://www.statista.com>