

Article

Climate Change and Food Security in the Northern and Eastern African Regions: A Panel Data Analysis

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Abstract: The problem of food insecurity is growing across the world, in particular in developing countries. Due to their economic structure, climate change represents one of the major threats for food security levels in African countries. The object of this work was to assess the impact of climate change on the level of food security in the North and East African countries, using a panel data analysis for the period 2000–2012. Average protein supply and average dietary energy supply adequacy were the two different indicators of food security we identified as most appropriate. Indeed, both indicators can provide information concerning the amount and the nutritional value of food supply. The determinants of food security are expressed as a function of rainfall, temperature, land area under cereal production, size of population and GDP. Findings showed that food security in the Northern and Eastern African countries is adversely affected by climate change. Policy makers need to promote those actions capable of mitigating global warming and reducing its economic impact.

Keywords: food security; climate change; panel data analysis; Africa



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1. Introduction

Over the last several decades, for almost all parts of northern Africa, there has been a considerable warming trend that is more pronounced in the summer, particularly concerning minimum temperatures [1]. The warming trend has included increases in hot nights and heat waves and also a reduction in cold waves [2–4]. As regards the quantity of rainfall, over the last few decades, there has been a decrease in the mean precipitation during the wet season, which extends from October to March, with the greatest decrease found in the Mediterranean Area: Morocco, Libya and Algeria for example [5–7]. Besides the decline in the amount of rainfall during the wet season, since the 1970s, an accompanying drying during winter has also been detected in large areas of western North Africa [8], leading to food safety problems. If, on the one hand, it is possible to affirm that there have been no notable trends of heavy rainfall events over most parts of North Africa in recent decades [9,10], on the other hand there has been a general increase in drought frequency all over [5].

For these reasons, in the recent years North Africa has been considered a “climate change hotspot” [11] and has been receiving increasing attention from natural and social scientists. Researchers of climate change, for example, have highlighted the great year-to-year variability of rainfall quantity and the consequent drought periods and heat waves [12,13]. Several studies have analyzed the effect of climate change on the water situation and agricultural production. For instance, Schmitz et al. [14] have forecast an increasing lack of water in North Africa, whereas Alboghdady and El-Hendawy [15] have demonstrated that a 1% rise in winter temperature leads to a 1.12% lowering of agricultural production in the Middle East and North Africa (MENA), worsening the problem of food safety. Some social scientists have affirmed that the water scarcity problem in the MENA region is “man-made” [16] and mostly due to great population growth. Other researchers, instead, have stressed that climate changes like decreased rainfall or more inconsistent rainfall, major causes of water scarcity, whose greatest impact is on the poorer inhabitants of the rural

areas [17]. Scheffran et al. [18] examine the situation from a different perspective, stating that in regions that depend on rain-fed agriculture, droughts can lead to an increased risk of civil conflict (see also [19]).

Obviously, in any of these cases, climate change will increase stress on water supply in the future [20], which leads to numerous consequences for food production and security levels [21].

As per the Intergovernmental Panel on Climate Change (IPCC), climate change is negatively affecting crops, livestock, and fisheries and general, agricultural production. Indeed, climatic variability represents one of the major threats for the agricultural sector and food security in the shape of damage to rural livelihoods, the loss of marine and inland water ecosystems and the disruption of food systems [22]. For instance, we can consider the destruction to the stability and food security of tropical communities hit by natural disasters. In fact, these tropical zones are regularly subject to food insecurity crises, in particular since the agriculture sector employs anywhere from 30 to more than 80 per cent of the population [23].

In recent years, we can find evidence of climate change in drought and high temperatures in Northern Africa, as well as other areas of Africa, which have negatively impacted agriculture [24]. Consequently, estimates of severe food insecurity all over Africa are increasing more and more [25].

Following the lines of the concepts established by the FAO (1996), food security is obtained 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” [26]. Therefore, the concept of food security includes four aspects: food availability, economical and physical accessibility, utilization and stability. Thus, it is not only sufficient to produce enough food to meet global needs, but it is also necessary that everyone be able to get this food in a timely fashion, and have access to the appropriate quantities and quality.

Nevertheless, there are few empirical studies that investigate the effects of global climate change on food security in Africa. This research is important to help policy makers devise agricultural policies that are easily adaptable to climate change, while at the same time safeguarding food security [27]. This paper attempts to evaluate the link between various climate-change factors, such as temperature and precipitation, and food security in Northern and Eastern African Regions (See Appendix A).

The rest of this paper is structured as follows. Section 2 explores climate change in Africa; Section 3 describes the applied methodology used in the empirical analysis; Section 4 explains the data used in this study; Section 5 shows and elaborates the final results; and lastly, Section 6 illustrates the principal conclusions and the policy ramifications.

2. Climate Change in Africa

In the agricultural sector, irrigation represents one of the key factors in food production. Unfortunately, most of the area of North Africa is covered by semi-arid areas or by the desert.

In particular, as regards Egypt and Tunisia, they hold less than 10% irrigated land. In these areas, arable land does not even reach 5% of the total surface [28], highlighting the limits of agricultural production and food security in these territories.

The strong territorial and water constraints impose the presence of a highly concentrated agriculture along the Nile and based on an intensive use of chemical inputs [29].

Due to these territorial stresses: climate change, water scarcity and food insecurity, developing countries have problems keeping a sustainable agricultural system in arid areas.

Most small-scale agricultural systems such as those in African countries are highly dependent on climate shocks, so variations in temperature or rainfall can affect the crop resulting in reduced yield or crop [30].

In this direction, many studies try to assess the impact of climate change on African regions, focusing on rainfall and temperature variability as with Philandras et al. [31] and

Cook et al. [12]; in their studies there have been estimates of a reduction in rainfall of around 20% with respect to the period 1960–1990. In this direction, findings of other studies report a progressive diminution in the quantity of rainfall in the Northern and Eastern African Region [14,32]

Figures 1 and 2 show the average value of climate variables in the sample for the period 2000–2012; from the trend of the two variables it is possible to affirm that the drought phenomenon will tend to be more frequent with a general increase in temperature and a reduction in the average level of rainfall.

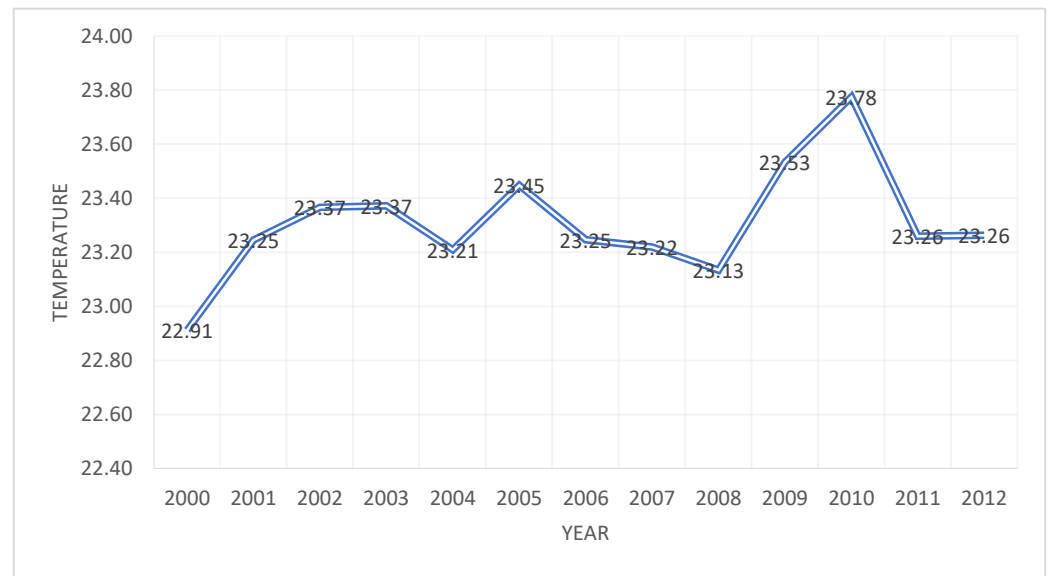


Figure 1. Average Temperature of Northern and Eastern African Regions.

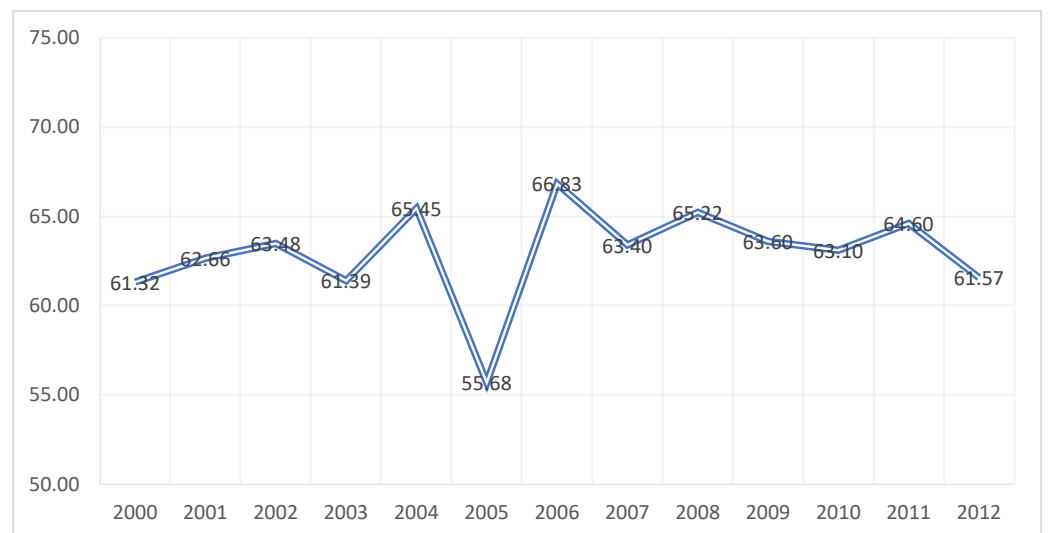


Figure 2. Average quantity of Rainfall, Northern and Eastern African Regions.

3. Materials and Methods

The objective of this paper is to analyze the link between food security level and climate change in Northern and Eastern Africa, according to previous studies [21,33–36]. In order to assess climate change effects on food security level we adopted a panel data analysis. This particular methodology allows us to analyze the same statistical unit in different instants. To represent this phenomenon, it is necessary to introduce a double index, $i =$ to indicate the statistical unit (m), and $t =$ to represent the time [37,38].

With this assumption a linear econometric model involving such data then takes the following form:

$$y_{i,t} = x'_{i,t}\beta + u_{i,t} \quad i = 1, \dots, M, \quad t = 1, \dots, T,$$

where β is the parameter to estimate.

Where $u_{i,t}$ is the error, in this particular methodology the error depends on both the characteristics of the single statistical unit and the random component.

When m statistical units remain the same over the time t the data are called “panel data” [39]; they are, instead, “pooled data” if they refer to different statistical units (statistical units m for each instant t , which do not remain the same as t varies) [40].

In the presence of panel data, there are different techniques to estimate the parameter β as panel data with fixed effects and panel data with random effects.

As previously stated, the aim of this work was to analyze the causal relationship between climatic variability and food security with a linear econometric model. For our analysis the econometric model is the following:

$$Y_{i,t} = \alpha_{i,t} + \beta X_{i,t} + \varepsilon_{i,t} \quad (1)$$

where $X_{i,t}$ is the matrix of explanatory variables, in our case: precipitation, temperature, population growth, land under cereal production, GDP growth and GDP per capita; in a country i for a period t . $\alpha_{i,t}$ indicates the specific effects unobserved in a country and $\varepsilon_{i,t}$ is the error term. Finally, $Y_{i,t}$ is our dependent variable food production index (FPI) representing food security [36].

4. Data Source and Data Description

We used panel data composed by Northern and Eastern African Regions for a total of 19 countries, over the period 2000–2012. We used this time frame based on data availability. This data range has been selected in order to obtain balanced panel data for our model.

The variables were selected through the analysis of the previous empirical literature [21,33–36]. The data for this study were extracted mainly from two datasets: the Climate Change Knowledge Portal and the World Development Indicators Database. Both databases come from the World Bank [41,42]. Our model included both climatic variables such as Temperature and Precipitation, and non-climatic variables such as population growth, land under cereal production, GDP growth, GDP per capita and Quality of Government; the non-climatic variables considered the entire quantity of economic resources, those available for agricultural production and the credibility level of the government in the implementation of policy. The dependent variable in the first model was the Food production Index (FPI); this variable indicates the quantity of food crops that are edible and contain nutrients (excluding coffee and tea, since they have no nutritional value), computing the variations in food production per any given year relative to the base year. The dependent variable used in the second model was average protein supply (av. Protein supply); this variable expresses the national average protein in grams daily per capita in each country. We also chose to perform an additional analysis in order to give robustness of our results. As concerns climatic variables, precipitation (Precipt) refers to the quantity of rainfall as measured in (mm) and temperature (Tempt) indicates the average annual temperature for each country expressed in centigrade ($^{\circ}$ C). For non-climatic variables, Population growth (pop growth) indicates the annual grow rate in the population measured as a percentage (%), Land under cereal production (LC) refers to harvested area of cereals and is measured in hectares, Gross Domestic Product (GDP growth) indicates the annual growth rate of GDP as a percentage (%) and finally, Gross Domestic Product (GDP per capita) refers to the total value of all goods and services produced by a country in one year, divided by the number of people living there.

Table 1 presents the variables and data source and Table 2 shows their summary statistics.

Table 1. Variables and data sources.

Variables	Unit	Data Source	Time Period
Food Production Index (FPI)	N°	World Development Indicators	2000–2012
Average protein supply	(g/cap/day)	FAOSTAT	2000–2012
Precipitation	mm	Climate Change Knowledge Portal	2000–2012
Temperature	°C	Climate Change Knowledge Portal	2000–2012
Population growth	Annual Percentage %	World Development Indicators	2000–2012
Land under cereal production	hectares	World Development Indicators	2000–2012
GDP growth	Percentage %	World Development Indicators	2000–2012
GDP per capita	USD	World Development Indicators	2000–2012
Quality of Government	N°	Worldwide Governance Indicators	2000–2012

Table 2. Summary Statistics.

Variables	Mean	Standard Deviation	Maximum	Minimum
Food Production Index (FPI)	104.372	20.063	180.33	66.13
Average protein supply	63.440	18.837	102.7	36.4
Precipitation	68.277	45.210	180.597	1.568
Temperature	23.292	2.129	27.761	18.059
Population growth	2.331	0.865	5.604	0.233
Land under cereal production	2,062,097	2,132,024	9,690,734	14,354
GDP growth	4.540	4.433	19.675	−17.668
GDP per capita	1307.575	1217.187	4777.427	194.873
Quality of Government	36.17	14.222	72.45	2.87

As described in the previous section, the object of this study was to evaluate climate change impact on food security level in the Northern and Eastern African Regions through a panel data analysis. According to prior studies, Kinda [34] and Mahrous [36], we used the econometric model as in Equation (1). So as to better the robustness of the empirical results we conducted, for each of the two different econometric models, two different panel data analyses, i.e., panel data analysis with fixed effect (FE) and panel data analysis with random effect (RE), with the variables described in Equations (2) and (3). Data on Food Production Index (FPI), Average protein supply (Av. protein supply) Precipitation (Precipt), Temperature (Temp), Land under cereal production (LC) and Gross domestic Product per capita (GDP per capita), were converted into natural logarithms to facilitate the estimation process.

$$\begin{aligned}
 \text{LnFPI}_{i,t} = a + & \beta \text{LnPrecipt}_{i,t} + \gamma \text{LnTemp}_{i,t} + \delta \text{Popgrowth}_{i,t} + \vartheta \text{LnLC}_{i,t} \\
 & + \theta \text{GDPgroth}_{i,t} + \omega \text{LnGDP per capita}_{i,t} \\
 & + \tau \text{Ln Quality of Government}_{i,t} + \varepsilon_{i,t}
 \end{aligned} \quad (2)$$

$$\begin{aligned}
 \text{LnAv. proteinsupply}_{i,t} &= a + \beta \text{LnPrecipt}_{i,t} + \gamma \text{LnTemp}_{i,t} + \delta \text{Popgrowth}_{i,t} \\
 &+ \vartheta \text{LnLC}_{i,t} + \theta \text{GDPgroth}_{i,t} + \omega \text{LnGDP per capita}_{i,t} \\
 &+ \tau \text{Ln Quality of Government}_{i,t} + \varepsilon_{i,t}
 \end{aligned} \quad (3)$$

5. Results and Discussions

Taking into consideration the possibility of collinearity in the model, a correlation analysis between the independent variables was carried out. Table 3 shows the correlation results [43]. From the results, we can affirm that there is not collinearity in the model.

Table 3. Correlation analysis.

Variables	Precipt	Temp	Pop Growth	LC	GDP Growth	GDP per Capita	Quality of Government
Precipt	1						
Temp	−0.0735	1					
Pop growth	0.4432	0.2053	1				
LC	−0.3103	−0.0585	−0.0811	1			
GDP growth	0.0815	0.0469	0.1861	0.2289	1		
GDP per capita	−0.6075	−0.1805	−0.6349	0.0446	−0.1195	1	
Quality of Government	−0.4568	−0.0448	−0.1980	−0.0018	−0.0277	0.431	1

Table 4 summarizes the results of the two different panel data analyses for each econometric model. The values in the table are: coefficients, their *p*-values, standard errors (in parentheses) and summary statistics.

Table 4. Panel analysis Results.

Dependent Variable: Ln FPI	FE Estimation (1)	RE Estimation (2)	Dependent Variable: Ln Av. Protein Supply	FE Estimation (3)	RE Estimation (4)
Constant	3.18705 *** (0.304070)	3.41200 *** (0.305904)		0.922328 (0.568455)	1.35550 (1.10431)
Ln Precipt	(0.108008) *** (0.0403668)	0.0536363 *** (0.0108284)		0.0393907 *** (0.148237)	−0.035746 ** (0.01635)
LnTemp	−0.430779 * (0.0836571)	−0.6486935 ** (0.256981)		0.546343 ** (0.274371)	−0.295450 * (0.314625)
Pop growth	0.0474747 * (0.0450011)	0.0398197 ** (0.0184540)		0.00390901 (0.0126538)	0.0099765 (0.0109567)
Ln LC	0.235136 ** (0.0434515)	0.0240474 *** (0.0108883)		0.0139367 ** (0.0186582)	0.0555214 ** (0.035356)
GDP growth	−0.00446078 (0.00346057)	0.00254876 (0.00204747)		0.0003158 (0.0009826)	0.0009358 (0.0009868)
Ln GDP per capita	0.708465 *** (0.147963)	0.0801060 *** (0.0181190)		0.192221 *** (0.0315943)	0.181851 *** (0.0388945)
Ln Quality of Government	0.0348776 * (0.0730188)	0.105895 ** (0.0620979)		0.0051399 (0.0153350)	0.00317527 (0.0158576)
<i>R</i> ²	0.712			0.776	
<i>SER</i>	0.20234	0.216997		0.27718	0.16098

Note: *, **, *** indicate 10%, 5% and 1% significant levels, respectively.

Table 4 shows the results of our analysis. In the column labelled (1) we investigate the relationship between climate change and food security level through a panel data analysis with fixed effect, while in column (2) with a random effect for the first econometric model; while in the columns labelled (3) and (4), the results for the second econometric model with the dependent variable *Ln Av. Protein supply* are presented.

From the results we can affirm that climate change, land cultivated and economic availability play an important role in determining the food security level in Northern and Eastern African Countries.

The *Precipitation*, *Land under cereal* and *Gross Domestic Product per capita* variables have a significant impact on our dependent variable *Food Price Index*. Regarding the specific impact for each variable, the results indicate that rainfall quantity has a positive impact on food security level; in particular, the food security level increases by 0.05% with a 1% increase in the level of precipitation. This value can be justified by the importance that rainfall plays in agriculture in the regions of North and East Africa. An increase in rainfall could generate an increment in agricultural production, household income and the food security level [44,45]. For the *Land under cereal* variable the results indicate that there is a positive and significant relationship between cultivated land area and food security levels. Any increase in land under cereal cultivation raises the food security level. This result is in agreement with previous studies [46–48]. Therefore, an increase in the cultivated area corresponds to greater agricultural production and consequently to an increase in the food security level for each nation. Finally, the empirical results confirm the relevance of the economic aspect in food security level. In particular, there is a positive and significant relation (p -value < 0.001) between the independent variable *GDP per capita* and our dependent variable. The GDP per capita variable is the most important indicator to express the level of wealth of inhabitants. Besides a higher level of GDP per capita, there is a greater economic ability to access the necessary food [49]. In order to measure the relationship between political and social factors in food security, we have included in the analysis the variable quality of government; findings show there is a significant and positive relationship between the quality of government and the level of food security. Columns (3) and (4) show the results of the supplementary analysis to evaluate the robustness of our empirical results. In fact, we used an alternate Food security indicator, *Av. Protein supply*, as the dependent variable. The results confirm that the connection between our dependent variable and independent variables is similar to columns (1, 2). In particular, there is a significant relationship between the climatic variable and our dependent variable. These results underline how climate change represents one of the major threats to guaranteeing a sufficient food security level [50,51]. Moreover, this alternate indicator also validates the important role of the economic and agricultural aspects in assuring valid levels of food security. In fact, there is a positive and significant relationship between the dependent variable (*Av. Protein supply*) and the independent variables (*Land under cereal*, *GDP per capita*).

6. Conclusions and Policy Implications

In this study, using a panel data approach we demonstrated that climate change (namely level of precipitation and temperature) on average has a statistically significant effect on food security in Northern and Eastern Africa. These impacts can be seen in energy and nutritional value perspectives. The results seem to show that increased rainfall could lead to incremented food production and food security. On the other hand, changing temperature patterns appear to be a challenge to achieving food security in Africa. Moreover, the analysis shows that the more resilient countries are the ones with higher per capita incomes. Therefore, we can say that the results highlight the importance of economic development, in that a greater level of GDP per capita and a greater extension of cultivated area guarantee an improvement in food security level [52].

Accordingly, policy makers need to develop and implement measures to alleviate hunger and increase food security in African countries. These could include:

- the adoption of agricultural methods to better food production and to mitigate the effects of climate change as climate-smart agriculture. [53];
- the implementation of programs of risk management such as agricultural insurance to improve rural households' ability to cope with losses due to climate variability [54];
- an increased investment in agricultural research that focuses on the reduction of losses in food production caused by climate change [55];
- the implementation of diversification in the economic structure of African countries in order to mitigate the negative effects of climatic shock in these countries, i.e., reducing the dependence on rain-fed agriculture [56,57];
- establishing an optimum use of precipitation and land under cereal production by investing in rainwater-harvesting systems and storage facilities and improving infiltration into soils [58,59].

Despite the strong results, this paper presents a number of limitations.

First, the data are available only for the period 2000–2012. Second, because of the limited data, it is not possible to include all the types of factors that impact food security. It is necessary to underline that the results of this study allow for consideration at a macro level on food safety, excluding the criticalities that may be present within the distribution channel.

In addition, a shortcoming of this study is its non-inclusion in its analysis of other aspects likely to identify causality in climate change, such as the number of extreme event occurrences; another possible development of this study might be to adopt a different Food security definition, for example, child malnutrition.

There are many opportunities for further research to explore how food security issues will evolve in the future taking into consideration other indicators and enriching the analysis sample.

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Conflicts of Interest: The author declares no conflict of interest.

Appendix A

See Table A1.

Table A1. List of African countries used in the analysis (14).

Algeria	Egypt	Ethiopia	Kenya
Madagascar	Malawi	Morocco	Uganda
Rwanda	Tanzania	Tunisia	

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