

The effects of climate change on fig tree yield in Bejaia

آثار تغير المناخ على محصول أشجار التين في بجاية

Bensmail Salem^{1*}

¹University of Bejaia (Algeria), salem.bensmail@univ-bejaia.dz

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Abstract:

The main objective of this research paper is to assess the impact of climate change on fig trees' yield in Bejaia, from 1996 to 2022, using an Autoregressive Distributed Lag (ARDL) model. This study analyzes how climate variables such as temperature and precipitation affect the yield of fig trees in the region. The results of this study highlight the negative impact of climate change on fig tree yield in the long term. An increase in temperature of 1C° leads to a decrease in fig tree yield of 12.31891 kg/tree, while an increase in precipitation of 1 mm leads to an increase in fig tree yield of 3.703809 kg/tree.

Keywords: climate change; agriculture; fig trees; ARDL; Bejaia.

Jel Classification Codes: C13; Q19; Q54.

*Bensmail Salem

Introduction:

Climate change is an unavoidable fact and a crisis facing humankind as a whole. Common sense, it is considered one of the most serious and complex problems facing the world today. The planet is being severely unsettled to the point that our survival as a species is at stake.

We see that Climate change is already having an effect on the frequency, intensity and duration of extreme weather events (droughts, heat waves, storms and floods) These are already affecting agriculture in troubling ways (NOAA, 2021).

«Agriculture is better known to be one of the most affected sectors due to climate change. Agricultural production is strongly influenced by meteorological and climatic factors such as temperature, precipitation and wind speed. Climate change affects crop production possibly leading to lower yield and destruction of crops in extreme cases, thereby threatening the functioning of agricultural production systems»(Raza, 2024).

The analysis of the relationships between climatic parameters such as temperatures and precipitation, and their impact on fig yields, is essential for understanding and predicting the effects of climate change.

Temperature significantly affects the phenological cycle of fig trees, directly influencing growth, flowering, and fruit maturation. Meanwhile, precipitation plays a vital role in ensuring water availability, a determining factor for the thriving of fig trees in Béjaia's semi-arid climate. Gaining a deeper insight into these interactions is fundamental not only to assess the effects of climate change more accurately but also to develop effective adaptation strategies aimed at sustaining fig production in this region.

Our problem revolves around the following main question: "What are the effects of climate change on fig tree yields in Bejaia? From this question stems the central hypothesis: Climate change has a negative impact on fig tree yields in Bejaia. This central hypothesis is followed by two secondary hypotheses:

H1- Fig tree yields are negatively impacted by increased temperatures.

H2- Increased precipitation has a positive impact on fig yield.

The main objective of this article is to assess the impact of climate change on fig yields in the Béjaia region of Algeria. To achieve this overarching goal, several specific axes are explored:

- Identify variations in temperature and precipitation over a given period in the Béjaia region.
- Study the interactions between climatic variables (temperatures and precipitation) and the yield of fig trees.
- Understand the consequences of climate change on fig production and propose adaptation strategies for local farmers.

To analyze the impact of climate change on fig yields in the Béjaia region, a quantitative approach was adopted using the ARDL (Autoregressive Distributed Lag) econometric model. This methodology allows for the examination of dynamic short-term and long-term relationships between climatic variables (temperatures and precipitation) and fig yields.

The data used cover the period from 1996 to 2022 and include annual observations of agricultural yields as well as climatic parameters collected from reliable sources. The choice of the ARDL model is based on its ability to handle integrated time series while providing a robust analysis of causal relationships in both the short and long term.

I-Climate change, its causes and consequences:

There is no country that is immune to climate change. They are one of the primary threats to the livelihoods of large portions of the global population, particularly in developing countries. *«It is predicted that in the medium term, climate change will contribute to an increase in poverty and food insecurity among the world's population, through accentuated environmental degradation,*

overexploitation of natural resources and intensification of natural disasters. Future conflicts and wars could be linked to climate change» (Renner, 2002).

Climate Change is at the forefront of global challenges. In order to appreciate the international attention to this problem, it is necessary to have a basic understanding of what climate change really is, what lies behind it, and its wide-ranging ramifications.

I-1- Definition of climate change:

The literature offers various definitions of climate change. Below is a summary of these definitions.

In 1992, the UNFCCC defined climate change as *«changes in climate which are attributed directly or indirectly to human activity that alters the composition of the global atmosphere, and which are in addition to natural climate variability observed over comparable time periods»*. For O'Brien, *«climate change is a natural phenomenon that is accelerated by man's anthropogenic actions»* (O'Brien , O'Keefe, Rose, & Wisner, 2006). *«Climate change manifests itself through variations in weather conditions, notably temperature, precipitation and wind»* (Tompkins & Adger, 2004).

Climate change is defined as *«a statistically significant variation in the mean state of the climate or its variability, persisting over an extended period of several decades. It is the cumulative result of internal variability within the climate system and external natural and anthropogenic factors»* (Gaye & Sylla , 2009).

For the IPCC (Intergovernmental Panel on Climate Change), the term "climate change" refers to *«any change over time, whether due to natural variability or human activities»*. In the United Nations Framework Convention on Climate Change, *«on the other hand, the term refers only to changes due to human activities. The term "climate variability" is used to designate naturally occurring climate changes»*(UNITED NATIONS, 2018).

Global warming, also known as planetary warming, or global warming, *«is a phenomenon of rising average ocean and atmospheric temperatures, measured on a global scale over several decades, and reflecting an increase in the amount of heat on the earth's surface»* (Mangenet , 2013).

I-2- Causes of climate change:

«Climate change results primarily from greenhouse gas (GHG) emissions produced by human activities, which significantly modify the earth's atmospheric composition. Alongside these anthropogenic emissions, natural climate variations also play a role. Estimates suggest that natural factors, including fluctuations in solar radiation and volcanic activity, have contributed to less than 0.1°C of the overall increase in global temperatures»(WMO & UNEP, 2021).

«This phenomenon enables us to maintain average temperatures of 15°C on our planet. Without it, the temperature would be around -18°C, which would not support life as we know it»(HUFTY, Introduction à la climatologie, 2001).

The main greenhouse gases are carbon dioxide (CO₂), nitrous oxide (N₂O), methane (CH₄) and fluorinated gases.

Table n°1: The main greenhouse gases

Gas	CO ₂	CH ₄	N ₂ O	CFC, HFC, SF ₄
Contribution	69,9 %	12,4 %	12,4 %	2,2 %

Source: (FENNI & MACHANE , 2010)

«The method that each greenhouse gas contributes to the greenhouse effect varies. In reality, they have different global warming potentials (GWPs) and atmospheric lifetimes. The GWP is a representation of the gas's capacity to retain heat and release it back to the earth. The GWP of GHGs is calculated by comparing them to the GWP of CO₂, the reference gas. CO₂-equivalent (CO_{2e}), according to GWP, is a measure of GHGs that makes it possible to compare the effects of each GHG. For example, for the same amount of warming, N₂O warms the atmosphere 310 times more than CO₂ and 21 times more than CH₄. Therefore, for every kilogram of N₂O released, 310 kilograms of CO₂ are created»(United Nations, 2004).

The average residence time of GHGs (CO₂ 500 to 200 years, CH₄ 12 years, and N₂O 114 years) is represented as residence time in the atmosphere. It is evident that the greenhouse gas emissions of today will continue to contribute to climate change for decades, if not centuries.

«The development of modern human activities, including transport, industry, deforestation and agriculture, is responsible for massive GHG emissions. The concentration of these three gases has increased considerably since the industrial era: by 35% for CO₂, 148% for CH₄ and 18% for N₂O»(MDDEP, 2010). This imbalance is modifying the earth's surface temperatures, causing numerous environmental impacts.

Table n°2: Contribution of human activities to greenhouse gas emissions

Human activities	Transport	Industry	Buildings	Agriculture	Energy	Waste and others
Contribution	27 %	21 %	20 %	16 %	13 %	04 %

Source: (FENNI & MACHANE , 2010)

«Sixteen percent (16%) of greenhouse gas emissions come from agriculture. It generates 50% of CH₄ emissions, which are linked to the anaerobic fermentation of plant matter (as in rice paddies) and ruminant digestive processes, and 75% of N₂O emissions, mostly from the transformation of nitrogen compounds in the soil. A portion of the CO₂ contained in the soil is released into the atmosphere during the breakdown of organic materials. Currently, more than 60% of the greenhouse effect is caused by carbon dioxide»(Gupta & Kumar , 2021).

The following are the reasons why greenhouse gas emissions are rising:

- Burning coal, oil, and gas produces nitrous oxide and carbon oxide;
- Deforestation or the clearing of forests. Because they collect carbon oxide (CO₂) from the atmosphere, trees aid in climate regulation;
- An increase in the production of livestock. When cattle and sheep digest their food, they release a lot of methane;
- Nitrogen containing fertilizers generate emissions of nitrous oxide
- Equipment and product that uses fluorinated gases emit these gases.

«Numerical models established by the scientific community agree that the increase in GHGs will cause climate change, which will mainly translate into an average warming of 1.6 to 6 degrees by 2100» (NEFZI, 2012). Already rainy regions will see heavier rains, while less-watered areas will experience more intense droughts. In addition, these models predict a significant increase in extreme events such as floods, droughts, heat waves and strong winds.

I-3- Consequences of climate change:

According to the IPCC report (2001), «the impact of climate change encompasses the effects of extreme weather and climate events on both natural and human systems. These impacts typically

involve the repercussions of climate change on lives, livelihoods, health, ecosystems, societies, cultures, services, and infrastructures»(IPCC, 2021).

Climate change has a significant impact on the environment, the planet, and the people who inhabit it in a variety of ways. This issue poses a serious threat, and its repercussions have far-reaching effects on numerous aspects of our lives:

- ✓ The planet's temperature is rising more quickly due to global warming;
- ✓ sea and ocean levels are rising, in part because of the melting of polar ice caps;
- ✓ Zones of salinization are produced by rising sea levels, as seawater moves inland and progressively reaches the water table;
- ✓ alterations in rainfall patterns
- ✓ Increased occurrence and severity of storms, hurricanes, and cyclones; heightened occurrence and intensity of floods and droughts;
- ✓ A considerable drop in water levels in large lakes, due to greater evaporation;
- ✓ Increased food and water crises, particularly in developing countries;
- ✓ Causes migratory flows (climate refugees);
- ✓ Continued warming will amplify the thawing of permafrost and loss of seasonal snow cover, the melting of glaciers and ice caps, and the shrinking of Arctic sea ice;
- ✓ Coastal areas will face rising sea levels throughout the 21st century, which will increase the frequency and severity of flooding in low-lying areas and accentuate coastal erosion;
- ✓ Changes in the oceans, including acidification and oxygen depletion;
- ✓ Risk to livelihood from forest fires and floods;
- ✓ Health hazards brought on by heat waves occurring more frequently and with greater severity (increased respiratory disorders including asthma, skin cancers, sicknesses, and deaths due to high heat);
- ✓ Economic repercussions as a result of removing climate-related effects;
- ✓ The spread of illnesses and pests;
- ✓ Biodiversity loss as a result of plants and animals' slow and limited ability to adapt.

II-Impact of climate change on agriculture:

«In many areas, different agricultural sectors; including crop production, livestock farming, fisheries, aquaculture, and forestry; are facing the consequences of climate change. As the effects of climate change intensify, maintaining traditional farming practices and locations will become progressively more difficult»(Singh, 2017).

II-1- Effects on crop yields:

Climate change exerts a profound influence on agriculture, presenting both beneficial and detrimental effects on various crops across different regions. Increased temperatures can lead to substantial declines in crop yields while also fostering conditions conducive to the proliferation of pests and weeds. Additionally, changes in precipitation patterns not only heighten the immediate risk of crop failures but also contribute to long-term reductions in agricultural productivity.

«Plants can only thrive in conditions conducive to their growth, be it optimal temperatures, or a sufficient supply of water» (FAO, Changement Climatique, Agriculture et Sécurité Alimentaire, état de l'alimentation et de l'agriculture., 2016, p. 05). The increasing frequency of extreme events, particularly floods and droughts, is a factor that affects crops and reduces their yields.

On a global scale, *«climate change has led to a reduction in global average yields of maize, wheat, and soybeans. The reduction in global average yields was 4.1% for maize, 1.8% for wheat, and 4.5% for soybeans between 1981 and 2010. These percentages are in comparison with the pre-*

industrial climate» (Iizumi , 2018). «Over the past few years, the production of essential crops like maize, wheat, sorghum, and fruit crops such as mangoes has decreased in Africa»(Ketiem, Makeni, & Maranga, 2017). «Climate change is affecting European crop yields, with long-term trends in temperature and precipitation since 1989 reducing continent-wide wheat and barley yields by 2.5% and 3.8% respectively, and slightly increasing maize and sugar beet yields. Although these overall effects appear small, the impacts are not evenly distributed» (Moore & Lobell , 2015).

Climate change alters the quality of fruit, vegetables and legumes, affecting their taste, shape and nutritional value (less crunchy apples, more acidic grapes, more bitter lettuce, etc.).

II-2- Effects on livestock farming:

Heat waves are expected to become more common due to climate change, posing a direct threat to livestock farming. *«As animals experience heat stress over time, their vulnerability to disease increases, leading to lower fertility and reduced meat and milk production. Furthermore, climate change will affect the prevalence of parasites and diseases in livestock» (FAO, Changement Climatique, Agriculture et Sécurité Alimentaire, état de l'alimentation et de l'agriculture., 2016, p. 06).*

«Climate change threatens the sustainability of grasslands and rangelands, impacting forage production for livestock in non-grazing systems. In pastoral systems, the effects of climate change are evident through the reduction of available rangelands, restricted mobility, declining livestock populations, overgrazing, land degradation, and conflicts over access to grazing areas»(Tugjamba, Walkerden, & Miller, 2023).

II-3- Effects on fishing and aquaculture:

«The fishing and aquaculture industries are under significant pressure from various factors, including overfishing, water pollution, and habitat destruction. These challenges are likely to worsen as a result of climate change. Rising water temperatures are expected to lead to the extinction of certain fish species and increases the risk of diseases throughout the production chain»(Ahmed, Thompson, & Glaser, 2019).

II-4- Effects on forests:

«Forests are vital for many communities, offering employment, sustenance, medicinal resources, and fuel. Climate change significantly affects forests, leading to both direct and indirect consequences for those who depend on them. This disruption threatens the forests' capacity to provide these essential resources and services»(Seydewitz, Pradhan , & Landholm, 2023).

III-Methodology:

To check if climate change is influencing the levels of agricultural production in general and fig in particular in the wilaya of Bejaia, we opted for the distributed lag autoregressive model (ARDL) which is the most appropriate method for performing this study.

Climate change is a complex, multi-dimensional event that cannot be measured directly, which is why scientists are using a range of indicators; precipitation, temperature, wind speed, CO2 emissions and more; to quantify it. The aim of this study is to capture the impacts of climate change, measured by mean annual temperature (temp) and mean annual precipitation on fig tree yield (r_fig) in Bejaia, using annual data from 1996 to 2022.

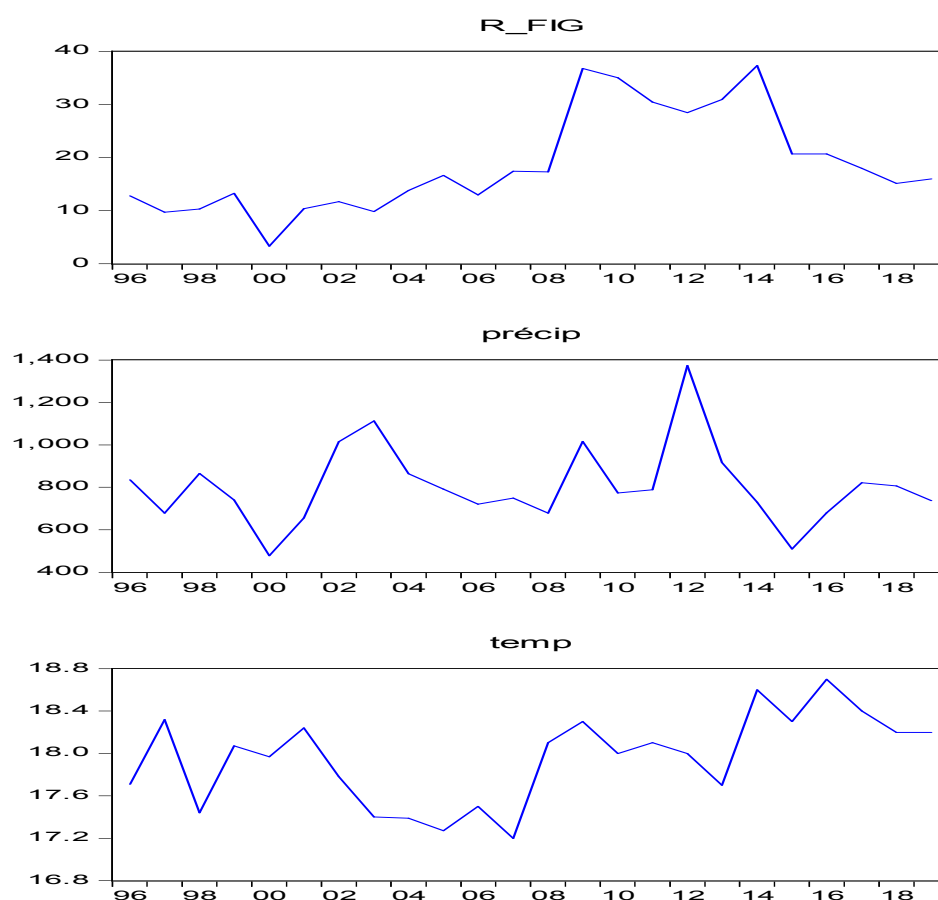
III-1- Graphical representation of model variables:

The graphical representation of econometric data is essential to highlight their evolution. In Bejaia, meteorological observations are already showing tangible signs of the impacts of global climate change.

Bejaia is located in the Mediterranean region of Algeria. The region's climate varies significantly from one zone to another. Bejaia's coastal zone is rainy and mild in winter, and dry and hot in summer. Mountainous areas are characterized by rainy, cold winters and hot, dry summers.

Climate change is threatening agricultural production in this region. Below, we outline the changes in fig tree yields alongside climatic factors, including annual rainfall and temperatures, from 1996 to 2022.

Figure n°1: Graphical representation of model variables



Source: Compiled by the author using EVIEWS software

The variables in this model are represented graphically in figure n°1. The fig yield curve (r_fig) shows a remarkable evolution in yield from 1996 to 2022. The highest yield was recorded in 2014 with a value of 36.76 kg/tree, the lowest yield was observed in 2000 with 3.27 kg/tree.

The mean annual temperature ($temp$) in Bejaia fluctuated erratically between 1996 and 2022. The highest temperature was 18.7°C in 2016 and the lowest was 17.2°C in 2007.

Average annual precipitation (prec) in Bejaia varied over the period 1996 to 2022, with the highest amount recorded in 2012 at 1373.41 mm.

III-2- Econometric study of the impact of climate change on fig yields:

«ARDL (Auto Regressive Distributed Lags) modeling is one of the most frequently recommended methods in econometrics for time series analysis. The primary advantage of this model is its ability to explore long term dependences among economic variables, It convey the long-term impact of exogenous (independent) variable on the endogenous (dependent) variable, while allowing for short-run adjustments . With the incorporation of autoregressive features and those of staggered lag models, the flexible structure underlying this model provides an autonomously validated approach for time series econometric analysis»(Dhrifi , Alnahdi, & Jaziri, 2021).

This study specifies an ARDL model where the fig tree yield variable (r_fig) is the endogenous variable and the climate variables (mean annual precipitation (prec) and mean annual temperature (temp)) are exogenous variables over the period 1996-2022.

We present the econometric analysis of the impact of climatic variables on fig tree yield in Bejaia, and to do so, we will study the stationarity of the variables, establish the cointegration test, estimate the long-run and short-run relationship and finally check the robustness and validity of the model.

Thus, we present an ARDL model for the following simple function:

$$R_fig = C + \beta_1 temp + \beta_2 prec + \mu$$

R_fig : Fig tree yield in kg/tree

Temp: Annual temperature in C°.

Prec: Annual precipitation in mm

C : Constant

β : Coefficients of explanatory variables

μ : Error term.

III-2-a-Stationarity test:

We employed the DickyFullarstationarity test (ADF) to determine whether our time series was stationar.

Table n°3: Contribution of human activities to greenhouse gas emissions

Variables	Stationnarité				
	ADF			Niveau	Résultat
	T-Statistic	Probabilité	modèle		
R_fig	-4.446654	0.0085	Trend and intercept	I(1)	Stationnaire
Temp	-2.187995	0.0023	intercept	I(0)	Stationnaire
Préc	-3.459871	0.0314	Intercept	I(0)	Stationnaire

Source: Compiled by the author using EViews software

The result of this test revealed that the dependent variable (R_fig) is stationary at first difference, while the independent variables Temp and Préc are stationary at level. This supports the use of the ARDL model, and makes the boundary cointegration test appropriate.

III-2-b-Boundary co-integration test:

The existence of co-integration between variables is ascertained using the boundary co-integration test. Its foundation is a comparison between the Fisher critical value of the two boundaries for each significance level and the Fisher statistics.

Table n°4: Boundary cointegration test

Null hypothesis: No levels relationship	
Test Statistic	Value
F-statistic	17.234620

Critical value						
10%			5%		1%	
Sample Size	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
30	4.427	4.957	5.377	5.963	7.593	8.350
Asymptotic	4.050	4.490	4.680	5.150	6.100	6.730

Source: Compiled by the author using EVIEWS software

The Fisher statistic (F of the ARDL test) is 17.234620, exceeding the upper bound of the critical values for all levels of significance. Thus, the null hypothesis of non-cointegration is rejected at 95% of the confidence interval, and the alternative is accepted. This result confirms the existence of a short- and long-term relationship between the explanatory variables and the variable to be explained.

III-2-c-Estimating the long-term relationship:

Having confirmed the existence of a long-term relationship between the variables in the model, the next step is to estimate this long-term relationship using mathematical formulas.

Table n°5: Estimation of the long-term or cointegrating relationship

Variable *	Coefficient	Std. Error	t-Statistic	Prob.
PREC	3.703809	0.491438	7.536680	0.0000
TEMP	-12.31891	0.663416	-1.856891	0.0087
@TREND	0.051596	0.008195	6.295620	0.0000

Source: Compiled by the author using EVIEWS software

The long-term model's findings demonstrate a statistically significant correlation between the variable to be explained (fig yield) in Bejaia and the explanatory variables (temperature and precipitation, two components of climate change).

The annual temperature coefficient is (-12.31891), which means that there is a negative relationship between temperature and fig yield in Bejaia over the long term. This means that a 1°C rise in temperature results in a 12.31891 kg/tree decrease in fig yield. There is a complex relationship between rising temperatures and fig tree yield. Temperatures between 32 and 37 C° are favorable to fruit development and ripening. Moderate temperatures can favor shoot emergence, while low temperatures (below -1 C°) can have a negative impact on buds and ripe figs. High temperatures (over 37.7 C°) can cause fruit drop during fruit set. So the relationship depends on the temperature thresholds reached. Temperatures in our study region in recent years have been high during the fruit-setting period, so higher temperatures mean lower fig yields.

There is also a positive relationship between rainfall and fig yield (its coefficient is 3.703809). An increase in rainfall of 1 mm will increase fig yield by (3.703809) kg/tree. Rainfall plays a key role in fig tree yield, influencing growth and fruit quality. During the fruit-setting period, rainfall improves the water supply to the fruit, which in turn enhances growth and improves quality (in terms of size, flavor and texture).

The results of this study highlight the negative impacts of climate change on fig tree yields over the long term. It shows that temperature increase has a more significant impact on fig yield in the long term than rainfall variations.

The model is represented in the long term by the following formula:

$$R_fig = 3.703809 \text{ prec} - 12.31891 \text{ temp}$$

III-2-d-Model validation test:

It is necessary to check whether the model meets the conditions and assumptions of normal distribution, non-autocorrelation of errors, homogeneity of error variance and model specification.

Table n°6: Model validation test

Hypothèse	Test	T-Statistic	P-value
Auto-corrélation	BreuschGodfrey	0.486355	0.6728
Hétéroscédasticité	ARCH	1.764740	0.2016
Normalité	Jarque-Bera	0.867816	0.647972
Spécification	RamseyRest	1.286979	0.4375

Source: Compiled by the author using EVIEWS software

We can determine whether the errors are auto-correlated by using the auto-correlation test (Breusch_Godfrey). The null hypothesis that there is no autocorrelation of model errors is accepted since the associated probability is (0.6728) higher than 5%. This indicates that the errors are independent for each other. To determine if the errors are homoscedastic, the heteroskedasticity test (ARCH) is employed. The associated probability is (0.2016) greater than 5%, so the null hypothesis is accepted: the residuals are homoscedastic for the model.

The normality test (Jarque-Bera) enables us to verify the normality of the residuals. The associated probability is (0.647972) greater than 5%, which verifies the normality of the model residuals. This indicates that the model captures the variability of the data.

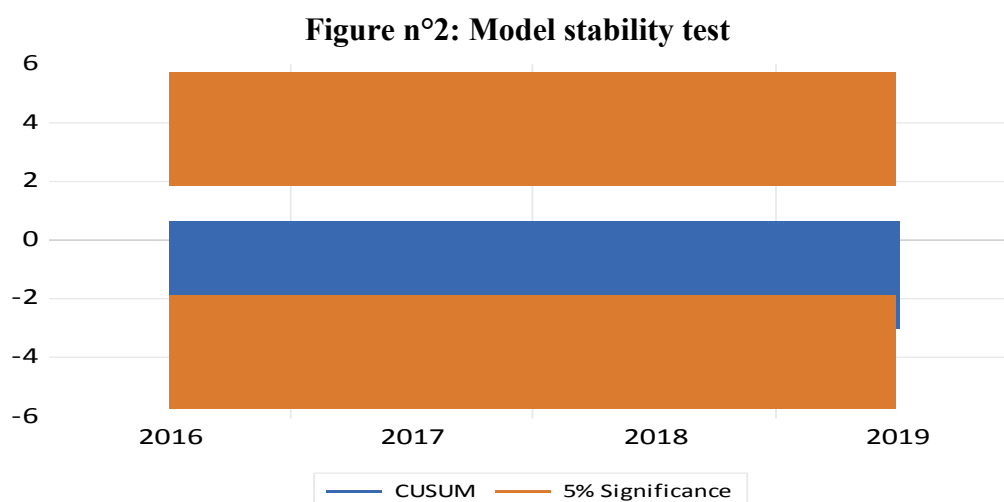
The specification test (Ramsey Rest) allows us to verify model specification. The associated probability is (0.4375) greater than 5%, so we accept the null hypothesis, i.e. the model is specified, i.e. the model structure (variables included, lags, etc.) is appropriate to represent the relationships studied.

Generalizing the results, the estimated ARDL model passes all validity tests (no autocorrelation, no heteroscedasticity and residuals are normally distributed), so the statistical

assumptions underlying the model are met. Overall, these findings suggest that the ARDL model is a good fit to the data and may be regarded as a trustworthy depiction of the relationship being studied.

III-2-e-Stability test:

Having confirmed the existence of a long-term relationship between the dependent and independent variables, we move on to testing the model's stability.



As can be seen from figure n°2, the COSUM and COSUMSQ statistics graphs stay within the critical value interval at the 5% level. This suggests that there is structural stability in the model coefficients.

Conclusion:

Climate change is profoundly affecting various regions in northern Algeria, especially the wilaya of Bejaia. The area has experienced a notable increase in average temperatures, characterized by hotter summers and milder winters. Additionally, there has been a significant decline in precipitation levels, resulting in more frequent and severe drought conditions. These climate changes have already had a detrimental effect on agriculture, and if appropriate mitigation measures are not implemented, the effects are only predicted to worsen.

This article analyzes the impact of climate change on fig tree yields In Bejaia over the period from 1996 to 2022, focusing on critical climate variables such as precipitation and temperature.

The results of this study highlight the long-term negative impacts of climate change on fig tree yields. It was found that increasing temperatures significantly affect fig production more than variations in rainfall. Specifically, a rise of 1°C in temperature corresponds to a reduction of roughly 12.32 kg per tree, while an additional 1 mm of rainfall contributes to an increase of approximately 3.70 kg per tree.

These results show the significant vulnerability of fig tree yields in the Bejaia region to the effects of climate change.

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