AGRODEP Working Paper 0004

April 2014

Investigating the Linkage Between Climate Variables and Food Security in ESA Countries

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Acknowledgements

I thank Luca Salvatici for valuable comments and suggestions. Gratitude goes to the African Growth and Development Policy Modeling Consortium for financial support from the AGRODEP Innovative Research Grants program.

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Abstract

This paper investigates the effect of climate variables (precipitation and temperature) on food security indicators from 1961-2011 for 10 Eastern and Southern African countries by estimating fixed effects models. Food security is approximated by three indicators: food production index, mortality rate of people under five years of age, and life expectancy at birth. The results show that GDP per capita, inflation, population growth, and land under cereal production are significant in explaining the indicators of food security. For climate variables, overall rainfall has a positive and significant effect on food security, whereas the effect of temperature is negative.

Our results suggest some policy implications. As expected, ESA countries will experience unstable rainfall and increases in temperature that could have adverse effects on food production, malnutrition, and mortality rates. Policymakers will need to base policy decisions on the adoption of modern agricultural techniques that optimize water use through increased and improved irrigation systems and crop development in order to mitigate and adapt to climate change.

JEL Classification Numbers: O1, P34, Q18, Q54.

Keywords: climate variables, food security indicators, Eastern and Southern African countries, panel data models.

Résumé

Cet article étudie l'effet des variables climatiques (précipitations et température) sur les indicateurs de sécurité alimentaire dans 10 pays de Sud-est de l'Afrique pendant la période de 1961 à 2011 en estimant des modèles à effets fixes. La sécurité alimentaire est approximée par trois indicateurs qui sont l'indice de production alimentaire, le taux de mortalité des enfants de moins de cinq ans, et l'espérance de vie à la naissance. Les résultats trouvés montrent que le PIB par personne, l'inflation, le taux de croissance de la population, et la terre utilisée pour la production des céréales expliquent significativement les trois indicateurs de la sécurité alimentaire. Concernant les variables climatiques, globalement la variable 'précipitations' a un effet positif et significatif alors que la température a un effet négatif sur la sécurité alimentaire dans les pays de Sud-est de l'Afrique dans les pays de Sud-est de l'Afrique.

Nos résultats suggèrent certaines implications politiques. Comme attendu, les pays de Sud-est de l'Afrique devront expérimenter des conditions climatiques variables caractérisées par une baisse dans les précipitations et une hausse dans la température. Cette variation climatique devrait affecter la production alimentaire, la malnutrition et le taux de mortalité. Pour faire face aux effets négatifs des changements climatiques, plusieurs mesures d'adaptation doivent être prises comme l'utilisation des techniques modernes d'irrigation ainsi que l'utilisation des nouvelles variétés des plantes.

Codes JEL: O1, P34, Q18, Q54.

Mots-clés: Variables climatiques, Indicateurs de sécurité alimentaire , Pays d'Afrique de l'Est et du Sud, Modèles de panel .

1. Introduction

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), climate change and climate variability will severely compromise food security in Africa, a region that is already vulnerable to food insecurity. Warming in Sub-Saharan Africa (SSA) is expected to be greater than the global average, and precipitation is expected to decrease in the majority of areas. Global circulation models (GCMs) have shown that temperatures are increasing throughout the Eastern and Southern Africa (ESA) region, while rainfall is decreasing from June through August in southern Africa and increasing from December through February in eastern Africa (Ringler et al., 2011). Easterling et al. (2007) conclude that climate change will potentially increase the number of people at risk for hunger compared with the reference scenario of no climate change. Under this climate change scenario, Sub-Saharan Africa (SSA) would likely surpass Asia as the most food-insecure region in the world. Rising food insecurity in Africa will make it harder for the continent to achieve the Millennium Development Goals, and higher food costs, which are likely to result from reduced agricultural production, will affect already poor populations the most. Hence, climate change, through its adverse effects on agricultural production and yields, could have dramatic social and economic consequences on the continent.

Other than Easterling et al. (2007), little known empirical research exists regarding the impacts of climate change on food security in general, and even less for the African region. Badolo and Kinda (2011) study the effects of climatic shocks on food security from 1960-2008 for 77 developing countries using panel data econometric models. The authors used two indicators of food security: malnutrition and food production. They found that rainfall volatility negatively affects food security in developing countries and those African countries are more vulnerable to rainfall variability than other regions. Demeke et al. (2011) investigate the impact of socio-economic and climatic factors on the food security index using a primary survey of households in Ethiopia. Kumar and Sharma (2013) study the impact of climate variation on food security in 13 major agriculturally intensive states of India from 1985-2009. Their food security index is regressed on climatic and non- climatic factors (socio-economic and other demographic variables such as gross sown area, irrigated area, agricultural labor, tractors, and government expenditures on agricultural and related activities). They find that climatic fluctuations adversely affected food security index in different Indian states.

In addition to informing the growing debate regarding climate change and its impacts, we believe that our analysis will generate policy implications that can help African countries to better prepare themselves for the potential adverse effects of climate change on food security.

We analyze the impacts of climate change on food security using a panel data econometric model. In general, the food security implications of changes in agricultural production patterns and performance due to climate change are of two kinds. Firstly, impacts on food production will affect food supply at the global and local levels; secondly, impacts on all forms of agricultural production will affect livelihoods and access to food.

There are a number of ways through which climate-related factors may impact food safety: changes in temperature and precipitation patterns, increased frequency and intensity of extreme weather events, ocean warming and acidification, and changes in contaminants' transport pathways, among others. Climate change may also affect socioeconomic factors related to food systems such as agriculture, animal production, global trade, demographics, and human behavior, all of which influence food safety (FAO, 2008; Tirado et al., 2010).

The main objective of this study is to analyze the effects of climate change on food security from 1961-2011 for 10 eastern and southern African countries. We focus on three indicators of food security: the food production index, malnutrition, and life expectancy at birth. These food security indicators will be explained by climate variables (rainfall and temperature) in addition to socioeconomic factors such as GDP per capita, inflation, population growth, and land under cereal production. Our hypothesis is that an increase in rainfall will increase food production, decrease the proportion of undernourished people, and increase life expectancy, whereas an increase in temperature will decrease food production, increase the proportion of undernourished people, and decrease life expectancy.

The paper is organized as follows. Section 2 describes climate change and food security in the ESA region. In this section, we present the definitions of food security, we describe the food security situation in Africa and in the ESA region in particular, and we present the predicted effects of climate changes on food security in this region. In section 3, we present our data and methodology. Section 4 shows empirical results and their analysis, and the last section concludes.

2. Climate Change and Food Security in ESA Region

2.1. Definitions of Food Security

The concept of the right to food was formally recognized by the adoption of the United Nations Universal Declaration of Human Rights in 1948. However, the concept of food security emerged at the FAO's 1974 World Food Conference, where availability of food was considered to be the sole component of food security. In 1986, the World Bank defined food security as "access by all people at all times to enough food for an active and healthy life;" this definition considered only two components of food security: availability and accessibility of food. At the World Food Summit of 1996, FAO defined food security as "Food security exists when all people at all times have physical or economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). This definition considered three components of food security: availability, access, and utilization of food. Finally, in 2002 during the Rome Declaration on World Food Security, FAO defined food security as when “all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.” Since this time, the definition of food security comprises four key dimensions: availability, stability, access, and utilization (ADB, 2012; Kumar and Sharma, 2013):

Availability of food means the physical presence of food in a particular region or place for certain duration of time and with given inventory levels, local and international trade, commercial imports, or food aid. Dev and Sharma (2010) and Shakeel et al. (2012) define food security as the quantity of food available for consumption in a specific time period and a particular place either through domestic supply or through imports.

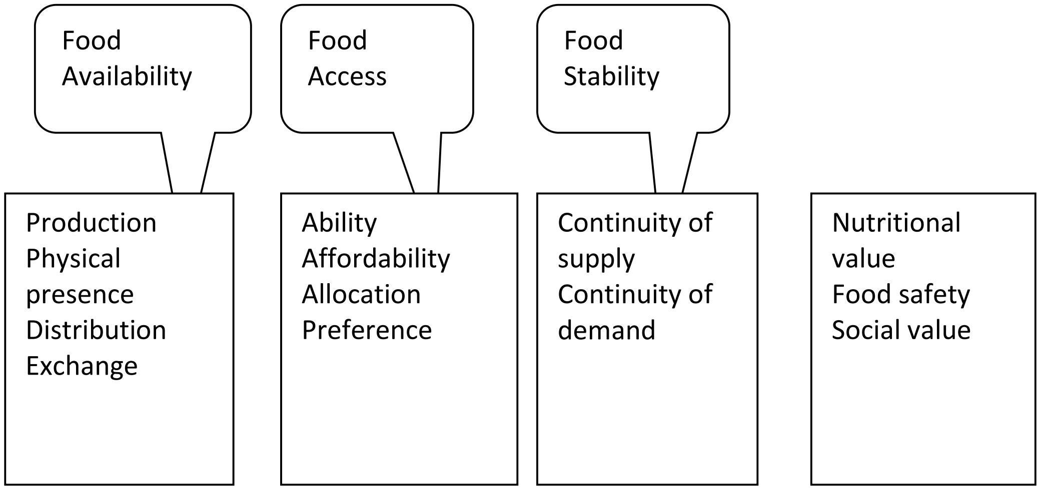
Access refers to having the means to acquire food through production and stocks, purchase, gifts, borrowing, and/or aid; this corresponds with people’s ability to obtain food, either through production, purchase, or transfers. This component of food security is directly linked with a population’s economic ability to afford the food needed for their survival.

Food stability refers to the condition in which food is regularly and periodically available in the domestic market so that it also contributes to nutritional security. This includes times of natural shock like floods and droughts, and focuses specifically on the continuity of supply and demand of food grain product (FAO, 2009).

Utilization of food refers to food safety, quality, and nutrition. It is defined as a household’s ability to absorb and metabolize the nutrients and appropriate nutritional content of the food consumed, and the ability of people’s bodies to use those nutrients effectively. Utilization of food is mainly linked with food’s nutritional value and the interaction of physiological condition and food safety.

The four components of food security are depicted in Figure 1. Food insecurity is hence defined as the absence of these components of food security. Food insecurity applies to a wide range of phenomena such as famine, periodic hunger, and uncertain food supply.

Figure 1. Main components of Food Security



Source: Adapted from Chijioke et al. (2011)

2.2. Food Security in ESA Region

The indicators of human development in SSA are below the average of those in the world. According to the WDI (2012), about 888 million (12.73%) of the world's people were undernourished in 2011; of this number, 213 million lived in sub-Saharan Africa (24.29%). The mortality rate for children under five years of age (per 1,000 live births) is also very high in sub-Saharan Africa: about 108 in 2011, compared to only 51 in the world. Moreover, this rate has fallen more slowly in SSA than in the rest of the world. Between 1968 and 2011, the global mortality rate for children under five (per 1,000) fell from 153 to 51; however, in Sub-Saharan Africa, the mortality rate of children under five (per 1,000) fell from 240 to 108. Globally, life expectancy at birth was about 70 years in 2010 and only 54 years in sub-Saharan Africa. In Africa as a whole, life expectancy at birth rose from 42 in 1961 to about 58 in 2011, whereas it only rose from 41 to 54 in Sub-Saharan Africa during the same period. During the same time, global life expectancy actually rose from 53 to 70. Table 1 shows the mortality rate of children under five and life expectancy at birth in Africa, Sub-Saharan Africa, and the 10 ESA countries investigated in this study.

In Africa as a whole, GDP per capita (constant 2000 US$) rose from US$ 481 in 1961 to US$ 922 in 2011; during the same period in SSA, GDP per capita rose only from US$ 420 to US$ 647. Globally, GDP rose from US$ 2448 in 1961 to US$ 6102 in 2011.

Large inequities in the distribution of land and income across and within African countries contributed to these trends. Conflicts, natural disasters due to climate change, crop failures, and other factors caused 20 African countries to need external food assistance in 2010 (Salami et al., 2011).

Table 1. Under-five mortality and life expectancy at birth in Africa and in 10 ESA countries

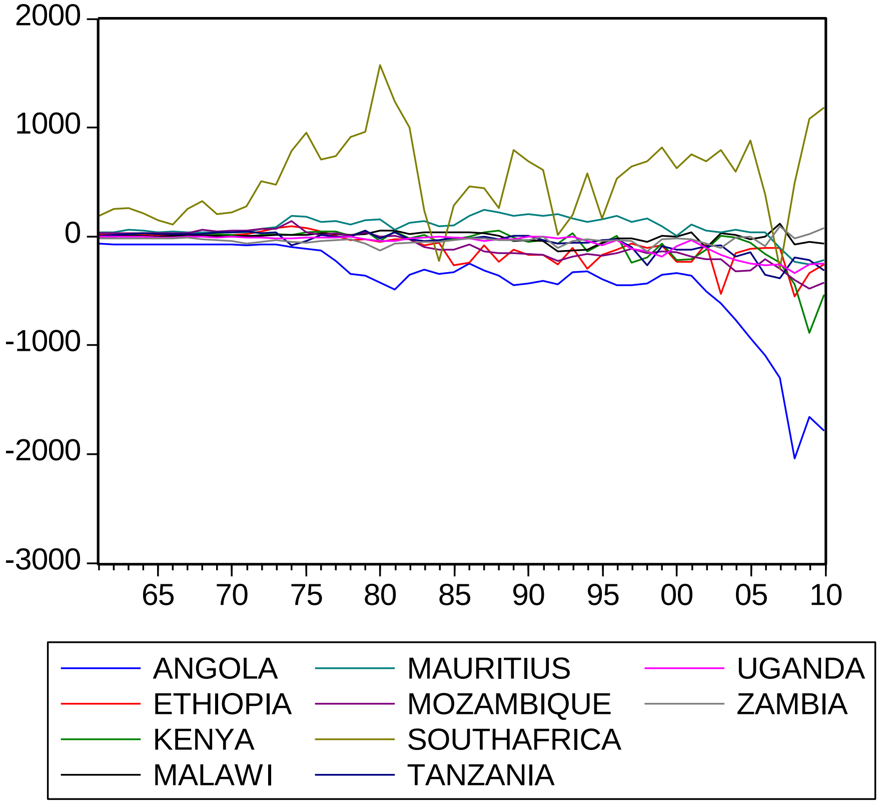
Countries	Life expectancy at birth (years)			Under-five mortality (deaths per 1,000)		
	1961	**1980**	**2011**	**1961**	**1980**	**2011**
Africa	42.09	49.92	57.64	266.007	186.67	100.17
SSA	40.89	48.03	54.63	-	196.26	108.57
Angola	33.38	40.16	51.06	-	286	157.6
Eritrea	39.52	43.97	61.41	-	186.3	67.8
Ethiopia	39.068	43.91	59.24	230.3	228.4	77
Kenya	47.013	57.74	57.08	192	108.3	72.8
Malawi	37.99	44.33	54.13	361.4	256.3	82.6
Mauritius	59.76	66.98	73.26	98.2	40.1	15.1
Mozambique	35.46	42.80	50.15	-	251.7	103.1
South Africa	49.42	56.97	52.61	-	92.1	46.7
Tanzania	43.91	50.45	58.15	240.1	172.3	67.6
Uganda	44.53	50.07	54.07	212.1	189.3	89.9
Zambia	45.48	52.02	48.96	210.4	159.7	82.9

Source: World Development Indicators (World Bank, 2012)
(-): The data are lacking.

In African countries, food security is closely linked to poverty and food prices. Energy prices, climate change, and other factors (such as rising demand due to population growth, conflicts, and exchange rate fluctuations) have caused food prices to increase since 2008. In 2011, the FAO Food Price Index exceeded the peak seen during the 2008 food crisis. For example, the price of wheat rose by 90% between June 2010 and March 2011, while that of rice increased by 33% during the same period (Salami et al., 2011). The percentage of the prevalence of undernourishment (also referred to as the percentage of the population below the minimum level of dietary energy consumption) decreased from 19.28% in 1991 to 13.21% in 2008 in the world, whereas it decreased from 33.57% in SSA during the same period. In Africa as a whole, the prevalence of undernourishment fell from 27.89% to 20.74%. The percentage of the population below the minimum level of dietary energy consumption increased in SSA from 24.18 % in 2008 to 24.29% in 2011 due to the increase in food prices during this period.

South Africa is the main producer and exporter of food products in Africa. The producer price of wheat had increased by 55% between 2009 and 2010 in South Africa (ADI, 2012). In Africa as a whole, the increase in producer prices is exacerbated by low agricultural productivity, severe distortions in agricultural markets, vast gaps in infrastructure, a higher incidence of conflict, and disproportionate damage from climate change. Net food exports (excluding fish) in sub-Saharan Africa have become negative since 1981. All of the ESA countries investigated in this study, with the exception of South Africa and Mauritius, have become net food importers since the 1980s (ADI, 2012). Figure 2 shows the evolution of net food exports excluding fish in the ESA countries during the period 1961 – 2010.

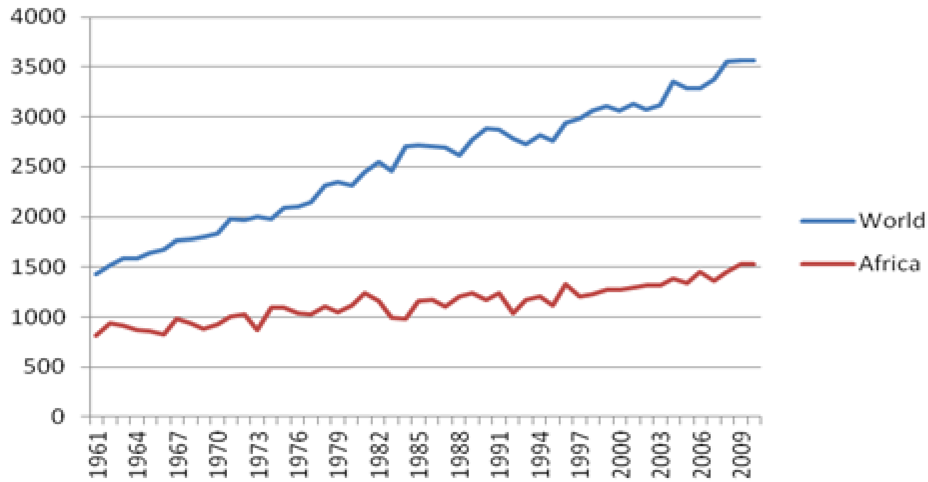
Figure 2. Evolution of net food exports excluding fish (FAO, current million US$)



Source: Author' calculations based on ADI (2012).

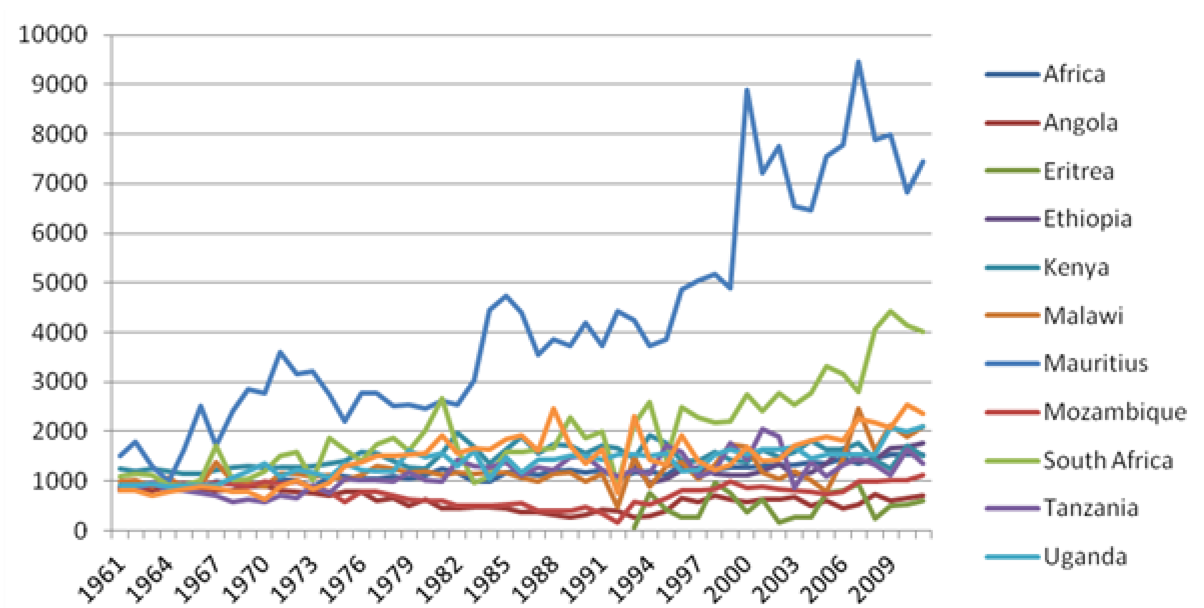
Figure 3 shows the evolution of cereal yields in Africa and globally. Cereal yields (kg per hectare) in Africa is lower than any other region in the world, and less than the half that of global yields. In 2010, cereal yields were 1533.794 kg per hectare in Africa, as opposed to 3563.538 kg per hectare globally. For the studied ESA countries, cereal yields are very low in Angola and Eritrea: 694.4 and 591.6, respectively, in 2010. Mauritius and South Africa are the only ESA countries with cereal yields surpassing the world cereal yield average (Figure 4). As shown in Table 2, except for Mauritius and South Africa, agriculture accounts for more than 70% of income in all other ESA countries. Clearly, increasing cereal yields, and thus incomes from agriculture, is a key component in reducing poverty and food insecurity in ESA countries.

Figure 3. Evolution of cereal yields in Africa and the World



Source: Author' calculations based on WDI (2012).

Figure 4. Evolution of cereal yields in ESA countries



Source: Author' calculations based on ADI (2012).

Table 2. Employment in agriculture as share of total employment, by regions and countries, 1994 – 2010.

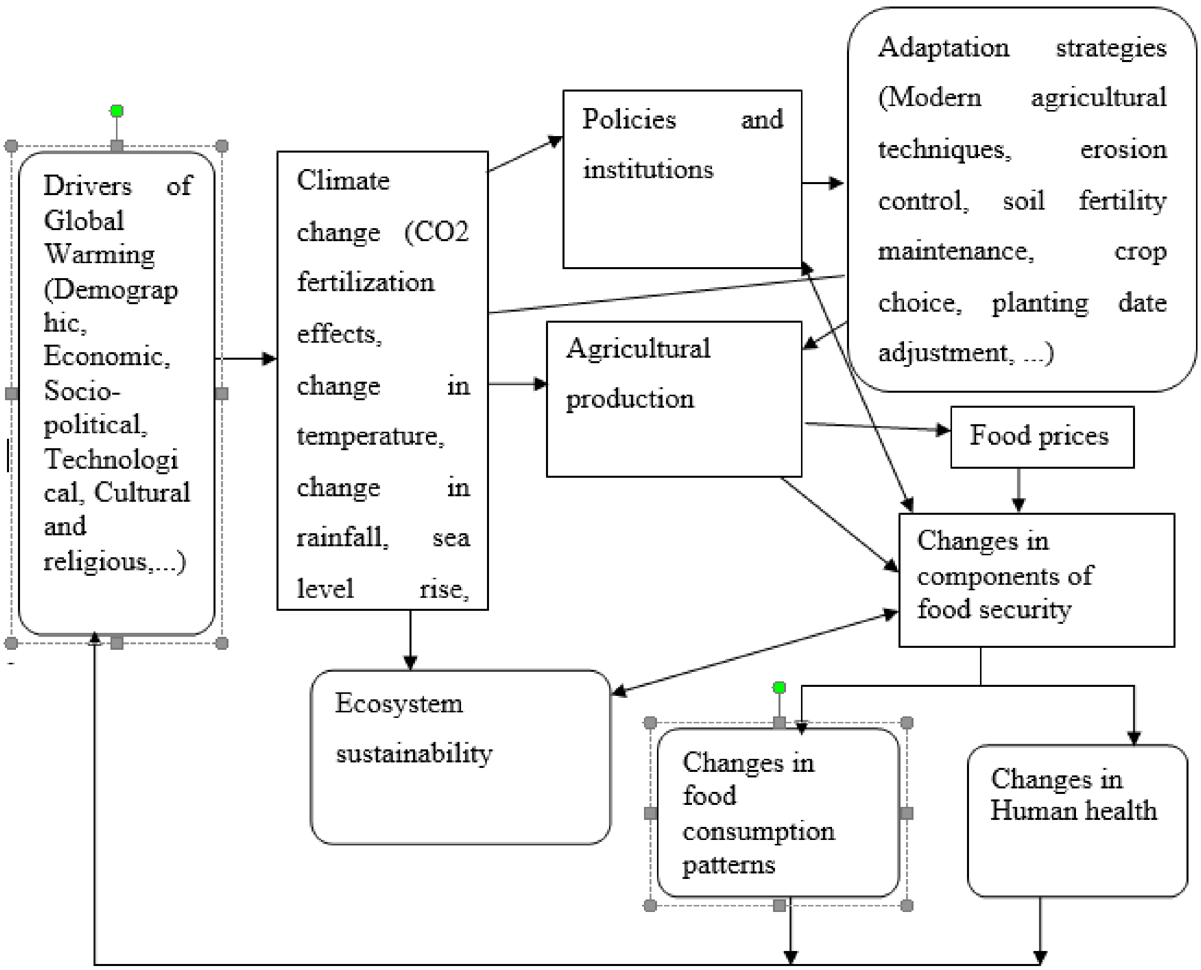
Years / Countries	1994	2000	2005	2011
World	40.82	37.28	35.01	-
Africa	62.19	59.12	56.66	53.98
Sub-Saharan Africa	67.17	64.08	61.71	58.88
Angola	84.02	83.44	83.75	82.01
Ethiopia	81.24	83.02	80.13	76.90
Kenya	88.95	90.71	91.06	84.55
Malawi	84.81	81.08	75.09	73.06
Mauritius	13.69	12.10	10.00	8.39
Mozambique	85.02	81.26	79.62	78.02
South Africa	13.11	15.60	7.50	4.59
Tanzania	84.64	81.16	77.63	76.12
Uganda	86.52	83.13	83.76	81.67
Zambia	63.21	59.98	58.24	57.63

Source: WDI (2012)
(-): The data are lacking.

2.3. Impacts of Climate Variables on Food Security in the ESA Region

Climate change is now a part of our reality. Even the most optimistic estimates of the effects of contemporary fossil fuel use suggest that the mean global temperature will rise by a minimum of 2°C by the end of this century. It is expected that climate change (the decrease in precipitation, the increase in temperature, sea level rise, droughts and floods caused by abnormal rainfall, etc.) negatively affects all economic sectors, but particularly agricultural production and hence food security in ESA countries. Climate change impacts food availability through multiple channels: agricultural production, economic growth, employment opportunities, income distribution, and agricultural demand (Schmidhuber and Tubiello, 2007). Stability of food systems, crop yields, and food supplies are also adversely affected by climatic variability (Greg et al., 2011); climate change can also negatively affect people's economic ability to access the food they need due to an increase in food prices (Greg et al., 2011). Utilization of food also may be adversely affected by climate variation through a reduction in food's real nutritional content, and it may increase several health problems (Greg et al., 2011). It will also have an impact on human health, livelihood assets, and food production and distribution channels (FAO, 2008). Overall, the results of climate change pose a serious threat of hunger, food insecurity, poverty, and malnutrition. Figure 5 shows the linkage between climate variables, agricultural production, and food security indicators.

Figure 5. Climate change variables and their impacts on food security



Source: Adaptation from Anbumozhi and Portugal (2011), Chijioke et al (2011) and FAO (2008)

In the 21st century, climate change is thought to be the greatest threat to agriculture and food security in sub-Saharan African countries (Shah et al., 2008; Nellemann et al., 2009). According to the United Nations Development Program (UNDP) of 2008, by 2080, the impacts of climate change could decrease agricultural productivity by 15-30 percent on average, and could hence increase the number of malnourished people by 600 million and the number of people facing water scarcity by 1.8 billion. The UNDP warns that climate change could slow the progress made in human development due to new threats to water access, food security, agricultural productivity, and nutrition and public health.

Agriculture remains the most important sector for poor people in most African countries; rural areas represent more than 70 percent of the total population. Improvements in agriculture can increase rural incomes and purchasing power for large numbers of people (NEPAD, 2002; Wiggins, 2006). According to the World Bank's development report for 2010, climate change threatens the economic development of all

African countries; the report also calls for a development agenda to be integrated into any future climate negotiations (World Bank, 2010*).* The Fourth Assessment Report of the IPCC also provides some results about the impact of climate change on African development. Projected reductions in crop yields in some countries could be as much as 50 percent by 2020, and crop net revenues could fall by as much as 90 percent by 2100. The population at risk of increased water stress is projected to be between 350-600 million by 2050, while between 25 and 40 percent of mammal species in national parks in sub-Saharan Africa will become endangered (Boko et al., 2007).

It is expected that cereal production growth in SSA will decline by 3.2 percent by 2050 due to climate change. Wheat and sweet potato yields are expected to be the most negatively affected by climate variability, whereas millet and sorghum yields are projected to be slightly positively affected due to their resistance to higher temperatures and drought stresses (Ringler et al., 2010). Food prices are a key indicator of the effects of climate change on food security; wheat, rice, and maize prices in SSA are expected to increase, respectively, by 15, 7, and 4 percent by 2050. These higher food prices are projected to dampen demand for food in the region, thus increasing the number of malnourished children by both 2030 and 2050 (Ringler et al., 2010).

When droughts occurred in 1983 and 1992, Zimbabwe's GDP fell by 3 percent and 11 percent, respectively. The Pacific warming of 1991-1992 caused the worst drought of the last century in southern Africa (Glantz et al., 1997), reducing regional maize production by about 60 percent and putting an estimated 30 million people on the brink of famine (Battersby, 1992; Chiledi, 1992; Harsch, 1992). Since 2001, severe droughts in some areas of southern Africa have led to serious food crisis in many countries. In 2001-2002, Lesotho, Malawi, Mozambique, Swaziland, Zambia, and Zimbabwe all faced a deficit of 1.2 million tons of cereals (SADC, 2002).

It is well known that daily and seasonal temperature patterns can affect the survival of mosquito and malaria parasites. Over the past four decades, climate change has played a big role in the spread of malaria to the highland areas of East Africa and elsewhere. Tanser et al. (2003) also projected that due to changing temperature patterns in Africa, there would be a 5-7 percent potential increase in malaria distribution, with surprisingly little increase in the disease's latitudinal reach by 2100.

Climate change also negatively affects public health in Africa (Boko et al., 2007). According to Gallup et al. (1999), malaria can have negative effects on labor productivity; this has implications for the future welfare of African society.

In summary, climate change has negative impacts in most tropical regions because rain-fed agriculture is the main livelihood of the majority of these countries' populations. To this end, decreasing precipitation and rising temperature patterns could have significant effects on agricultural production, farm incomes, and food security and could increase the incidence of poverty, hunger, and mortality (Ramasamy and Moorthy, 2012).

3. Data and Econometric Model

In this study, we analyze the effect of climatic factors on food security from 1961-2011 for 10 ESA countries using a panel data econometric model. This approach is motivated by the hypothesis that drier crop seasons reduce food production and increase the proportion of undernourished people. As such, rainfall and temperature are key determinants of food insecurity in the agriculture-dependent ESA countries, both directly and indirectly through food prices.

We will estimate the model given by the following equation (Badolo and Kinda, 2011; Kumar and Sharma, 2013). This model is a part of the conceptual model presented in Figure 5, which depicts the linkage between climate variables and food security indicators:

$$FS_{it} = \beta\, CC_{it} + \lambda\, X_{it} + \alpha_i + \mu_t + \varepsilon_{it} \qquad (1)$$

where FS_{it} is the variable representing an indicator of food security; X_{it} is a vector of control variables (such as income per capita, inflation, population growth, agriculture land under cereal production); CC_{it} is the vector of climate variables (rainfall, temperature) in a country i at a period t; ε_{it} is the error term; μ_t is time effect; α_i represents country fixed effects and β and λ are vectors of parameters to be estimated.

Alternative measures may be used to measure food security: food production index, the proportion of undernourished people, the mortality rate among children under five years of age, life expectancy at birth, and the Global Hunger Index (GHI). The GHI is an arithmetic average of child malnutrition, the proportion of undernourished people, and the mortality rate of children under five years of age[1]. In our empirical analysis, we shall use three indicators of food security: food production index, the mortality rate among children under five years of age, and life expectancy at birth.

The food production index, measured by FAO, covers food crops that are considered edible and that contain nutrients. The under-five mortality rate is the probability per 1,000 that a newborn baby will die before reaching the age of five, if subject to current age-specific mortality rates. Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of birth were to stay the same throughout the child's life[2].

All data are taken from WDI (2012) except for the data on rainfall and temperature, which are taken from NOAA. Descriptive statistics of different variables are presented in Table 3.

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1 The data on the GHI are available only for a short-term horizon.

2 These definitions of mortality rate for children under five and life expectancy at birth are those of the World Bank.

Table 3. Descriptive Statistics

Variable Codes	Name of variables	Obs.	Mean	Std. Dev.	Min.	Max.
Y1	Food production index (2004-2006 = 100)	478	68.601	28.556	23.05	188.24
Y2	Mortality rate, under-5 (per 1,000)	476	158.891	75.227	15.1	377
Y3	Life expectancy at birth, total (years)	510	50.084	8.236	33.386	73.266
X1	GDP per capita (constant 2000 US$)	384	935.083	1249.072	98.180	5370.832
X2	Inflation, consumer prices (annual %)	375	45.580	269.087	-9.808	4145.107
X3	Population growth (annual %)	510	2.610	0.808	-0.217	5.921
X4	Land under cereal production (hectares)	510	2261410	2193044	14	1.01e+07
X5	Average precipitation in depth (mm per year)	460	1023.448	345.601	321	2731.08
X6	Mean annual temperature (C)	460	21.432	1.804	16.88	25.35

Income per capita is represented by "GDP per capita," which is gross domestic product divided by mid-year population and expressed in constant US$ 2000. Inflation, as measured by the consumer price index, reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. Annual population growth rate is the growth rate of the population between two successive years. Land under cereal production refers to harvested area, although some countries report only sown or cultivated area. Cereals include wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains.

It is expected that the increase in "GDP per capita" has a positive effect on food security, whereas the impact of inflation on food security will be negative. The increase in food product prices reduces people's access to food. A higher income per capita will reduce poverty, which should positively affect food security through the channels of food accessibility and human health. Sustained economic growth has a direct impact on food security by supporting agricultural production and an indirect impact by providing high incomes that support greater food access. Population growth can have mixed effects on food security, but in general, it is expected to have a negative effect. According to Malthus (1992), population growth puts pressure on agricultural resources; this pressure can reduce agricultural productivity and food production. However, some other authors believe that population growth is not an obstacle to food security because it can encourage technical progress and thus increase agricultural productivity (Boserup, 1965). The increase in land under cereal production increases the availability of food products and food security.

Since global warming poses environmental implications that have a significant impact on agriculture production; a central issue emerges: What is the link between climate change and food security? It is projected that climate variability will adversely affect food security directly through a decrease in cereal yields and indirectly through an increase in food product prices.

4. Empirical Results

Different specifications of the model given by equation 1 are estimated and their empirical results are presented in Tables 4, 5, and 6. Table 4 shows the results of the impact of climate variables and control variables on the food production index. Table 5 shows the results of the impact of climate variables and control variables on mortality rates. Table 6 shows the results of the impact of climate variables and control variables on life expectancy at birth.

We estimate three versions of the model. In the first version, we consider the control variables and climate factors (precipitation and temperature). In the second specification, we add the term squared temperature. The third specification includes time dummies. The results of the Hausman test show that country-level effects are fixed in all the models estimated except for the model of life expectancy at birth with time dummies. The results of Wooldridge and Breusch Pagan tests show that the term errors are correlated and heteroskedastic. All our results are robust with (or without) temporal effects.

Overall, as expected, GDP per capita has a positive and significant effect on the food production index. Income per capita increases the level of food production and is an indicator of a country's economic growth. Economic growth contributes to poverty reduction and hence reduces individuals' constraints on food access (Ravallion and Chen, 1997; Roemer and Gugerty, 1997). Moreover, high incomes allow an economy to increase investments in food sectors (Smith and Haddad, 2000). Increased levels of development can increase national food availability by improving the resources available for purchasing food on international markets.

However, the results are unexpected in the third version of the model when considering time dummies. Inflation has a negative and significant effect on the food production index. The increase in food prices reduces access to food. As advanced by Malthus, population growth is shown to have a negative and significant effect on the food production index. Our results are not different from previous authors such as Merrick (2002), who concludes that population growth can exacerbate the harmful effects of inappropriate policies on food security. Land under cereal production has a positive effect on the food production index but it is not significant.

Regarding the climate variables, rainfall is shown to have a positive and significant effect on the food production index when we do not consider time effects. The increase in precipitation affects agricultural productivity which in turn positively affects the availability of food products. The results for temperature are mixed, but when we include time effects in the model, the variable temperature is shown to have a negative and significant effect on food production. It has been found in many previous studies that an increase in temperature in African countries should negatively affect agricultural production, thus reducing the availability of food products and increasing food prices.

Table 4. Results of the impact of climate variables on Food production index

Models / Variables	FE model with robust standard errors		FE model with robust standard errors		FE model with robust standard errors	
	coefficient	**Probability**	**coefficient**	**Probability**	**coefficient**	**Probability**
X1	0.011	0.00	0.011	0.00	-0.011	0.00
X2	-0.008	0.02	-0.009	0.02	-0.002	0.09
X3	-4.826	0.02	-4.521	0.03	1.422	0.09
X4	1.37e-06	0.45	1.11e-06	0.54	5.53e-06	0.00
X5	0.011	0.04	0.009	0.08	0.005	0.12
X6	23.365	0.00	-22.948	0.46	-4.114	0.09
X7*	-	-	1.085	0.14	-	-
Constant	-440.58	0.00	49.49	0.88	103.29	0.04
Time dummies	No		No		Yes	
F-test	18.68	0.00	16.71	0.00	99.60	0.00
F-u	14.78	0.00	14.53	0.00	26.70	0.00
R-sq	0.503	-	0.508	-	0.912	-
Chi-squared stat of Hausman test	-	-	52.63	0.00	316.12	0.00
F stat of Wooldridge test	23.580	0.00	22.743	0.001	7.803	0.02
Chi-squared stat of Breusch Pagan test	25.405	0.00	24.274	0.00		

(*) This variable is the squared term of temperature.

As expected, GDP per capita is shown to have a negative and significant effect on the mortality rate in the two models without time dummies. The mortality rate of children under five years of age is linked to the level of development. When income per capita increases the mortality rate of children will decrease. Inflation has a positive and significant effect on mortality rate in the two models without time dummies. The reverse effect is found in the model with time dummies, but it is not significant. Demographic expansion has a positive and significant effect on the mortality rate of children under five. This result conforms to the Malthus hypothesis; however, when considering time dummies, population growth has a negative and significant impact on the mortality rate. This implies that population growth can encourage technical progress and rising agricultural productivity, as advanced by Boserup (1965). Table 5 suggests that an increase in cultivated lands under cereal production has a negative and significant effect on the mortality rate. This result implies that land under cereal production increases agricultural production and hence increases food security and human health.

The results for rainfall are surprising in the three versions of the model. When precipitation increases, the mortality rate for children under five years of age also increases. The effect of precipitation is only significant in the model with time dummies, and the positive effect may be explained by rainfall variability. Variable rainfall can reduce land suitability and crop yields and have a negative effect on food production. In other words, rainfall variability can have effects on the viability of economic systems, food production, and food availability, and can increase the percentage of total undernourished population.

When considering time dummies, the coefficient of the effect of temperature on the mortality rate is positive and significant at 1 percent. This implies that when temperature increases, the mortality rate will increase.

Table 5. Results of the impact of climate variables on mortality rate

Models / **Variables**	**FE model with robust standard errors**		**FE model with robust standard errors**		**FE model with robust standard errors**	
	coefficient	**Probability**	**coefficient**	**Probability**	**coefficient**	**Probability**
X1	-0.009	0.00	-0.0103	0.00	0.019	0.00
X2	0.008	0.04	0.0079	0.04	-0.002	0.13
X3	4.884	0.13	5.233	0.10	-4.148	0.03
X4	-0.00001	0.00	-.00001	0.00	-0.00001	0.00
X5	0.006	0.39	0.004	0.57	0.011	0.08
X6	-30.44	0.00	-85.005	0.15	14.08	0.004
X7	-	-	1.271	0.35		
Constant	808.04	0.00	1389.918	0.03	-98.74	0.35
Time dummies	No		No		Yes	
F-test	23.62	0.00	20.42	0.00	………..	……..
F-u	35.57	0.00	35.03	0.00	146.48	0.00
R-sq	0.849	-	0.859	-	0.962	-
Chi-squared of Hausman test	20.88	0.00	21.42	0.00	131.41	0.00
F stat of Wooldridge test	5374.51	0.00	5643.041	0.00		
Chi-squared stat of Breusch Pagan test	17.33	0.00	23.77	0.00		

The third indicator of food security is life expectancy at birth. When estimating the effect of climate change factors and control variables on this indicator, the results are as expected for GDP per capita, inflation, and land under cereal production. The impact of population growth on life expectancy at birth is positive and significant. The coefficient of precipitation is not significant, whereas temperature has a positive and significant effect on life expectancy at birth.

Table 6. Results of the impact of climate variables on life expectancy at birth

Models / Variables	FE model with robust standard errors		FE model with robust standard errors		RE model with robust standard errors	
	coefficient	**Probability**	**coefficient**	**Probability**	**coefficient**	**Probability**
X1	0.002	0.00	0.002	0.00	0.005	0.00
X2	-0.0006	0.02	-0.0006	0.02	-0.003	0.00
X3	0.734	0.001	0.659	0.001	1.011	0.37
X4	1.39e-06	0.00	1.45e-06	0.00	4.46e-07	0.06
X5	-0.0009	0.22	-0.0006	0.45	.0002	0.95
X6	0.972	0.06	13.03	0.023	2.503	0.00
X7	-	-	-0.282	0.032	-	-
Constant	24.113	0.03	-103.599	0.09	-11.35	0.27
Time dummies	No		No		Yes	
F-test	27.55	0.00	26.61	0.00		
F-u	33.98	0.00	34.96	0.00	60.81	0.00
R-sq	0.904	-	0.906	-	0.895* (between)	
Chi-squared of Hausman test	31.14	0.00	40.30	0.00	13.20	1.00
F stat of Wooldridge test	6023.949	0.00	5963.122	0.00		
Chi-squared stat of Breusch Pagan test	50.02	0.00	47.822	0.00	504.24	0.00

5. Conclusion

This paper analyses the effect of climate variables on food security indicators from 1961-2011 for 10 Eastern and Southern African (ESA) countries. We use three indicators of food security: food production index, mortality rate of children under five years of age, and life expectancy at birth. The results show that precipitation and temperature can negatively affect food security in ESA countries. The decrease and variability of rainfall coupled with the continuing rise in temperature will reduce food production and increase the percentage of the total undernourished population, thus increasing the mortality rate.

Our results suggest some policy implications. As expected, ESA countries will experience rainfall variability and an increase in temperature, which will have adverse effects on food production, malnutrition, and the mortality rate. It seems evident that policymakers should encourage the adoption of modern agricultural techniques that optimize water use through increased and improved irrigation systems and crop development in order to mitigate and adapt to the changing climate. These measures could lead to higher rates of agricultural productivity, availability of food products, and access to food, as well as improved infrastructure and lower food prices in local markets. African countries should also remove barriers to trade, especially intra-regional food trade, and food price volatility should be managed through policies regulating the global food trade. In addition, the development of adequate rural infrastructure (roads, storage facilities, market access, handling and conservation systems, and supply networks) is essential to improve the competitiveness of local producers and to allow fast and efficient food distribution throughout the region. Providing support to agricultural research as well as to the development of human resource capacity should be a prioritized strategy for all African countries. Finally, land property rights should be improved in order to facilitate the access to and efficient use of land.

References

Asian Development Bank (ADB), 2012. Food security and Poverty in Asia and the Pacific: Key Challenge and Policy Issues. Mandaluyong City, Philippines: ADB.

African Development Indicators (ADI), 2012. The World Bank IBRD. Washington, DC: World Bank.

Anbumozhi, V. and Portugal, J., 2011. Adapting to Climate Change and Achieving Food Security: Prospects and Frameworks. Presented during the ADBI-APO-KPC Workshop on Climate Change and Its Impact on Agriculture, December 13-16, Seoul, South Korea.

Badolo, F. and Kinda, S.R., 2011. *Do Climatic Shocks Matter for Food Security in Developing Countries?* Clermont-Ferrand, France : Centre d'Etudes et de Recherches sur le Développement International (CERDI).

Battersby, J., 1992. Southern Africa Fights Drought of the Century. *The Christian Science Monitor*, 9.

Boko M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R., and Yanda, P., 2007. *Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds). Cambridge, UK: Cambridge University Press.

Boserup, E., 1965**.** *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*. London: Allen and Unwin LTD.

Chijioke, O.B., Haile, M., and Waschkeit, C., 2011. Implications of Climate Change on Crop Yield and Food Accessibility in Sub-Saharan Africa. Bonn: Center for Development Research, University of Bonn, Germany.

Chiledi, A., 1992. *Southern Africa: Drought Worsens, More Aid Urgently Needed*. Inter Press Service.

Demeke, A.B., Keil, A., and Zeller, M., 2011. Using Panel Data to Estimate the Effect of Rainfall Shock on Smallholders' Food Security and Vulnerability in Rural Ethiopia. *Climate Change,* 108, p. 185-206.

Dev, S.M. and Sharma, A.N., 2010. Food Security in India: Performance, Challenges and Policies. Oxfam India Working Paper Series 08. New Delhi: Oxfam.

Easterling, W., Aggarwal, P., Batima, P., Brander, K., Erda, L., Howden, M., Kirilenko, A., Morton, J., Soussana, J.-F., Schmidhuber, S., and Tubiello, F., 2007. Food Security and Vulnerability. Chapter 5 in M.L. Parry, et al (eds.). *Food, Fiber, and Forest Products. Climate Change 2007: impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth*

Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge UK: Cambridge University Press.

Food and Agriculture Organization of the United Nations (FAO), 1996. Rome Declaration and World Food Summit Plan of Action. Rome.

Available at: www.fao.org/docrep/003/X8346E/x8346e02.htm#P1_10.

FAO, 2008. Climate Change and Food Security: A Framework Document. Rome: FAO.

FAO, 2009. Food Security and Agricultural Mitigation in Developing Countries: Options for Capturing Synergies. Rome: FAO.

Gallup, J.L., Mellinger, A., and Sachs, J.D., 1999. Geography and Economic Development. *International Regional Science Review*, 22(2), p. 179-232.

Glantz, M.H., Betsill, M., and Crandall, K., 1997. *Food Security in Southern Africa: Assessing the Use and Value of ENSO Information.* Boulder, Colorado: National Center for Atmospheric Research.

Harsch, E., 1992. Drought Devastates Southern Africa. *Africa Recovery*, 3.

Goswami, P.K. and Chatterjee, B., 2010. Linkage between Rural Poverty and Agricultural Productivity across the Districts of Uttar Pradesh in India. *Journal of Development and Agricultural Economics*, 2(2), p. 26-40.

Greg, E.E., Anam, B.E., William, M.F., and Duru, E.J.C., 2011. Climate Change, Food Security and Agricultural Productivity in African: Issues and Policy Directions. *International Journal of Humanities and Social Science*, 1(21), p. 205-223.

Hoddinott, J., 2009. *Choosing Outcome Indicators of Household Food Security: Technical Guide.* Washington DC: International Food Policy Research Institute (IFPRI).

Kumar, A. and Sharma, P., 2013. Impact of Climate Variation on Agricultural Productivity and Food Security in Rural India. Economics Discussion Papers, No 2013-43. Kiel: Kiel Institute for the World Economy. Available at http://www.economics-ejournal.org/economics/discussionpapers/2013-43.

Malthus, T.R., 1992. *An Essay on the Principle of Population, (Based upon the Malthus's Second Essay).* D. Winch (ed.). Cambridge, UK: Cambridge University Press.

Masters, G., Baker, P., and Flood, J., 2010. Climate Change and Agricultural Commodities. CABI Working Paper 02. UK: CABI.

Merrick, T.W., 2002. Population and Poverty: New Views on an Old Controversy. *International Family Planning*, 28(1), p. 41-46.

National Climatic Data Center (NCDC). Available at www.ncdc.noaa.gov.

Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A., and Kaltenborn, B. (eds.), 2009. *The Environmental Food Crisis. The Environment's Role in Averting Future Food Crises. A UNEP Rapid Response Assessment*. Arendal: UNDP.

Oluoko-Odingo, A.A., 2009. Determinants of Poverty: Lessons from Kenya. *GeoJournal*, 74, p. 311–331.

Ramasamy, J., and Moorthy, P., 2012. Managing Food Insecurity and Poverty in India in the Era of Globalization. *International Journal of Multidisciplinary Research*, 2(1), p. 411-421.

Ravallion, M. and Chen, S., 1997. What Can New Survey Data Tell Us about Recent Changes in Distribution of Poverty? *The World Bank Economic Review*, 11, p. 357-382.

Ringler, C., Zhu, T., Cai, X., Koo, J., and Wang, D., 2010. *Climate Change Impacts on Food Security in Sub-Saharan Africa: Insights from Comprehensive Climate Change Modeling*. IFPRI Research Brief, 15-20. Washington, DC: International Food Policy Research Institute.

Roemer, M., and Gugerty, M.K., 1997. Does Economic Growth Reduce Poverty? CAER II Discussion Paper No. 5. Cambridge, MA: Harvard Institute for International Development.

Rukhsana, A., 2011. Dimension of Food Security in a Selected State Uttar Pradesh. *Journal of Agricultural Extension and Rural Development*, 3(2), p. 29-41.

Salami, A., Brixiova, Z., Kandil, H. and Mafusire, A., 2011. Toward Food Security in Africa: Challenges, Policies and the Role of the African Development Bank. *Africa Economic Brief*, 2(2).

Schmidhuber, J. and Tubiello, F.N., 2007. Global Food Security under Climate Change. *Proceedings of the National Academy of Sciences of the United States of America*, 104(50), p. 581-596.

Shah, M., Fischer, G., and van Velthuizen, H., 2008. *Food Security and Sustainable Agriculture. The Challenges of Climate Change in Sub-Saharan Africa*. Luxemburg: International Institute for Applied Systems Analysis.

Shakeel, A., Jamal, A., and Zaidy, M.N., 2012. A Regional Analysis of Food Security in Bundelkhand Region Uttar Pradesh (India). *Journal of Geography and Regional Planning*, 5(9), p. 252-262.

Smith, L. and Haddad, L., 2000. *Explaining Child Malnutrition in Developing Countries: A Cross-country Analysis*. Washington, DC: International Food Policy Research Institute.

Tanser, F.C., Sharp, B., and le Seur, D., 2003. *Potential Effect of Climate Change on Malaria Transmission in Africa.*

The New Partnership for Africa's Development (NEPAD), 2002. Comprehensive Africa Agriculture Development Programme.

The Southern African Development Community (SADC), 2002. Annual Report 2001-2002, Southern Africa Development Community. Available at www.sadc.int.

Wiggins, S., 2006. Agricultural Growth and Poverty Reduction: A Scoping Study. Working Paper No. 2 on Globalization, Growth and Poverty. Ottawa: IDRC.

World Bank, 2010. World Development Report – Development and Climate Change. Washington DC: World Development Report.

World Development Indicators, 2006. World Development Indicators 2006 (CD-ROM). IBRD. Washington DC: World Bank.

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