The impacts of climate change on agriculture sector - Case study: Mediterranean countries

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Abstract

Climate change is a complex phenomenon, and the agricultural sector is the most vulnerable to its effects since it affects negatively the food security dimensions, which are directly associated with agriculture. Climate change influences food production and inflation; the impacts have been examined in twelve Mediterranean countries. The paper was equipped with simple and advanced statistics and econometric instruments like descriptive statistics, unit root tests, ARDL (2002-2022), and forecasting models. The results show that climate change has a negative impact on the agriculture sector for many Mediterranean countries in both the current situation and future scenarios. Both temperature and CO2 emissions have a significant negative effect on food production and inflation in the selected countries. Moreover, combining climate change with a rapid increase in population growth rate will put more pressure on the agriculture sector, resulting in an increase in the percentage of POU among the people of those countries. The findings confirm the interlinkage between the sustainable development goals in SDG 3 and SDG 13.

Keywords: *Climate change, Agricultural sector, Food security, ARDL model, Sustainable development goals*

1. Introduction

Climate change is one of the main global challenges, and all countries are affected by it in different degrees, levels, and negative impacts. The United Nations Framework Convention on Climate Change (UNFCCC, 1992) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". Climate change increases risks to food security, particularly in coastal countries like Spain, France, Monaco, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece, Turkey, Syria, Lebanon, Palestine, and Egypt (IPCC, 2012). The World Food Summit (1996) defines food security as "a situation when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life". A new study and international reports showed that there is an increase in the expansion of food insecurity levels among coastal countries, leading to more conflicts, food prices, and catastrophic levels of hunger in those countries. The Agricul-

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ture Organization of the United Nations (1996) defines food insecurity as "when people do not have adequate physical and economic access to sufficient, safe, and nutritious foods that meet their dietary needs and preferences for an active and healthy life". According to the Global Food Security Index (GFSI) in 2022, Spain ranks 20 out of 113 countries with an overall food security score of 75.7, France ranks 4 with an overall score of 80.2, Italy ranks 27 with an overall score of 74, Greece ranks 31 with an overall score of 72.2, Turkey ranks 49 with an overall score of 65.3, Syria ranks 113 with an overall score of 36.3, and Egypt ranks 77 out of 113 countries with an overall food security score of 56. In most coastal countries, the agricultural sector is the primary sector that plays a vital role in their economies. For example, the agricultural sector in Egypt represents about 11% of the country's GDP, employs more than 50% of the labor force, and provides about 50% of the food of the country (The World Bank, 2023). So, a global challenge like climate change can affect the agricultural sector, leading to negative impacts on food security and causing national insecurity and political instability all over the country and/or region. Climate change has an effect on the four food security dimensions, which are food availability, food access, food utilization, and food stability. According to the IPCC in 2012, there are five key risks caused by climate change that have a direct negative impact on food security: (1) breakdown of food systems; (2) loss of marine and coastal ecosystems; (3) loss of rural livelihoods and income; (4) loss of terrestrial and inland water resources; and (5) negative effects on trade flows, food markets, and price stability. The main problem of this paper is that climate change has a negative effect on the agriculture sector, particularly in the Mediterranean countries whose economies are based on agriculture. Climate change has effects on temperature (rising it up), leading to a decrease in crop yields. In addition, it affects annual precipitation (decreasing), leading to a reduction in agricultural production. Moreover, climate change has an effect not only on the quantity of food production but also on the food quality standards, leading to the spread of diseases due to a decrease in air, water, and food quality, especially among children under the age of five. Therefore, climate change has a negative effect on all food security dimensions based on the strong direct relationship between agriculture and food security. According to the Global Hunger Index (GHI) in 2023, the global hunger index scores for coastal countries are as follows: Albania with a 6.1 score, Bosnia and Herzegovina with a 5 score, Croatia with a 5 score, Egypt with a 12.8 score, Libya with a 16.1 score, Morocco with a 9 score, Syria with a 26.1 score, Turkey with a 5 score, and Tunisia with a 5.9 score. So, this paper serves a main objective, which is to investigate the negative impacts of climate change on the agriculture sector of Mediterranean countries such as Albania, Algeria, Morocco, France, Croatia, Egypt, Syria, Tunisia, Turkey, Greece, Spain, and Italy. This paper serves a main objective, which is to investigate the impacts of climate change on the agriculture sector, with a focus on Mediterranean countries like Spain, France, Monaco, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Greece, Turkey, Syria, Lebanon, and Egypt. In order to achieve the paper's main objective, this paper depends on using an auto-regressive distributed lag model (ARDL) during the period (2002-2022) to examine the current impacts of climate change on the agriculture sector for the selected Mediterranean countries and then estimate the potential impacts of climate change on the agriculture sector for those countries in the future. The data in this paper relies on different secondary sources like the Climate Change Knowledge Portal (CCKP), the Food and Agriculture Organization of the United Nations (FAO), and the World Bank (WB). This paper will contribute to the existing literature on the impacts of climate change by conducting a comprehensive study on those negative impacts on the agriculture sector in the selected Mediterranean countries, since less attention has been given to studying the actual and predicted impacts of climate change in the Mediterranean countries. So, the paper is organized as follows: Section (1) includes a literature review for previous studies that investigate the impacts of climate change on the agriculture sector, particularly in the Mediterranean countries; Section (2) includes data sources, variables, and descriptive statistics beside the theoretical framework of the ARDL model; Section (3) illustrates the current and potential negative impacts of climate change on the agriculture sector in the selected Mediterranean countries; and Section (4) includes the expected recommendations and conclusions based on the results shown and collected by the ARDL model.

2. Literature review

This paper will follow two main studies (Yassin, 2016) and (Hashem, 2020), but the contribution in this paper will be on a larger scale. The study by Yasin (2016) focuses on the impacts of climate change on food security in Egypt by concentrating on their agricultural sector and the food production system. This study relies on interviews with many experts in the agricultural field from different organizational levels (governmental, local, and international). The study highlights the challenges and obstacles that the agricultural and food production systems faced because of climate change. Additionally, this study also investigates different management and adaptation policy options to reduce the negative impacts of climate change on the agricultural sector in Egypt. Moreover, the study finds that the current policies are not efficient or effective due to political, social, and organizational obstacles. So, the study recommends that establishing and enhancing a clear, comprehensive legal policy toward lowering the potential impacts of climate change will lead to a higher level of cooperation among different stakeholders. The other study that was conducted by Hashem (2020) focused on the negative impacts of climate change on agricultural, food, and environmental systems. The study uses the ARDL model to examine the expected impacts of climate change on the food security dimension. The results showed that there is a negative and significant impact of temperature on food production, while there is a positive and significant impact of temperature on food access. So, the study recommends that promoting a comprehensive adaptation system will reduce the impacts of climate change on the agricultural sector.

The impacts of climate change on the agriculture sector have been pointed out in many previous studies. Climate change has a negative effect on food availability. The U.S. Department of Agriculture (USDA, 2015) defines food availability as "the availability of sufficient food quantities in a stable way. It includes production, processing, packing, transport, storage of food, and all necessary systems included in doing those procedures". Climate change has a direct impact on food production since agricultural production depends on climate conditions; therefore, the agriculture sector is vulnerable to the risks of climate change effects (Greg, 2011). There is another indirect impact of climate change on agricultural production by effecting income distribution and growth, which therefore affects the demand for products from the agriculture sector (Schmidhuber and Tubiello, 2007). Based on several studies and reports, there is a potential disturbance in crop production because of climate change in the near future (2030-2050). Climate change can increase the frequency of heat stress waves, and more warm nights can lead to a reduction in rice production, especially in the Asia region, by 10% for every 1°C above critical temperature (> 24°C). It is expected to reduce rice production in north-eastern Thailand by 17.8% (without an adaptation strategy). Increasing the global temperature in the next few years will also affect the production of wheat, like in India, where the potential reduction will reach 50% by 2050 and in South East Australia by 24% in 2050 without an adaptation strategy (Nelson, 2009). Moreover, changes in rainfall systems caused by climate change can affect crop yields directly and indirectly, particularly in developing countries, since the rainfall provides the crops with their water and CO_2 fertilization requirements. A study by Ray (2009) investigates the relationship between climate change effects on rainfall and crop yields for the main crops in the world. The results show that climate change can affect rainfall systems, leading to lower crop yields for most selected crops, like -13.4% oil palm production, -0.3% rice production, and -0.9% wheat production.

The effects of climate change on food access have been analyzed in several studies. The

World Food Programme (WFP, 2009) defines food access as "a household's ability to acquire an adequate amount of food regularly through a combination of purchases, barter, borrowings, food assistance, or gifts". Climate change has a negative effect on the food access dimension because a decrease in agricultural production (a decrease in food supply) will lead to a rise in food prices. Nelson (2014). Moreover, studies such as Nelson (2009) and Jobbins & Henley (2015) point to the negative effects of climate change on rural incomes that influence the agriculture sector, leading to a lowering purchasing power (decrease in incomes), which affects negatively economic access, and rural households will be the most vulnerable since their primary income comes from agriculture. Additionally, climate change can cause imbalances between demand and supply sides through increasing prices of food, which influence the demand side by decreasing incomes and the supply side by decreasing productivity. This Nelson's study estimates that prices will rise by 97% for maize, 67% for rice, and 56% for wheat by 2050 because of climate change effects. A study by FAO (2018) indicates the negative impacts of climate change on food access and that food prices will rise by an average of 15% by 2050. There is also a study by Hertel and Rosch (2010) that assesses the negative impact of climate change on staple prices, and the results showed that the global price of many staples will increase from 10 to 60% by 2030 and levels of poverty will rise from 20 to 50% in different areas of Asia and Africa. A study by Ivanic and Martin (2008) investigated the relationship between increased food prices and poverty in nine low-income countries, and the results showed that raising food prices led to an increase in poverty levels in these low-income countries. This study estimates that more than 100 million people (out of 2.4 billion people in low-income countries) who live in those low-income countries will suffer from poverty based on national rates of poverty (US $1 per day).

The negative impacts of climate change on food utilization have been discussed in many previous studies. The World Food Programme (WFP, 2009) defines food utilization as "safe and nutritious food that meets their dietary needs". Based on this definition, it is not enough that food be available and accessible for people; it also must be a safe and nutritious diet. A study conducted by Nelson (2009) showed that climate change can increase child malnutrition and lower calorie consumption. This study estimates that a decrease in calorie availability will lead to an increase in child malnutrition by 20% by 2050. A study by Jobbins and Henley (2015) investigates the negative impacts on food utilization dimensions caused by climate change, like spreading diseases (due to rising temperatures) and poor quality of water (due to droughts and floods). This study assessed the number of children malnourished under the age of five in MENA countries, and the results showed that about two million children under the age of five will suffer from malnutrition by 2050 because of climate change effects. Another study by Porter (2014) and Tirado (2010) analyzes the potential impacts of climate change on the food utilization dimension and how that influences the production and consumption of some foods, the nutritional quality of foods, and the spreading of diseases and illnesses like diarrhea. Moreover, a study by Simon J. Lioyed (2011) discussed the relationship between stunting and a lack of food because of climate change. This study showed that climate change will increase moderate stunting from 1% to 29% by 2050. In addition, climate change will also lead to a rise in severe stunting rates, which will reach 23% in central Sub-Saharan Africa (SSA) and 62% in South Asia by 2050 relative to the future scenario without a climate change adaptation strategy.

Stability is the fourth dimension of food security, and according to the World Food Summit, "to be food secure, a population, household, or individual must have access to adequate food at all times". Based on this definition, food stability points out the security of food, as all people must have access to sufficient food at all times, and there is no risk of sudden food supply shocks such as climatic crises that can cause seasonal food insecurity. Moreover, the agriculture sector has sensitivity and vulnerability to external shocks like economic crises, climatic crises, increases in food prices, and emergencies like spreading diseases, droughts, floods, and pests (FAO, 2006). So, food stability means a permanent situation "sustainability" that does not occur in a moment, a day, or a season. According to FAO (2013), food stability indicators include political stability and absence of violence or terrorism, domestic food price volatility, per capita food production variability, per capita food supply variability, cereal import dependency ratio, percentage of arable land equipped for irrigation, and the value of food imports over total merchandise exports. Climate changes can affect the food stability dimension, which influences the stability of the other food security dimensions (stability of food availability, access, and utilization). Climate change can lead to food instability by decreasing global production (food supply shocks) and raising the real prices of food (food inaccessibility). A study by Nathan (2016) indicates that several crops have fluctuations in yields because of climate change effects on rainfall, temperature degrees, and the frequency of droughts and floods. Therefore, the World Food Programme (WFP, 2009) defines food insecurity as "a situation where some people do not have access to sufficient quantities of safe and nutritious food and hence do not consume the food that they need to grow normally and conduct an active and healthy life". Food insecurity can occur due to lack of food (food unavailability), lack of resources (food inaccessibility), improper use (no food utilization), and changes in time and/or dimension (food instability).

3. Data and methods

In this part of the paper, the author will describe the data characteristics, sources, selected variables, and selected countries that have been taken into consideration to obtain an appropriate result from the ARDL model, which tackles the similarity and differences for specific characteristics between the Mediterranean countries to measure the food security performances or scores for each MENA country in this study based on the data availability and limitations.

3.1. *Data sources*

The data was collected from different secondary sources and based on international organizations that specialize in collecting facts and databases about the global situation of climate change and/or food security, like the Food and Agriculture Organization of the United Nations (FAO), the World Bank (WB), and the Climate Change Knowledge Portal (CCKP). The data sources also include trusted websites such as the Population Pyramid, Country Economics, and Trading Economics databases. The main limitation of this paper is that only secondary data has been used. Conducting a survey across the selected countries could have strengthened the paper, but it was avoided due to the high financial cost required to gather accurate primary data.

3.2. *Data variables*

Climate change and food security variables that related to agriculture sector and used in this paper are as follows: (1) *Mean temperature*: "The average temperature of the air as indicated by a properly exposed thermometer during a given time period, usually a day, a month, or a year"; (2) *Per capita CO_2 emissions*: "represent the emissions of an average person in a country or region - they are calculated as the total emissions divided by population"; (3) *Food production index*: "Food production index covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because, although edible, they have no nutritive value"; (4) *Consumer price index*: "The CPI is a measure of the change in the purchasing power of a country's currency and the price level of a basket of goods and services"; (5) *Prevalence of undernourishments*: "POU expresses the probability that a randomly selected individual from the population consumes a number of calories that is insufficient to cover her/his energy requirement for an active and healthy life. The indicator is computed by comparing a probability distribution of habitual daily dietary energy consumption with a threshold level called the minimum dietary energy Requirement. Both are based on the notion of an average individual in the reference population"; and (6) *Cereal import dependency ratio*: "The cereals import dependency ratio tells how much of the available domestic food supply of cereals has been imported and how much comes from the country's own production".

3.3. *ARDL model specifications*

In this section, the author will review the methodology used for this paper, which studies the impacts of climate change (as an independent variable) on selected indicators of the agricultural sector (as a dependent variable) through the use of time series analysis methods. So, the paper will rely on using the time series method through the co-integration method, as it must first ensure the stability of the time series, which is done by testing the presence of the unit root in the time series by the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The process of unit root testing is to perform the following regression:

$$\Delta y_t = \phi_1 y_{y-1} + \alpha + \beta t + \mu_t \quad (1)$$

On the time series data for which the unit root is to be tested, the test can be performed with the presence of the trend or not, and the extended formula is the most commonly used in performing the unit root test, and it is in the form shown below:

$$\Delta y_t = \beta_1 + \beta_2 t + \delta y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta y_{t-1} + \varepsilon_t \quad (2)$$

But it should be noted here that the PP test offers another way to test the static of the time series and is considered better than the ADF test because the latter is based on the assumption that the time series is generated by the autoregressive process, while the PP test is based on a more general assumption, the time series is generated by the autoregressive integrated moving average process, whose methodology is attributed to Box-Jenkins.

After ensuring that the time series is stable, a co-integration test must be conducted. If there is co-integration between two or more variables, that means they participate in the same direction, i.e., if they have a long-term equilibrium relationship. Regression between them, and the most famous of these methods are the Engel-Granger method and the Johnson technique. The first method is often used in simple models that contain only two variables and have a large number of observations, as the method assumes that if the time series are integrated in the first order as individuals, CI~(1) (stable after the first difference) and regression can be performed in simple linear form according to the following equation:

$$y_t = \alpha + \beta x_t + \varepsilon_t \quad (3)$$

As for the second method, it provides another method for testing co-integration. The idea of the Johansson test is to know the number of cointegration vectors between the variables based on the Max-Eigen statistic and the Trace statistic, and the general form of the Johansen technique is as follows:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{p} In(1 - \lambda^{\wedge} t) \quad (4)$$

$$\lambda_{max}(r, r+1) = -T \, In\,(1 - \lambda^{\wedge}{}_{r+1}) \quad (5)$$

Where (r) represents the number of integration vectors under the null hypothesis, the null hypothesis is tested, which states that the number of cointegration vectors is at least equal to (r) vector, and this hypothesis is rejected in return for accepting the hypothesis that states that the number of integration vectors is more than (r) vector If the calculated value of the statistic for the maximum value (λmax) and the value of the effect statistic (λtrace) are greater than the critical values at an assumed significance level.

4. Results and discussion

The agricultural sector is one of the most vital sectors in most Mediterranean countries, and it is vulnerable to climate change. So, in this section, the paper will estimate the potential impact of climate change on agriculture sector of selected Mediterranean countries. In order to estimate those potential impacts, the author will adopt the ARDL model approach to investigate the negative impacts of climate change on the agricultural sector of those countries that affect food security dimensions (food availability, access, utilization, and stability). Therefore, the paper will focus on certain indicators related to climate change, agriculture, and food security, like mean temperature, per capita carbon dioxide emission, production index, consumer price index, POU, and cereal import dependency ratio.

4.1. *Descriptive statistics*

Descriptive statistics were conducted to describe or summarize the characteristics of the data for all variables mentioned earlier in Table 1. It includes three main categories of measures: (1) *Measures of central tendency*: summarize the center of the data set, like mean, median, and etc.; (2) *Measures of frequency distribution*: the occurrence of data within the data set as count; and (3) *Measures of variability*: summarize the dispersion of the data set with terms like standard deviation, min., max., kurtosis, and skewness.

Table 1 - Descriptive statistics of the variables for each selected country.

Countries	*Variables*	*Mean*	*Kurtosis*	*Skewness.*	*Mn.*	*Mix.*	*Count*
Albania	Mean Temperature	12	-0.6	-0.5	11	13	21
	Per capita CO_2	1	0.3	0.1	1	2	21
	Production index	85	-1.5	-0.2	61	106	21
	Consumer Price Index	4	2.6	1.1	2	8	21
	Undernourishment	6	-0.9	0.8	4.1	8.9	21
	Cereal import	43	-1.5	0.6	37.3	51.7	21
Algeria	Mean Temperature	24	-2	-0.5	23.0	24.0	21
	Per capita CO_2	3	-1	-0.7	2.5	3.9	21
	Production index	85	-1	-0.4	55.9	103.8	21
	Consumer Price Index	5	1	1.0	1.0	12.2	21
	Undernourishment	4	-1	0.4	2.0	8.1	21
	Cereal import	73	0	0.5	68.0	79.7	21
Morocco	Mean Temperature	18.2	0.0	0.2	17	19	21
	Per capita CO_2	1.5	-1.4	0.5	1.3	1.8	21
	Production index	93.6	-0.9	-0.4	69	111	21
	Consumer Price Index	2.4	2.8	1.7	0.60	7.3	21
	Undernourishment	5.0	-1.5	-0.2	3.6	6.3	21
	Cereal import	48.0	-0.1	0.7	36.4	65.7	21
France	Mean Temperature	11.4	0.2	0.3	10.0	13.0	21
	Per capita CO_2	5.7	-1.7	0.2	4.6	6.7	21
	Production index	101	0.3	0.5	92.2	112.0	21
	Consumer Price Index	2.7	1.6	0.8	1.0	5.5	21
	Undernourishment	3.0	1	-1	3.0	3.0	21
	Cereal import	-89.9	-0.3	-0.8	-123	-69.5	21
Croatia	Mean Temperature	11.4	0.2	0.3	10.0	13.0	21
	Per capita CO_2	1.0	-1.1	2.0	0.1	9.3	21
	Production index	-0.7	3.2	1.4	-0.3	2.7	21
	Consumer Price Index	10.0	1113.0	4.2	62.2	1.0	21
	Undernourishment	12.0	1113.0	4.4	90.3	2.6	21
	Cereal import	1.0	-1.2	2.0	0.1	9.3	21
Egypt	Mean Temperature	23.0	18.0	2.1	100.7	12.0	21
	Per capita CO_2	0.0	-0.8	-0.1	0.0	1.4	21
	Production index	22.0	18.0	1.8	91.3	0.9	21
	Consumer Price Index	24.0	18.0	2.4	111.0	38.9	21
	Undernourishment	10.0	-2.9	-1.8	-0.8	3.4	21
	Cereal import	0.01	-0.5	-0.1	0.0	1.4	21

Countries	Variables	Mean	Kurtosis	Skewness.	Mn.	Mix.	Count
Syria	Mean Temperature	18.7	0.3	-0.3	0.0	18	21
	Per capita CO_2	2.3	0.4	-0.9	-0.4	1.2	21
	Production index	118.3	357	-1.0	0.4	88.4	21
	Consumer Price Index	28.2	1406	2.2	1.7	0.4	21
	Undernourishment	11.4	61.6	-0.4	1.0	4.0	21
	Cereal import	34.7	24.3	0.3	1.0	28.8	21
Tunisia	Mean Temperature	20.4	-2.1	0.3	20.0	21.0	21
	Per capita CO_2	2.4	-0.4	0.8	2.1	2.9	21
	Production index	93.7	1.4	-0.4	67.4	116.7	21
	Consumer Price Index	4.8	-0.9	0.0	2.2	7.3	21
	Undernourishment	3.5	-1.5	0.3	2.6	4.5	21
	Cereal import	63.7	-1.2	-0.3	54.5	71.5	21
Greece	Mean Temperature	14.3	652.0	7.5	101.5	2.3	21
	Per capita CO_2	1.0	0.2	0.0	0.5	0.8	21
	Production index	14.0	652.0	5.7	93.6	0.5	21
	Consumer Price Index	15.0	652.0	9.2	109.3	5.4	21
	Undernourishment	14.3	652.0	7.5	101.5	2.3	21
	Cereal import	-1.1	-2.3	-1.8	0.2	-0.8	21
Spain	Mean Temperature	14.0	636.0	6.6	101.5	2.7	21
	Per capita CO_2	4.6	-1.8	0.0	0.2	0.8	21
	Production index	14.0	636.0	5.2	85.4	1.0	21
	Consumer Price Index	15.0	-0.38	1	6	8.1	21
	Undernourishment	21.0	-2.7	-1.8	-0.4	-0.5	21
	Cereal import	4.6	-0.1	0.0	0.2	0.8	21
Italy	Mean Temperature	13.0	832.0	7.2	108	2.1	21
	Per capita CO_2	4.6	-1.6	-0.4	0.3	1.1	21
	Production index	13.0	832	5.7	95	0.6	21
	Consumer Price Index	14.0	832	8.4	124	5.4	21
	Undernourishment	21.0	-2.3	-1.8	-1.1	1.3	21
	Cereal import	4.6	-0.9	-0.4	0.3	1.1	21

Source: Author.

4.2. *Unit root test*

In order to capture the order of integration for the selected variables in this paper, we have chosen to do the unit root test by using both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The results of the unit root test for variable stationarity are shown in Table 2 at both level (I_0) and level (I_1). The results showed that almost all variables are stationary for all selected countries and also for both tests at level (I_1), which means variables are integrated in order one, known as "first differences", except the Consumer Price Index variable is stationary at level (I_0), which means variables are integrated in order zero, known as "no differences".

4.3. *ARDL model estimations*

To estimate the impacts of climate change on food security in Mediterranean countries, we use the ARDL model Autoregressive distributed lag). The author assesses the impacts of climate change (temperature and CO_2 emission per capita) variables on food availability, which was measured by the food production index, and food access, which was measured by food inflation. The results showed that there is a cur-

Table 2 - Unit root results: ADF and PP tests.

Countries	*Variables*	*ADF Level (I_0)*	*ADF Level (I_1)*	*PP Level (I_0)*	*PP Level (I_1)*
Albania	Mean Temperature	-1.396 (0.561)	-5.990* (0.001)	-1.231 (0.639)	-6.665* (0.001)
	Per capita CO_2	-1.995 (0285)	-4.858* (0.001)	-1.996 (0.287)	-5.082 (0.007)
	Production index	-1.282 (0.616)	-3.292* (0.030)	-1.228 (0.641)	-3.408* (0.023)
	Consumer Price Index	-3.439* (0.023)	-	-4.146* (0.004)	-
	Undernourishment	-1.528 (0.518)	-2.447* (0.014)	-1.121 (0.685)	-3.382 (0.015)
	Cereal import	-1.905 (0.323)	-3.201* (0.021)	-1.006 (0.730)	-4.153* (0.027)
Algeria	Mean Temperature	-1.242 (0.634)	-4.358* (0.003)	-1.236 (0.637)	-5.354* (0.004)
	Per capita CO_2	-1.579 (0.473)	-5.302* (0.001)	-1.584 (0.480)	-5.210* (0.001)
	Production index	-1.867 (0.339)	-3.356* (0.026)	-1.861 (0.342)	-3.371* (0.025)
	Consumer Price Index	-3.937* (0.007)	-	-3.894* (0.008)	-
	Undernourishment	-1.418 (0.552)	-5.022* (0.008)	-1.639 (0.445)	-5.071* (0.008)
	Cereal import	-3.452* (0.023)	-	-3.292* (0.029)	-
Morocco	Mean Temperature	-4.282* (0.005)	-	-4.091* (0.006)	-
	Per capita CO_2	-0.411 (0.883)	- 2.383* (0.086)	0.708 (0.989)	-4.493* (0.003)
	Production index	-2.411 (0.151)	-6.234* (0.001)	-2.318 (0.176)	-10.12* (0.000)
	Consumer Price Index	-4.172* (0.004)	-	-4.24* (0.005)	-
	Undernourishment	-1.808 (0.364)	-3.444* (0.01)	-1.295 (0.611)	-3.831* (0.015)
	Cereal import	-0.864 (0.992)	-7.162* (0.000)	-2.069 (0.257)	-7.263* (0.000)
France	Mean Temperature	-0.601 (0.849)	-5.297* (0.005)	-0.121 (0.932)	-5.320* (0.004)
	Per capita CO_2	-0.545 (0.862)	-5.871* (0.001)	-0.413 (0.889)	-5.875* (0.001)
	Production index	-2.435 (0.145)	-8.438* (0.000)	-2.436 (0.146)	-14.64* (0.000)
	Consumer Price Index	-6.217* (0.001)	-	-5.477* (0.003)	-
	Undernourishment	-0.541 (0.862)	-9.746* (0.000)	-1.411 (0.556)	-10.63* (0.000)
	Cereal import	1.213 (0.996)	-7.341* (0.000)	-2.775 (0.079)	-7.988* (0.000)
Croatia	Mean Temperature	-0.930 (0.753)	-6.393 (0.001)	-1.421 (0.601)	- 5.026* (0.008)
	Per capita CO_2	-2.723 (0.086)	-4.319* (0.003)	-2.731 (0.087)	-4.907* (0.001)
	Production index	-2.296 (0.182)	-6.707* (0.000)	-2.297 (0.183)	-7.505* (0.000)
	Consumer Price Index	-3.961* (0.007)	-	-3.967* (0.008)	-
	Undernourishment	-2.001 (0.281)	-4.457* (0.002)	-2.595 (0.190)	-7.228* (0.000)
	Cereal import	-1.488 (0.998)	-3.463* (0.021)	-1.719 (0.999)	3.468* (0.022)
Egypt	Mean Temperature	-7.348* (0.000)	-	-7.348* (0.001)	-
	Per capita CO_2	-0.995 (0.734)	-3.013* (0.047)	-1.059 (0.710)	-3.017* (0.048)
	Production index	-1.048 (0.714)	-4.451* (0.002)	-1.048 (0.714)	-4.473* (0.003)
	Consumer Price Index	-3.080* (0.044)	-	-3.080* (0.044)	-
	Undernourishment	-1.396 (0.563)	-3.767* (0.02)	-1.440 (0.542)	-3.767* (0.02)
	Cereal import	-0.235 (0.918)	-3.031* (0.044)	-0.493 (0.873)	-3.832* (0.001)
Syria	Mean Temperature	-2.396 (0.155)	-6.509* (0.000)	-2.371 (0.161)	-7.975* (0.000)
	Per capita CO_2	-0.253 (0.969)	-4.268* (0.004)	-0.087 (0.956)	-4.348* (0.003)
	Production index	-1.243 (0.633)	-5.287* (0.001)	-1.050 (0.714)	-6.304* (0.001)
	Consumer Price Index	-2.359 (0.164)	-5.281* (0.001)	-2.294 (0.182)	-7.059* (0.000)
	Undernourishment	-2.845 (0.999)	-3.831* (0.014)	-2.201 (0.998)	-3.832* (0.015)
	Cereal import	-2.560 (0.117)	-4.529* (0.002)	-2.475 (0.135)	-5.496* (0.003)
Tunisia	Mean Temperature	-0.809 (0.794)	-4.358* (0.003)	-0.809 (0.795)	-4.358* (0.003)
	Per capita CO_2	-0.663 (0.987)	-4.929* (0.001)	-1.837 (0.994)	-4.938* (0.001)
	Production index	-3.597* (0.015)	-	-6.848 (0.000)	-
	Consumer Price Index	-2.757 (0.082)	-4.932* (0.001)	-2.757 (0.082)	-7.923* (0.000)
	Undernourishment	-1.212 (0.647)	-5.308* (0.001)	-0.937 (0.754)	-5.753* (0.000)
	Cereal import	-2.435 (0.145)	-4.748* (0.002)	-2.465 (0.138)	-4.495* (0.003)

Countries	*Variables*	*ADF Level (I_0)*	*ADF Level (I_1)*	*PP Level (I_0)*	*PP Level (I_1)*
Greece	Mean Temperature	-2.396 (0.155)	-6.508* (0.000)	-2.371 (0.161)	-7.975* (0.000)
	Per capita CO_2	-0.519 (0.982)	-2.637* (0.06)	-1.418 (0.998)	-4.988* (0.000)
	Production index	-0.496 (0.873)	-5.531* (0.003)	-0.179 (0.923)	-5.775* (0.002)
	Consumer Price Index	-3.001* (0.044)	-	-3.413* (0.024)	-
	Undernourishment	-4.929* (0.009)	-	-4.913* (0.009)	-
	Cereal import	-3.345* (0.027)	-	-1.652 (0.486)	-3.398* (0.155)
Spain	Mean Temperature	-0.262 (0.913)	-9.746* (0.000)	-1.397 (0.563)	-10.63* (0.000)
	Per capita CO_2	-0.239 (0.918)	-3.265* (0.031)	-0.371 (0.896)	-3.19 4* (0.036)
	Production index	-2.501 (0.130)	-3.959* (0.039)	-2.466 (0.137)	-9.446* (0.000)
	Consumer Price Index	-2.754 (0.083)	-6.032* (0.001)	-2.754 (0.083)	-7.915* (0.000)
	Undernourishment	-6.062* (0.001)	-	-5.892* (0.001)	-
	Cereal import	-2.216 (0.206)	-5.043* (0.001)	-2.201 (0.211)	-5.035* (0.001)
Italy	Mean Temperature	-0.644 (0.839)	-4.358* (0.003)	-0.644 (0.839)	-4.358* (0.003)
	Per capita CO_2	-0.113 (0.958)	-3.295* (0.029)	-0.005 (0.947)	-3.244* (0.033)
	Production index	-1.595 (0.466)	-5.470* (0.003)	-1.463 (0.531)	-9.170* (0.000)
	Consumer Price Index	-2.779 (0.07)	-5.001* (0.001)	-2.641 (0.101)	-8.094* (0.000)
	Undernourishment	-3.919* (0.007)	-	-3.919* (0.007)	-
	Cereal import	-3.296 (0.999)	-3.8723* (0.006)	-0.691 (0.988)	-3.995* (0.007)

() = the values between parentheses represent the value of prob. (*) at significant level 5%. Source: Author.

Table 3 - ARDL models estimation.

Country	*Variables*	*Food Production Index*		*Food Inflation Rate*	
		B	*Prob.*	*B*	*Prob.*
Albania	Mean Temp.	4.789	0.041	-0.354	0.398
	Per capita CO_2	7.409	0.285	-1.934	0.232
Algeria	Mean Temp.	18.478	0.004	-1.387	0.797
	Per capita CO_2	-9.482	0.284	1.777	0.789
Morocco	Mean Temp.	-5.997	0.031	0.378	0.639
	Per capita CO_2	3.421	0.938	-8.188	0.043
France	Mean Temp.	-3.479	0.037	-0.751	0.041
	Per capita CO_2	0.043	0.993	-1.131	0.045
Croatia	Mean Temp.	0.587	0.950	-1.991	0.043
	Per capita CO_2	2.924	0.851	6.945	0.022
Egypt	Mean Temp.	5.241	0.081	-4.333	0.551
	Per capita CO_2	10.394	0.039	21.641	0.023
Syria	Mean Temp.	4.956	0.028	4.089	0.842
	Per capita CO_2	-3.995	0.741	-46.098	0.014
Tunisia	Mean Temp.	7.277	0.029	-2.214	0.041
	Per capita CO_2	41.56	0.044	4.488	0.011
Turkey	Mean Temp.	0.346	0.843	-1.736	0.574
	Per capita CO_2	8.964	0.042	4.771	0.008
Greece	Mean Temp.	0.346	0.843	-1.736	0.574
	Per capita CO_2	8.964	0.042	4.571	0.041
Spain	Mean Temp.	-0.749	0.928	1.464	0.364
	Per capita CO_2	-5.583	0.012	2.331	0.038
Italy	Mean Temp.	1.331	0.754	-0.928	0.373
	Per capita CO_2	-1.938	0.739	0.841	0.035

Source: Author.

rent negative impact of temperature and/or CO_2 emissions per capita on food availability and access dimensions in which mean temperature as an independent variable shows a significant effect on food production index as it is the dependent variable where is the value of probability is less than 0.05 in most selected Mediterranean counties while CO_2 emissions per capita as an independent variable show a significant effect on both food production index and food inflation where is the value of probability is less than 0.05 in most selected Mediterranean counties due to CO_2 emissions is the main contribution on greenhouse gases effects and driven-force to climate change phenomena (Table 3).

Based on results obtained from Tables 2 and 3, the main finding of this paper is that climate change has a negative impact on both the food security dimensions and the agriculture sector for many Mediterranean countries, and therefore, our findings show that they are in synergy with what has been published on the topic in the last decade, like Ehab (2023), Antonelli (2022), Del Pozo (2019), Sameh (2015), and Jeder (2011).

4.4. *Potential impact of climate change by 2070*

The potential impacts of climate change on the agriculture sector of selected Mediterranean countries were estimated and measured by temperature since it has effects on both food availability and access dimensions by 2070. Food production will be decreasing from 11% to 37%, while food prices will be increasing from 10% to 24%. We expect a population growth of 57% in 2070 compared to 2022 and a rise in temperature from 1.0 to 2.5 Celsius, and POU will increase by 1% every 10 years. All those impacts will take place without an adaptive strategy and only during the next 45 years. So, there is a negative relationship between population growth and food availability, while there is a positive relationship between population growth and food access. Moreover, there is a negative relationship between temperature and food availability, while there is a positive relationship between temperature and food access. Therefore, climate change has a negative impact on the agriculture sector of selected countries in terms of both food availability and access.

5. Recommendations and conclusions

Climate change is a complex phenomenon, and the agricultural sector is the most vulnerable to its effects since climate change affects negatively the food security dimensions, which are directly associated with agriculture. The main climate change variables (temperature and CO2 emissions) influencing food production index and food inflation rate in Mediterranean countries have been examined in this paper for the following twelve countries: Algeria, Morocco, France, Croatia, Egypt, Syria, Tunisia, Turkey, Greece, Spain, and Italy. Equipped with simple and advanced statistics and econometric instruments like descriptive statistics, unit root tests, ARDL, and forecasting models, time series data was used on the actual period from 2002 to 2022, while it was used on the forecast period from 2023 to 2070. The results show that climate

Table 4 - Forecasting the impact of climate change on agriculture sector of selected Mediterranean countries.

Year	** Population of Selected countries (No.)*	*Yearly Change on population (%)*	*Temperature Scenario (°C)*	*Impact on Food Production (%)*	*Impact on Food Prices (%)*	*Prevalence of Undernourishment (%)*
2030	555,130,470	1.24	1.0	-9%	7%	5%
2040	621,360,990	1.19	1.2	-11%	10%	6%
2050	687,591,510	1.13	1.5	-17%	13%	7%
2060	774,448,568	1.08	1.7	-24%	17%	8%
2070	861,305,626	1.02	2.0	-37%	24%	9%

(*) Selected Mediterranean countries: Albania, Algeria, Morocco, France, Croatia, Egypt, Syria, Tunisia, Turkey, Greece, and Spain. Source: Author, results produced by EViews (version 20) software.

change has a negative impact on the agriculture sector for many Mediterranean countries in both the current situation and future scenarios. Both temperature and CO_2 emissions have a significant effect on food production and have a negative relationship with it, as well as a significant effect on food inflation and a positive relationship with it in those countries. Moreover, combining climate change with a rapid increase in population growth rate will put more pressure on the agriculture sector, which will accelerate the decreasing rate of food production and increase the rate of food inflation, causing an increase in POU among the people of those countries. The findings confirm the interlinkage between sustainable development goal number three (ending hunger and ensuring food security) and sustainable development goal number thirteen (climate action), in which climate indicators affect food availability by decreasing agriculture productivity, leading to a decrease in food supply, resulting in negative effects on the dimension of food access that are due to a shortage in food supply facing an increase in food demand.

The governments, policymakers, and stakeholders in those Mediterranean countries must pay more attention to the negative impact of climate change on their agriculture sector before it is too late, at which point the costs (economically, socially, and environmentally) will be destructive and irreversible. Therefore, we are recommending the following: (1) The Mediterranean governments must invest more in rural development to increase the food availability dimension and create more economic opportunities to increase the food access dimension; (2) there is a necessity to design and apply new national adaptation strategy targeting the reduction of climate change impacts on the agriculture sector and this adaptation strategy to be based on different climate change pathways and according to each Mediterranean country scenario; (3) establishing and activating a different comprehensive legal framework in those countries aims to increase cooperation between all stakeholders, including both governmental and non-governmental organizations, to raise awareness of the climate change effects and find effective solutions to reduce the expected climate change impacts on the agriculture sector; (4) The Mediterranean countries should invest more in new adaptation options such as clean technologies (environment-friendly) like renewable energy (RE) technologies and other agriculture adaptation technologies (i.e., green ones), with a focus also on training stakeholders on using them to reduce GHG emissions. (5) Reactivating and revitalizing the role of agricultural research institutes in Mediterranean countries, particularly the low-income ones, to improve soil fertility and crop traits, manage water and soil resources, and provide crop protection and insurance to farmers against climate change effects; and (6) Mediterranean countries must establish strong and high levels of cooperation with each other to devise creative adaptation strategies and options against climate change risks, especially in the agriculture field, to reduce potential negative impacts.

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