CLIMATE CHANGE AND AGRICULTURE IN MENA COUNTRIES: IMPACTS AND STRATEGIES OF MITIGATION

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ABSTRACT

Countries in the MENA region are highly vulnerable to the impacts of climate change. In addition to severe climatic conditions, namely extremely high temperatures and limited rainfall groundwater, they are particularly affected by scarce agricultural land. Although research on the impacts of climate change in the region has been given more importance over the recent years by both researchers and policymakers, it remains insufficient, especially when compared to the significant number of climate studies addressing climate variability in Africa. In this study, changes in annual precipitation, carbon dioxide emissions and temperature are estimated to capture the impact of climate change on production and trade agriculture in 5 MENA countries through panel data and generalized method of moments (GMM) estimation. The empirical results have established key relationships which have important policy implications. First, the results reveal that climate variables are negatively correlated with crop yield and agricultural trade. Second, increased fertilizer use reflects inefficient application that affects agricultural productivity. Lastly, we recommend adopting some strategies to tackle climate change, by investing in Climate-Smart Agriculture (CSA) and similar practices.

Keywords: Climate Change, Agriculture Trade, MENA Region, GMM Estimation.

JEL classification: F18 O44 Q17 Q54.

INTRODUCTION

The Middle East and North Africa (MENA) region is known for its hot and dry weather, compared to the rest of the world. As a result of high temperature, droughts, rising sea level, floods, and polluted air, largely attributed to climate change, MENA countries have been facing many economic challenges, especially food insecurity and water scarcity. Indeed, according to a report by the World Bank[1], the MENA region is one of the most vulnerable to the impacts of climate change in the globe. When extreme weather conditions and temperatures are combined, the consequences are multiplied many times, not only in the MENA region but also in the rest of the world.

In recent years, policy makers and researchers have started to give more attention to the ravages of extreme weather, adding to the list the effects of the rising levels of GHG emissions. Many steps have been taken in the attempt to address these issues with the aim of mitigating the effects of climate change (meetings, negotiations and cooperation)**.** Furthermore, many developed and developing countries have attempted to limit greenhouse

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gas (GHG) emissions to a tolerable level of 2°C and to1.5°C in the next few years (Tekce & Deniz, 2016). As its adverse effects intensify, increasing concentrations of greenhouse gas as well as global temperature lead to an increase in the total amount of water vapor in the atmosphere, which amplifies, in turn, the impact of climate change. In (Nordhaus, 2019) suggests that an increase in global temperature may provide a loss of around $15 trillion in 2150.

The literature on the effects of climate change is enormous. Nevertheless, the controversial results of the empirical studies have generated some confusion and concern among researchers. Generally, the impacts are investigated to analyze the relationship between climate and other indicators such as income, GDP growth, and agricultural productivity. Nevertheless, the topic still remains a fertile ground to be discovered. Many researchers have focused on the issue of how temperature, precipitation, and storms have influenced the economic performance of different countries. For instance, (Naeem, 2014) analyzes the effects of climate change on the economic growth of some Asian countries and concludes that changes in temperature, precipitation and population growth threaten economic growth. In the same vein, (Abidoye & Odusola, 2015) conclude that the resources needed to counter the adverse effects of global warming reduce the availability of resources needed to invest in physical infrastructure, R&D and human capital. As a result, economic growth will decline. By contrast, (Wiebel et al., 2014) confirm that climate change has an overall negative effect but remains weak. In (Newell, 2021) finds no significant effect of temperature on GDP growth.

The climate change is an important factor affecting crop production. For this reason, agriculture has been considered to be one of the most vulnerable sectors to precipitation variability and temperature. Many empirical studies developed the link between climate change and agriculture around the world using several analytical methods. For example, (Dudu & Çakmak, 2018) conclude that the rise of temperature and reducing precipitation could seriously threaten global food security. In (Doğan & Kan, 2019) similarly, analyze the relationship between precipitation, temperature and wheat yield in Turkey between 1997 and 2016. The study was carried out in three regions on the basis of the intensity of drought (severe drought, moderate drought and light drought).Their results demonstrate that precipitation increases wheat yield, while temperature minimizes production in these zones. There are also related studies with identified results, such as (Solaymani, 2018; Guntukula & Goyari, 2020). Further research has been developed to analyze the relationship between climate change and agricultural yield and trade. Most researchers agree that climate change has generally a significant impact on agricultural production while noting that the magnitude of the impact differs in view of the many variables like the choice of time periods, the type of crop, regions.

Most of the existing studies have just investigated the effects of climate change on income, GDP growth and agricultural productivity, only few studies have analyzed the link between climatic variables and agricultural trade, particularly in MENA countries. The contribution of this article will be placed in this context. The main objective of this paper is to study the relationship between climate change and agricultural production and trade in five MENA countries. The remainder of the paper is organized as follows: Section 2 will be devoted to a review of the literature. The methodology of our analysis will be presented in Section 3. In Section 4, we will present the empirical results. Finally, the last section will outline our conclusions.

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LITERATURE REVIEW

Policy makers have been deeply interested in the effects and consequences of climate change over the last decades. For a long time, the MENA region has been dependent on agriculture and climatic conditions. The agricultural sector still plays a crucial role in many Arab countries. However, today's climatic and demographic trends do not guarantee its ability to support the population and the local economy in the coming years. In (Niang et al., 2010) argue that climate change has already been observed in the region and is expected to accelerate in the near future. They confirmed a process of global warming, both in terms of annual and seasonal average temperature and the drop in precipitation over recent decades in North Africa. Also, (Borghesi & Ticci, 2019) show that this region will experience increasingly higher temperatures compared to the global average not only in terms of annual and seasonal average but also heat waves. In other words, a region that contains vast desert and semi-arid areas is becoming increasingly drier, threatened by extremely high temperatures and chronic water shortages. However, these consequences obviously vary from one country to another since the MENA region is very heterogeneous in terms of economic and social condition.

Climate change affects significantly agricultural production in various ways, threatens food security, livelihoods and global economies. Shifts in temperature and precipitation patterns can lead to droughts, floods, and heat waves, which can, in turn, reduce crop growth cycles, yields and quality. Many researchers have argued for the negative impacts of climate change on agriculture, coming up with the conclusion that this sector is the most vulnerable. In Morocco, (Achli et al., 2024) examine the vulnerability of wheat, barley, and maize to growing season temperature changes as well as socio-economic adaptive capacity proxies, over the period 1991-2016. These findings indicate that wheat has the lowest vulnerability index and the greatest adaptive capacity index, while barley has the strongest vulnerability and lowest adaptive capacity index.

In a research conducted in Sudan for the period 1970-2018, (Musa et al., 2024) find a negative correlation between wheat yield and extreme temperature (low and high). Similarly, (Gamal et al., 2024) detect the same significant negative relationship in different regions of Egypt covering the period from 1987 to 2019. Climatic fluctuations constitute the most important source of risk which affects directly or indirectly agricultural production. In (Pickson et al., 2020) suggests that increasing temperatures and changes in precipitation patterns have a direct impact on the timing of crop growth. Arable land becomes unsuitable for agricultural production due to heat waves, which has long-term negative consequences on agricultural productivity. The attendant changes in precipitation patterns would lead to both crop losses and a slowdown in agricultural production. In the same vein, the report of (FAO, 2016) explains that regions such as the Levant and North Africa could see a drop in agricultural productivity due to the reduction in precipitation, as many countries of the area rely heavily on rain-fed agriculture. Global warming also leads to soil degradation, which can reduce agricultural productivity. The studies of (El-Basyuni et al., 2019) indicates that rising temperatures and decreasing precipitation can threaten soils, salinization and nutrient depletion. This can have disastrous consequences for the viability of agricultural land in Egypt and Tunisia, where soil quality is already affected.

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As we know, the increase in temperature is attributed to the increase in GHG (Green House Gases) emissions. Some research has been carried out to study the effect of CO2 emission on agriculture in the MENA region, focusing on crop yields, water resources, soil health, and other socio economic indicators. In (Zhao et al., 2017) find that high CO2 concentrations could increase the yield of staple crops such as wheat and barley in MENA countries. However, the advantages of increased CO2 are often limited by other climate factors, such as rising temperatures and water scarcity. Similarly, (Mostafa et al., 2021) conduct a meta-analysis of various crops in the MENA region, concluding that while CO2 enrichment could lead to yield increases of 10-30% for some crops, these gains remain highly dependent on the availability of water and nutrient management practices. The link between CO2 and other environmental factors is critical in determining the overall effect on agricultural productivity. Moreover, research by (Haddad et al., 2021) suggests the need for integrated water management strategies that consider the impacts of CO2 on crop water requirements. Sustainable irrigation practices, such as rainwater harvesting and drip irrigation, are essential to reduce the adverse effects of water shortage while maximizing the benefits of high CO2.

Empirical findings suggest that the impact of increased CO2 on agriculture in MENA countries is profound and multifaceted, with potential benefits in crop yields. However, their implications are tempered by challenges related to soil health, water scarcity and other socio-economic disparities. For instance, (Alboghdady & El-Hendawy, 2016) indicate that while some farmers may profit from increased yields due to higher CO_2, others may face challenges related to water shortage and climate change conditions. This disparity can exacerbate existing inequalities within the agricultural sector. In addition, the potential for increased agricultural yields does not always guarantee food security if markets and infrastructure are less developed. Therefore, policy makers must give more importance to resource management and sustainable agricultural practices to overcome climate change, ensure food security and agricultural trade.

Compared to the vast literature on the effects of climate change, there are relatively few studies on the impact of climate change on agricultural trade. The World Bank's report in 2021 (World Bank, 2021) suggests that lowered agricultural productivity could lead to high food prices, threaten food security and trade balances. Countries heavily dependent on agricultural exports, such as Tunisia and Jordan, could face economic instability as climate change affects their agricultural sector. Furthermore, the possibility of heavy reliance on imports could pressure national economies. Water scarcity is a problem in the MENA region, where agriculture is so dependent on irrigation. According to the Food and Agriculture Organization (FOA, 2021), climate change is estimated to reduce freshwater availability, leading to conflict for water resources among domestic, agricultural, and industrial users. This situation can affect trade by reducing the ability of countries to produce reserve crops intended for export. Studies by (Hejazi et al., 2023) indicate that countries like Egypt and Morocco may face significant difficulties in maintaining their agricultural trade due to water shortages. Other researchers emphasize the importance of adapting strategies to mitigate the effect of climate change on agricultural trade for the MENA region. For example, (Govind, 2022) discuss the potential of drought resistant crop varieties and improved irrigation techniques for sustaining agricultural trade. Also, (Ciampittiello et al., 2024) highlight the need for integrated water resource management (IWRM) to reinforce resilience.

The impact of temperature, precipitation and CO_2 emissions on agricultural production and trade can vary depending on the country and the indicators used. Indeed, there

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is no consensus among studies examining this relationship. Our study participates in this debate by testing this thesis in 5 MENA countries. The countries in our sample were Tunisia, Morocco, Egypt, Jordan and Lebanon. Most of them are cereals importers. These economies are generally not agricultural although some of them depend on the export of some agricultural products like Tunisia and Morocco. Limiting this study to these countries is due to two reasons: Firstly, the Gulf countries depend mainly on oil revenues. Secondly, the unavailability of the necessary data for certain countries due to war and political instability, such as Libya, Iraq, Yemen and Iran.

EMPIRICAL ANALYSIS

Methodology and Data

The present study examines the impact of climatic variables on agricultural production and trade. Our model is largely inspired from the empirical works of (Blundel & Bond, 1998) and (Bond et al., 2021).

The equation to be estimated has the following structure :

$$\mathrm{AVAG}_{\mathrm{it}} = \beta_0 \mathrm{AVAG}_{\mathrm{it}-1} + \beta_1 \mathrm{TP}_{\mathrm{it}} + \beta_2 \mathrm{PR}_{\mathrm{it}} + \beta_3 \mathrm{CO2}_{\mathrm{it}} + \beta_4 \mathrm{HC}_{\mathrm{it}} + \beta_5 \mathrm{GFCF}_{\mathrm{it}} + \beta_6 \mathrm{FC}_{\mathrm{it}} + \varepsilon_{it} \quad (1)$$

$$\mathrm{AT}_{\mathrm{it}} = \beta_0 \mathrm{AT}_{\mathrm{it}-1} + \beta_1 \mathrm{TP}_{\mathrm{it}} + \beta_2 \mathrm{PR}_{\mathrm{it}} + \beta_3 \mathrm{CO2}_{\mathrm{it}} + \beta_4 \mathrm{HC}_{\mathrm{it}} + \beta_5 \mathrm{GFCF}_{\mathrm{it}} + \beta_6 \mathrm{FC}_{\mathrm{it}} + \varepsilon_{it} \quad (2)$$

We used a dynamic panel data analysis in which the index t refers to the observation years 2000-2022 and i refers to a group of five MENA countries.The dependent variable is expressed by two measures**,** namely the added value of agriculture as a percentage of GDP (AVAG) and trade export which denotes agricultural raw materials exports as % of merchandises exports (AT). The interest variables are temperature (TP), precipitation (PR) and CO2 emissions. These three variables could be considered as the most popular climate change proxy for this phenomenon. We estimate the model in three different scenarios because of the correlation between temperature and CO2. Human capital (HC), fixed capital (GFCF) and fertilizer consumption (FC) are qualified as control variables to isolate the effects of interest variables.

It is important to note that some variables are used in the form of natural logarithms to reduce the heterogeneity data issues. The variables used in our econometric study are presented in Table 1 & Table 2.

Table 1
VARIABLE DEFINITIONS

Variables	Definitions	Source
AVAG	Agricultural value added in USD	World Development Indicators (WDI)
AT	Agricultural raw materials exports as % of merchandises exports	World Development Indicators (WDI)
TP	The annual average of temperature is calculated using monthly data	World Meteorological Organization (WMO)
PR	The annual average of precipitation is calculated using monthly data	World Meteorological Organization (WMO)
CO2	CO2 emissions per unit of GDP in Kiloton	World Development Indicators (WDI)
HC	Percentage of working population in agriculture	World Development Indicators (WDI)

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GFCF	Gross fixed capital formation as a percentage of GDP	World Development Indicators (WDI)
FC	kilograms per hectare of arable land	World Development Indicators (WDI)

Table 2
CORRELATION ANALYSIS

	AVAG	HC	GFCF	TP	PR	CO2	FC	AT
AVAG	1.0000							
HC	0.4515	1.0000						
GFCF	0.5413	0.3517	1.0000					
TP	0.4571	-0.1561	0.1023	1.0000				
PR	-0.4065	0.1365	0.0353	-0.3490	1.0000			
CO2	-0.4052	-0.2845	-0.2408	-0.3830	0.0308	1.0000		
FC	0.7376	-0.0965	0.1802	0.5263	-0.6046	0.0329	1.0000	
AT	-0.6216	-0.1600	0.0030	-0.4821	0.4527	0.0836	-0.6767	1.0000

Econometric Methodology

We used the system GMM estimation method for the dynamic panel data analysis. This approach can accommodate omitted variable biases; multicollinearity problems, unobserved country heterogeneity issues, and errors analysis that are common in regression methods fixed effects and pooled OLS. Although system GMM findings are considered advantageous, it is necessary to assess the validity of the instruments and the absence of second-order serial correlation in the first-differenced residuals. According to Sargan and Hansen tests, instrumental variables are validated.

When there is an absence of correlation between the error term and the instruments. Hence, the second order serial correlation tested by the Arellano-Bond tests. Based on our sample, we preferred the findings of the tow-step GMM system.

RESULTS AND INTERPRETATION

Climate change and Agriculture

To estimate the dynamic panel data model, it is important to apply the Sargan Test and the Error Autocorrelation Test. As Table 3 and Table 4 show, the (Sargan, 1958) test of overidentifying restrictions p-values ($p > 0.10$) indicates that the instruments are well-identified, and that overidentifying restrictions are valid in all scenarios. In (Arellano–Bond's, 1991) test for autocorrelation in first-differenced AR (2) errors p-values ($p > 0.10$) reveals that the residuals have no autocorrelation in order 2. As a result of diagnostic tests, all models which employ (Blundell–Bond's, 1998) two-step GMM-system estimator are justified. Thus, the control and interest variables we involve in the model are statistically significant, at least at the 5% level. As shown in Table 3, the 1% increase in agricultural yield in the previous year has an increasing effect on the current year's agriculture production of 0.9531%. The skills, knowledge, and experience possessed by human capital play a crucial role in enhancing agricultural productivity in MENA region, where agriculture is a significant

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sector in economic development. Several studies have demonstrated a positive correlation between education levels and agricultural productivity in MENA countries. For instance, a study by (Qureshi et al., 2016) in Egypt concluded that farmers who participated in agricultural extension services reported high productivity and income levels compared to those who did not. Also, research by (World Bank, 2018) emphasizes that investments in human capital can generate significant returns in terms of agricultural productivity and rural development.

Our findings demonstrate that the rise in the agricultural labor force is increases agriculture yield in most scenarios. Moreover, results of investment indicate a positive and significant correlation with agriculture in the last two scenarios. This suggests that the adoption of improved farming techniques, developed irrigation and investments in agricultural sustainability lead to higher crop yields. In a recent study, (Waha et al., 2017) showed that countries that enhanced agricultural investments experienced advanced increases in crop yields and overall agricultural production. Fertilizers consumption is the last control variable which plays an important role in increasing agricultural productivity by offering essential nutrients to crops. In MENA countries, where water is scarce and soils are infertile, fertilizer use is fundamental to improve crop yields and enhance resilience to climate change. In scenario 2, the variable is insignificant and negatively correlated with agriculture. This relationship is validated because of the disparity in access to fertilizers in MENA countries, influenced by economic conditions, infrastructure and market dynamics. Therefore, excessive consumption of fertilizers can degrade soils and reduce agricultural productivity, particularly in arid regions. Furthermore, it reflects ineffective management fertilizer application. In (Avery, 2021) suggest that excessive use of fertilizers can lead to soil acidification and nutritional imbalances, thereby lowering soil fertility and, consequently, crop yield. On the other hand, optimal fertilizer management improves agricultural yield and balks the negative impacts of climate change (scenario 3). A study conducted on wheat production in Egypt demonstrated that the application of balanced fertilizers significantly improved yield and quality (Achli et al., 2024). Other research on Morocco has found the positive effects of fertilizers on olive production, which is a key agricultural sector in the country (Bouhafa 2022).

The main findings about interest variables present a significant and negative relationship between precipitation and crop yield. The agriculture yield is reduced by 0.002 percent as precipitation related to climate change decreases in 5 MENA countries (Scenario 1). Scenarios 2 and 3 also yield the same outcomes with slight coefficient differences. As a result, all scenarios validate the fall in precipitation which leads to a drop in rain-fed agriculture specifically with the challenge of water scarcity. Several studies have found a direct link between precipitation levels and crop yields in MENA countries. For instance, (Amouzay et al., 2024) indicate that reduced rainfall significantly impacts the yields of wheat and barley, which are crucial for food security in the region Table 3.

Table 3
THE IMPACT OF CLIMATE CHANGE ON AGRICULTURE

Dependent Variable $AVAG_{it}$	Scenario 1	Scenario 2	Scenario 3
$AVAG_{it-1}$	0.9531	0.936	0.8607
	[0.000]***	[0.000]***	[0.000]***
HC_{it}	0.0054	0.0055	0.0082

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	[0.045]**	[0.022]**	[0.007]***
$GFCF_{it}$	0.0018	0.0059	0.0063
	[0.811]	[0.000]***	[0.021]**
FC_{it}	-	-0.0003	0.0003
		[0.275]	[0.089]*
Interest Variables			
TP_{it}	0.0168	0.0259	-
	[0.183]	[0.137]	
PR_{it}	-0.0029	-0.0032	-0.0021
	[0.088]*	[0.080]*	[0.000]***
CO_2	-	-	-1.1334
			[0.096]*
_Cons	0.7387	0.9785	3.2921
	[0.092]*	[0.056]**	[0.025]**
Number of Observation : N=5 T=22			
Diagnostic Tests	4.57	2.99	6.17
Sargan Test	P>0.10	P>0.10	P>0.10
Arellano Bond test for AR (2) test	-1.66	-1.7	-1.64
	P>0.10	P>0.10	P>0.10

(***) (**) (*) Indicate the significance at 1%, 5% and 10% respectively.

The results also show a positive link between temperature (TP_{it}) and agriculture in scenario 1 and 2. Also, CO2 emissions have a negative sign and are largely significant at the 5% level, which reflects a negative impact on agricultural yield (cereals, plants...) and food security. Certain studies indicate that elevated CO2 levels can lead to higher evaporation rates and altered precipitation patterns which affect negatively agriculture productivity and crop varieties. Other researchers suggest that increased CO2 can enhance photosynthesis leading to high crop yield. But these effects can diminish by other factors such as water scarcity, soil degradation, and extreme warm. Unprecedented rise of CO2 emissions lead to a significant increase of temperature which have serious implications for crop yields, water availability, and overall agricultural sustainability. In the same vein, (Waha et al., 2017) maintain that, while CO2 enrichment can increase yields, the continuous rise in temperatures can neutralize these benefits, leading to reduced overall productivity. In some areas, warmer temperatures associated with climate change may lead to longer growing seasons, allowing for multiple cropping cycles or the introduction of new crops.

Climate Change and Agricultural Trade

The findings of GMM estimation reveal the impact of climate change on agricultural trade in five MENA countries (Tunisia, Egypt, Morocco, Jordan and Lebanon). Two of these countries, Tunisia and Egypt, are non-OPEC members but are petroleum-exporting countries (petroleum comes as the top export product). Jordan has a developed banking sector and is among the emerging market economies. Morocco is one of the most important players in the African economy, with a services sector representing more than 60% of GDP. These countries, in fact, are not agricultural economies and agricultural products are negligible in

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their exports. MENA countries are basically importers of cereals. In terms of climatic variables, the results of table 4 show that a rise in temperature has negative and significant effect on agricultural trade in all scenarios at least at 5% level. Agriculture is highly vulnerable to temperature changes. Many countries in the MENA region already experience arid and semi-arid climates where rising temperatures can lead to lower crop yields, affecting agricultural exports.

In (El-Saady et al., 2023) emphasize trade patterns in the region and find that countries with elevated temperatures tend to import more food, particularly grains. It is also obvious that there is a negative and significant relationship between precipitation and agricultural exports since these economies are not agricultural countries and rainfall is low compared to other regions. The precipitation variable is a key determinant of crop yields. For instance, (Fahad et al., 2020) project that changes in precipitation can lead to significant fluctuations in agricultural production, which in turn impacts trade balances. In the same vein, (Wehrey et al., 2023) find that increasing temperatures and change in precipitation patterns will cause water scarcity, leading to lowered agricultural productivity. This scenario could result in greater dependence on food imports, converting trade dynamics in MENA region.

Table 4 illustrates the link between CO2 emissions and agricultural trade. This link has become increasingly important following climate change and food security challenge, influenced by environmental, economic, and social factors. For example, elevated CO2 can increase photosynthesis and potentially improve the yield of some crops such as wheat and rice. However, this benefit may be eliminated by other climate change factors such as rising temperatures and altered precipitation patterns, leading to lower crop yields and consequently higher food imports. The last scenario confirms these results. The MENA region is diverse, and the effect of CO2 on agriculture and trade varies significantly across countries. In (McCarl et al., 2013) find that Egypt's dependence on the Nile for irrigation makes it particularly sensitive to climate change, while investments in sustainable agriculture in Morocco remain promising. Some countries may opt for agricultural exports, particularly in the context of climate-smart agriculture practices that minimize emissions while improving productivity Table 4.

Table 4
THE IMPACT OF CLIMATE CHANGE ON AGRICULTURAL TRADE

Dependent Variable AT_{it}	**Scenario 1**	**Scenario 2**	**Scenario 3**
AT_{it-1}	0.7925	0.6464	1.0024
	[0.000]***	[0.000]***	[0.000]***
HC_{it}	-0.0745	-0.1368	-0.0344
	[0.243]	[0.100]*	[0.816]
$GFCF_{it}$	0.5507	0.9748	0.3002
	[0.010]***	[0.000]***	[0.403]
FC_{it}	-	-0.0159	-5.8982
		[0.025]**	[0.016]***
Interest Variables			
TP_{it}	-1.0028	-1.3672	-
	[0.025]**	[0.092]*	

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PR_{it}	-0.0963	-0.1615	-0.3896
	[0.007]***	[0.009]***	[0.026]**
CO_2	-	-	-8.8638
			[0.039]**
_Cons	33.5289	52.7432	50.2128
	[0.000]***	[0.012]***	[0.009]***
Number of Observation : N=5 T=22			
Diagnostic Tests	12.86	5.99	0.48
Sargan Test	P>0.10	P>0.10	P>0.10
Arellano Bond test for AR (2) test	-1.65	-1.66	-1.86
	P>0.10	P>0.10	P>0.10

(***) (**) (*)Indicate the significance at 1%, 5% and *10% respectively.

Regarding economic variables, The results show a negative relationship between human capital and agricultural trade. The workforce in the countries in our sample is characterized by its lack of skills and limited ability to use new technologies, which has a negative impact on agricultural productivity and the competitiveness of local products on world markets, leading to a significant drop in agricultural exports. Therefore, there is a need to improve and focus the quality of human capital to strengthen the development of the agricultural sector.

Agricultural investment and trade are positively and significantly correlated in most scenarios. As shown in Table 4, increasing agricultural investment in MENA countries leads to increased crop yields, which can consequently improve the competitiveness of agricultural products in domestic and international markets. Several studies indicate that countries that invest in modern agricultural techniques tend to experience higher agricultural exports (Alboghdady & El-Hendawy, 2016). Moreover, in recent years, government policies in these countries have attempted to support agricultural investment, either by subsidizing farmers or encouraging agribusinesses, to boost production and trade and build resilience to climate impacts. Fertilizers play a crucial role in increasing agricultural production and trade. According to the Food and Agriculture Organization of the United Nations (FAO, 2021), fertilizer consumption in the region has increased in recent decades due to growing food demand and efforts to improve agricultural productivity. Some studies also indicate that countries such as Egypt, Iran and Turkey are among the largest consumers of fertilizers in the region. Fertilizers, however, can have adverse effects on agricultural trade as the overuse of nitrogen fertilizers.

CONCLUSION

Climate change has been a very serious challenge for the economy, the environment, and for the daily lives and the livelihoods of people across the globe. The agricultural sector is regarded as one of the most vulnerable economic activities to climate change, especially in the MENA region. Although the literature on the impact of climate change is generally abundant, the link between climatic variables such as CO2 emissions and agricultural trade is not sufficiently examined. We have analyzed the effect of climate change on the agricultural sector in the five MENA countries (Egypt, Jordan, Lebanon, Morocco, and Tunisia) in 2000–2022 using dynamic panel data estimation. This model consists of control variables, such as investment, agricultural workers, fertilizer consumption**,** and interested variables, such as

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temperature, precipitation and CO2 emissions related to climate change. The model employed tested initially the relationship between climatic variables and crop yield and then agricultural trade in three scenarios. Diagnostic tests to panel data show that the econometric model is validated, and all variables used are statistically significant at a 5% level.

In general, on the basis of the empirical analysis we can conclude the following: First, we observe that climate change in the form of elevated CO2 emission and temperature with altering precipitation has negative impact on crops yield and consequently on domestic consumption. Reduced agricultural output due to evaporated water through elevated temperature can lead to increased imports of food goods, affecting exports and food security. Such variability may change trade dynamics and countries that traditionally export certain crops may find themselves importing them. Second, investment in agriculture is positively correlated with crop yields and trade in MENA countries. Third, investment in agriculture is positively correlated with crop yields and trade in MENA countries. This is explained by the investment effort in agricultural infrastructure, technology and research specifically since climate change, which impact positively not only productivity but also food imports and exports. Fourth, educated farmers and agricultural workers affect positively agriculture by implementing sustainable practices. Finally, it is observed that fertilizers are negatively correlated with agriculture. This can be explained as follows: In order to overcome the effects of climate change, farmers can increase the consumption of fertilizers to improve productivity and crop quality. However, excessive application and mismanagement of fertilizers can harm agricultural yield. This is due to the resulting soil degradation through erosion, increased salinity and loss of organic matter which consequently affects agricultural trade. There will be a decline in exports of agricultural products for exporting countries such as Tunisia and Morocco and an increase in imports.

Regarding policy implication, climate change poses a serious challenge that requires a combination of adaptive strategies, policy interventions and investments to build resilience to climate change in the MENA region. In terms of policy implications, climate change poses a serious challenge that requires a combination of adaptive strategies, policy interventions, and investments to build resilience to climate change in the MENA region. To resolve the water issue, these countries need to implement more efficient irrigation systems, such as drip irrigation, and promote rainwater harvesting to optimize water use. Increasing agricultural production requires efficient application of fertilizers to avoid soil degradation and salinization. Governments in the MENA countries need to further encourage the adoption of sustainable agricultural techniques such as Climate-Smart Agriculture that aims to reduce greenhouse gas emissions and pest management. They also need to implement more policies that help farmers mitigate the effects of climate conditions, including financial assistance, research funding, and infrastructure development. Other strategies that can support agricultural trade following climate change include investing in transport and storage infrastructure to reduce post-harvest losses and improve logistics efficiency. These practices can help to tackle the impacts of climate change on agriculture in the MENA region, strengthening the resilience of agricultural systems and ensuring food security.

Future research can examine the relationship between climate change and agriculture by examining other climate variables such as forest conversion and humidity. In addition, new control variables such as foreign direct investment, political instability and fertilizer prices could be added to the model and alternative econometric frameworks could be used as the short and long-run estimation.

END NOTE

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