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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

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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[3], 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 gas (GHG) emissions to a tolerable level of 2°C and to1.5°C in the next few years (Tekce and 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. 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 Akram (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 and 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

[3] https://www.worldbank.org/en/region/mena/brief/climate-and-development-in-the-middle east-and-north-africa

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has an overall negative effect but remains weak. 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 and Çakmak (2018) conclude that the rise of temperature and reducing precipitation could seriously threaten global food security. Doğan and 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 and 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...

This paper contributes to the existing literature on several grounds. First, while 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. This study ultimately highlights some policy action to tackle climate change in studied countries.

The main objective of this paper is to investigate the relationship between climate change and production and trade agriculture in five MENA countries, namely: Tunisia, Morocco, Egypt, Jordan and Lebanon over the period 2000–2022. All equations are estimated using a GMM method and a Dynamic Panel.

The remainder of the paper is structured as follows: Section two describes the data, analytical techniques, and model specifications. Section three summarizes the main results and discussion, with a focus on the key findings. The fourth section concludes the main themes and implications of the findings. The last concluding section discusses some policy actions based on the key empirical results.

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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. Niang et al. (2014) 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 and 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. Figure 1 depicts the World Bank's estimate[4] of the increase in water scarcity in MENA countries in 2050. The variability in precipitation patterns affects water availability for irrigation, causing water stress in agricultural regions. Rising evaporation rates and changes in river flow further intensify water shortage problems, particularly in arid and semi-arid countries.

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

[4] World Bank report (2018) ″The Water-Energy-Food Nexus in the Middle East and North Africa: Scenarios for Sustainable Future″.

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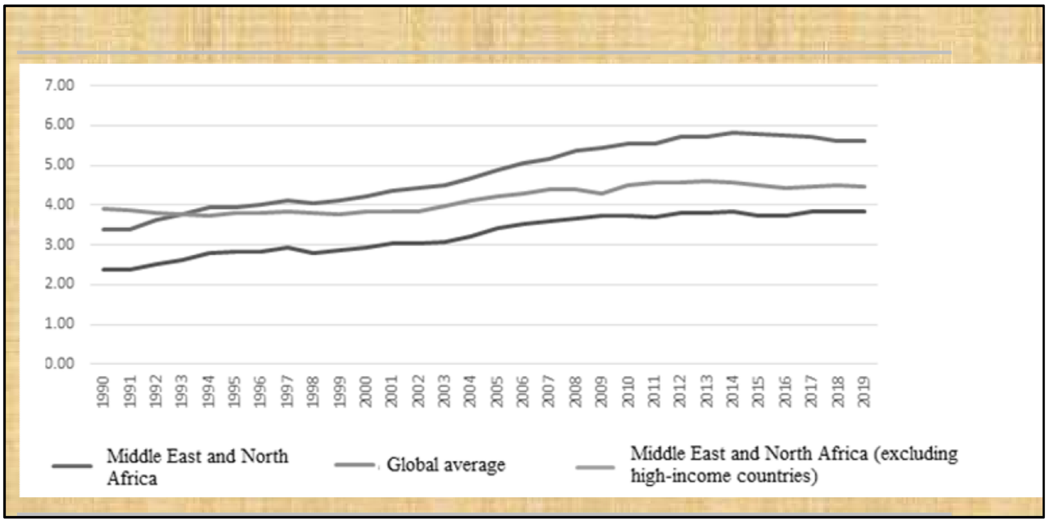
fluctuations constitute the most important source of risk which affects directly or indirectly agricultural production. Pickson et al. (2020) suggests that increasing temperatures and changes in precipitation patterns have a direct impact on the timing of crop growth. Arable land becomes unsuitable for 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.

Figure.1 Projected range of Water scarcity increase in MENA countries by 2050



Source : World Bank, 2022

As we know, the increase in temperature is attributed to the increase in GHG (Green House Gases) emissions. Figure2 shows the substantial change in CO2 emissions of MENA countries, which is the main GHG, emitted by activities such as the combustion of fossil fuels (natural gas, coal, and oil). According to the World Bank[5], the increase in CO2 levels is expected to increase significantly from 1990 to 2050. This is becoming a significant factor affecting agricultural

[5] The report of World Bank (2021) "The economic impact of climate change on agriculture in the MENA region".

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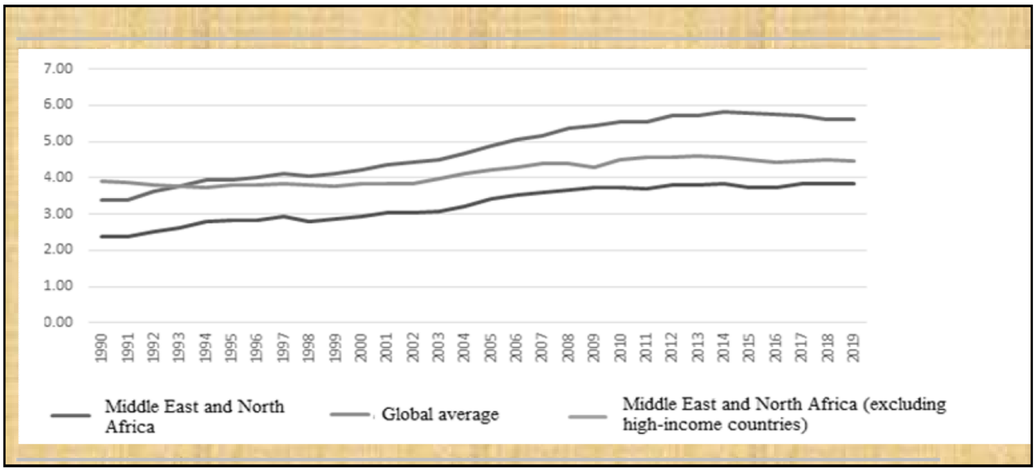
productivity. Some research has been carried out to study the effect of CO2 emission on agriculture in the MENA region, focusing on crop yields, water resources, soil health, and other socio economic indicators. Zhao et al. (2017) find that high CO2 concentrations could increase the yield of staple crops 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.

Figure.2 Change of Carbon dioxide emissions (Metric Tons per capita) in the MENA countries



Source : World Bank, 2022

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 and El-Hendawy (2016) indicate that while some farmers may profit from increased yields due to higher CO2, 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

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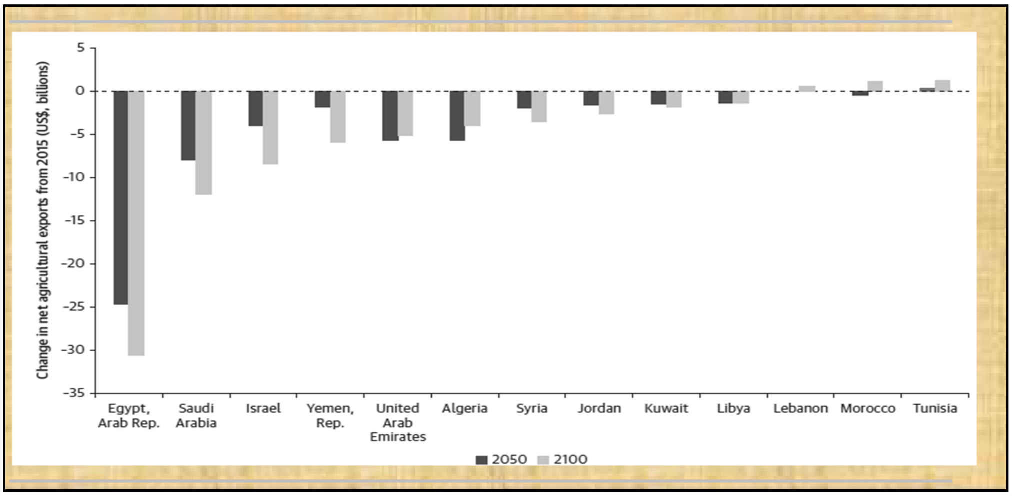
always guarantee food security if markets and infrastructure are less developed. Therefore, policy makers must give more importance to resource management and sustainable agricultural practices to overcome climate change, ensure food security and agricultural trade.

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 (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. As seen in figure 3, the drop in agricultural production has significant economic consequences, and is expected to lead to a total reduction of around $50 billion in net agricultural exports by 2050.

Figure.3 Projected change in the net agricultural exports in the MENA countries



Source : World Bank, 2022

Water scarcity is a problem in the MENA region, where agriculture is so dependent on irrigation. According to the Food and Agriculture Organization (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)

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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.

Although climate change and agricultural trade are discussed in various aspects in the literature, empirical studies in MENA countries are limited. This study attempts to address two points. The first is associated with the empirical papers concentrating on climate change and agricultural trade which had controversial findings. In addition to previous studies, this study uses a 22-year (2000–2022) dataset covering panel data from MENA countries. This increases the validity and reliability of the model results. The second gap is associated with effective practices for sustaining agricultural trade such as Climate-Smart Agriculture (CSA).

SPECIFICATIONS, METHODOLOGY, DATA AND MODEL

MENA countries are generally grain importers, not exporters. This region is characterized by its arid and semi-arid climate which makes agriculture particularly vulnerable to climate change. According to the international classification, 5 are among the world's first 20 largest cereal importers and 4 are among the world's first 20 largest wheat and meslin importers. This section deals with the econometric method to investigate the relationship between climate change and agricultural trade. The Dynamic Lag Effect is essential for agricultural trade because climate change may take some time to impact the agriculture sector and the trade balance. For example, areas that are vulnerable to climate change experience a drop in production, therefore a decline in supply and an increase in agricultural prices. This is the direct impact. Overall, considering the dynamic effect when analyzing climate change can bring about a more accurate and comprehensive understanding of the dynamics of agricultural trade. As a result, in this study, we use a dynamic panel data model to focus on the dynamic effect of climate change.

Several different econometric methods have been used to estimate dynamic panel data model. The DPD model owns for the endogeneity of explanatory variables and accounts for unobservable, time-invariant country effects (Urfalıoğlu Şahin and Yerdelen Tatoğlu, 2022).To eliminate the endogeneity concern with explanatory variables, Arellano and Bond (1991) estimated the difference generalized method of moments (difference GMM), in which instrumental variables are used to derive the GMM of the corresponding moment conditions. The basic idea is that this method takes the first difference of the regression to remove the individual fixed effects and then utilizes the

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lagged variable as the instrumental variable of endogenous variables. Although it is an important method to reduce the endogeneity problem, it suffers from the problem of "weak instruments" in the case of small samples and results in low precision (Bond et al., 2021).As a solution to this problem, the system GMM estimator of Blundel and Bond (1998) combines the first difference equations with the level equations. The instruments in the first difference equation are expressed in level, and vice versa.

$$\Delta Y_{it} = \beta_0 + \beta_1 \Delta X_{it} + \alpha \Delta Y_{it-1} + \Delta \vartheta_i \ (1)$$

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \alpha Y_{it-1} + \vartheta_i + \varepsilon_{it} \ (2)$$

$$i = 1, \dots\dots\dots.., N; t = 1, \dots\dots\dots, T$$

Where α is persistence autoregressive parameter; β_1 is a vector of parameters to be estimated, Y_{it-1} endogenous lagged dependent variable, X_{it} is a vector of strictly exogenous covariates, ϑ_i are the panel-level effects (which may be correlated with the covariates), and ε_{it} is iid disturbance term. ϑ_i and ε_{it} are assumed to be independent for each i overall t. The Method of GMM System can accommodate omitted variable biases; multicollinearity problems, unobserved country heterogeneity issues, and error analysis that are common in regression methods fixed effects and pooled OLS. The Method of GMM System 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. In addition, it's more efficient and gives better results than the other GMM estimators which create biased estimates.

Hence, this study is based on the system GMM estimation method for the dynamic panel data analysis. 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. There are two different GMM systems, i.e one-step and two-step estimation methods. In fact, the application of a one-step GMM system is recommended for a model with a restricted number of countries and a longer time period, and a two-step GMM system is used for a model with a large number of country and a shorter period. Therefore, given that our analysis involves data from 5 MENA countries over 22 years, we preferred the findings of the tow-step GMM system.

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The data and variables[6]

This empirical study is conducted using panel data from five MENA countries (i.e., Egypt, Jordan, Lebanon, Morocco and Tunisia[7]) over 22 years (2000–2022).This follows two essential criteria: First, most of the countries are cereals importers. Second, these economies are generally not agricultural although some of them depend on the export of some agricultural products like Tunisia and Morocco. The time period covers precisely the years when climate change is an important concern worldwide.

The dependent variable is expressed by two measures**,** namely the added value of agriculture as a percentage of GDP and trade export which denotes agricultural raw materials exports as % of merchandises exports.

The interest variables are temperature, rainfall 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.

A set of control variables is considered to isolate the effects of interest variables. They are inspired by both the theoretical model and the literature: Human capital, fixed capital and Fertilizer consumption.

* Human capital is calculated as a percentage of working population, associated with the knowledge, skills, experience, and health that individual's hold, which can boost their productivity and efficiency in various sectors, including agriculture. In the theoretical literature, a positive relationship was found between human capital and agricultural output. Workforce has a crucial role in increasing agricultural production through skills development, health, decision-making, innovation, and social collaboration.

* Fixed capital is expressed as a percentage of GDP, which designates long-term assets that are not easily converted into cash and are used in the production process. In the context of agriculture, fixed capital involves items such as: Land, Perennial Crops and Plantations and Irrigation Systems. The linkage between fixed capital and agriculture is significant and multifaceted. For instance, capital investments in irrigation infrastructure can enhance water management, making better crop yields,

6 See the series of interest variables in appendix
[7] These countries have a similar level of development and climatic conditions. The added value created in this region comes mainly from certain activity, such as agriculture, tourism and textiles.

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specifically in drought areas. Also, investments in fixed capital improve farming practices, higher yields, and lead to better quality produce.

* Fertilizer consumption represents potash, nitrogenous, and phosphate fertilizers including ground rock phosphate. Consumption rates are measured in kilograms per hectare of arable land. Moreover, the relationship between Fertilizer use and agriculture covers a wide area of theoretical and empirical research; this can be understood through several key dimensions involving economic, social, environmental, and technological factors. Many studies have confirmed a positive correlation between crop yields and fertilizer use in the MENA region, since the application of nitrogen, phosphorus, and potassium fertilizers improve soil fertility and boost agricultural productivity.

As a result, the variables and their predicted signs are described in Table 1 based on empirical studies and economic literature.

Table 1.Variable Descriptions and their expected signs

Variable name	**Expected Signs**	**Source**	**Definition of variables**
Agriculture (AVAG)	+	WDI	Agricultural value added in USD.
Agricultural trade(AT)	-	WTO	Agricultural raw materials exports as % of merchandises exports.
Temperature (TP)	-	WMO	The annual average of temperature is calculated using monthly data.
Precipitation (PR)	+/-	WMO	The annual average of precipitation is calculated using monthly data.
CO2 emissions (CO2)	-	WDI	CO2 emissions per unit of GDP are expressed in Kiloton.
Human capital (HC)	+	WDI	Percentage of working population.
Fixed capital (FC)	+	WDI	Gross fixed capital formation as a percentage of GDP.
Fertilizer consumption (FC)	+/-	WDI	kilograms per hectare of arable land.

As can be seen from Table 1, annual average temperature and rainfall data were collected from the World Meteorological Organization (WMO). However, the CO2 emissions data were expressed in Kiloton per unit GDP and available on the site of the World Development Indicators (WDI, 2010), including other economic variables such as the added value of agriculture, human capital, fixed capital, and fertilizer consumption. Agricultural trade values were collected from the

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World Trade Organization (WTO) website. Some of them are used in the form of natural logarithms to reduce the heterogeneity data issues.

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

Table 2 calculates Pearson's correlation coefficients between the study variables. The first column visualizes correlation coefficients among the dependent variables, interest, and control variables. However, the other columns denote correlation coefficients between interest and control variables. Table 2 shows that agriculture (AVAG) has negative correlation with precipitation (PR), CO2 emissions. Conversely, agriculture has a positive correlation with temperature (TP), investment (FBCF), agriculture labor force (HC) and fertilizer consumption (FC). Hence, to enhance the quality of the model and to eliminate multicollinearity, we involve AVAG and AT in the model as different scenarios, not in the same model.

Model specification

The present study investigates the impact of climate change on agriculture production (AVAG) and trade (AT) in MENA countries using climatic factors such as temperature, precipitation, and carbon emissions. The dynamic panel data model is developed as in Equation (3):

$$\mathrm{AVAG_{it}} = \beta_0 \mathrm{AVAG_{it-1}} + \beta_1 \mathrm{TP_{it}} + \beta_2 \mathrm{PR_{it}} + \beta_3 \mathrm{CO2_{it}} + \beta_4 \mathrm{HC_{it}} + \beta_5 \mathrm{GFCF_{it}} + \beta_6 \mathrm{FC_{it}} + \varepsilon_{it} \quad (3)$$

The basic model examined in our empirical validation essay is drawn from the literature on climate change and its impact on agriculture. We postulate that agricultural production and trade are function of their lagged values and climatic variables such as temperature (TP), precipitation (PR) and CO2 emissions (CO2).Agriculture labor force (HC), global fixed capital formation (GFCF) and

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Fertilizer consumption (FC) are used as instrumental variables to control the endogeneity problem. Thus, we define:

$\mathrm{AVAG}_{\mathrm{it}}$: The added values of agriculture

AT_{it} : Agricultural trade for country (i) in year t.

TP_{it} : The annual average temperature for country (i) in year t.

PR_{it}: The annual average of precipitation for country (i) in year t.

$CO2_{it}$: CO2 emissions per unit of GDP for country (i) in year t.

HC_{it}: Percentage of working population for country (i) in year t.

$GFCF_{it}$: The global fixed capital formation for country (i) in year t.

FC_{it}: Fertilizer consumption for country (i) in year t.

ε_{it}: Stochastic error term capturing other factors that influence climate change on agriculture.

Furthermore, the coefficients for independent variables are meant to be measured by $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ and β_6.We adapt our analysis keeping in view the objective of the Egypt and the availability of data, using Blundell–Bond's (1998) GMM-system two-step estimator. We hypothesize that as a result of global warming, i.e. an increase in temperature and a decrease in precipitation, there will be a negative effect on agricultural production and, perhaps, agricultural trade and vice versa. By contrast, a high number of workers, a high investment effort and developed Fertilizer consumption will have a positive effect on agriculture production and trade. These hypotheses are supported globally by the literature.

ANALYSIS OF RESULTS

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. 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

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(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 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. 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., 2023). 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).

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The main findings about interest variables present a significant and negative relationship between precipitation (PR_{it}) and crop yield ($AVAG_{it}$).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.The impact of climate change on agriculture

Dependent Variable $\mathbf{AVAG_{it}}$	**Scenario 1**	**Scenario 2**	**Scenario 3**
Control Variables			
$AVAG_{it-1}$	0.9531393	0.9360047	0.8607668
	[0.000]***	[0.000]***	[0.000]***
HC_{it}	0.0053613	0.005552	0.0082294
	[0.045]**	[0.022]**	[0.007]***
$GFCF_{it}$	0.0018327	0.005861	0.0063634
	[0.811]	[0.000]***	[0.021]**
FC_{it}	-	-0.0002684	0.0003625
		[0.275]	[0.089]*
Interest Variables			
TP_{it}	0.0167836	0.025893	-
	[0.183]	[0.137]	
PR_{it}	-0.0029045	-0.0032362	-0.0020987
	[0.088]*	[0.080]*	[0.000]***
$CO2_{it}$	-	-	-1.133401
			[0.096]*
_Cons	0.7387288	0.9785503	3.2921
	[0.092]*	[0.056]**	[0.025]**
Number of Observation			
N=5 T= 22			
Diagnostic Tests			
Sargan Test	4.57	2.99	6.17

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	P>0.10	P>0.10	P>0.10
Arellano Bond test for AR (2) test	-1.66	-1.70	-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 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. Moreover, extreme temperatures can lead to more severe droughts, further stressing agricultural systems and potentially leading to elevated imports of food.

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As a matter of fact, s temperatures increase and crop yields decline, these countries may become more reliant on agricultural imports. 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. This dependence on imports can lead to high vulnerability to overall market fluctuations. 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. When precipitation is low, countries may experience lowered exports and increased imports to meet domestic demand. Conversely, high precipitation can improve export potential. 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. Most MENA countries are largely dependent on food imports. Variability in agricultural output due to CO2 and climate change can impact their ability to produce domestically more food, leading to increased import reliance and vulnerability to global market volatility. The MENA region is diverse, and the effect of CO2 on agriculture and trade varies significantly across countries. McCarl and Musumba (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.

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Table 4.The impact of climate change on agricultural trade

Dependent Variable $\mathbf{AT_{it}}$	**Scenario 1**	**Scenario 2**	**Scenario 3**
Control Variables			
AT_{it-1}	0.7925572	0.646388	1.002427
	[0.000]***	[0.000]***	[0.000]***
HC_{it}	-0.0745675	-0.1368775	-0.0343749
	[0.243]	[0.100]*	[0.816]
$GFCF_{it}$	0.5507326	0.9748267	0.300203
	[0.010]***	[0.000]***	[0.403]
FC_{it}	-	-0.0159526	-5.898194
		[0.025]**	[0.016]***
Interest Variables			
TP_{it}	-1.002792	-1.367193	-
	[0.025]**	[0.092]*	
PR_{it}	-0.0962978	-0.1614707	-0.3896697
	[0.007]***	[0.009]***	[0.026]**
$CO2_{it}$	-	-	-8.863827
			[0.039]**
_Cons	33.52896	52.74319	50.21282
	[0.000]***	[0.012]***	[0.009]***
Number of Observations			
N=5 T= 22			
Diagnostic Tests			
Sargan Test	12.86	5.99	0.48
	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.

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Regarding economic variables, agricultural investment and trade are positively and significantly correlated in most scenarios. As shown in Table4, 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 and 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, for instance, can lead to soil degradation and water pollution, which can impact crops and consequently agricultural exports. Avery (2021) suggest that over-reliance on chemical fertilizers can lead to water pollution and soil degradation, which may ultimately impact agricultural trade negatively. It is, therefore, necessary to use sustainable practices with balanced fertilizer consumption to maintain competitiveness in global markets.

CONCLUSION AND POLICY IMPLICATION

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 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

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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

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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.

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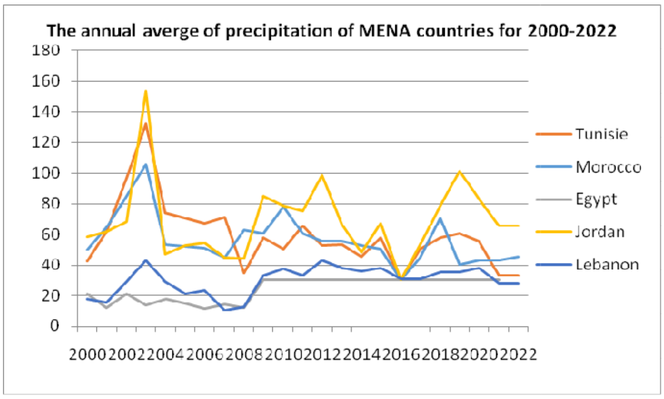
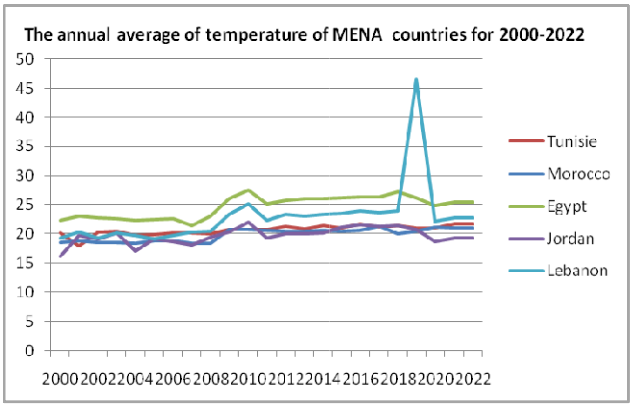
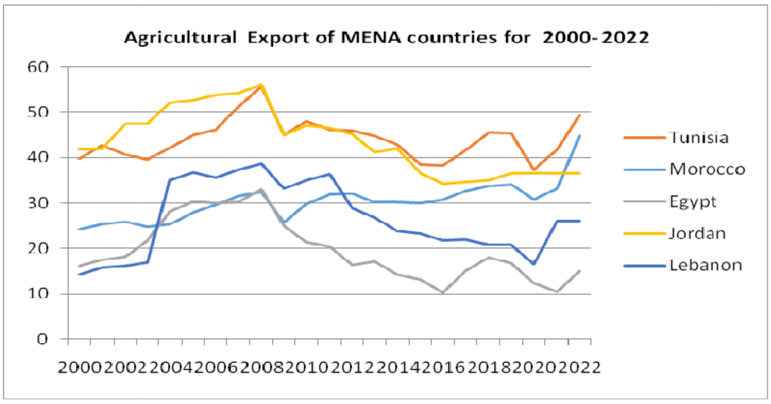
APPENDIX







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