Climate Change, Food Security and Agricultural Productivity in Africa: Issues and policy directions.

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Abstract

This paper examines the economic impact of climate change (CC) on food security and agricultural productivity in Sub Saharan Africa (SSA). It examine the impact on the basic components of food security; availability, accessibility, affordability, preference, utilization and nutritional value and food system stability. The so-called "greenhouse fertilization effect" produces local beneficial effects where higher levels of atmospheric CO2 stimulate plant growth. This occur primarily in temperate zones, with yields expected to increase by 10 to 25 percent for crops with a lower rate of photosynthetic efficiency (C3 crops), and by 0 to 10 percent for those with a higher rate of photosynthetic efficiency (C4 crops), assuming that CO2 levels in the atmosphere reach 550 parts per million. the European heat wave of 2003, when temperatures was 6 ºC above long-term means, crop yields dropped significantly, by 36 percent for maize in Italy, and by 25 percent for fruit and 30 percent for forage in France. Increased intensity and frequency of storms, altered hydrological cycles, and precipitation variance also have long-term implications on the viability of current world agro ecosystems and future food availability. Climate change has been described as the most significant environmental threat of the 21st century. Wetter climates and more floods are predicted for parts of East Africa and Latin America. Agricultural productivity in Africa, Asia and Latin America is expected to decrease by as much as 20%. In 2004, agriculture directly contributed about 14% of global anthropogenic greenhouse gas (GHG) emissions, according to the Intergovernmental Panel on Climate Change (IPCC). Agriculture is particularly vulnerable to climate change. Projections to 2050 suggest both an increase in global mean temperatures and increased weather variability, with implications for the type and distribution of agricultural production worldwide. One successful path to tread is to boost agricultural production. Projections based on population growth and food consumption patterns indicate that agricultural production will need to increase by at least 70 percent to meet demands by 2050

Keywords: Africa, CC, agriculture, food security.

JEL Classification: O13, O21, Q54.

1.0 Introduction

Climate change has been described as the most significant environmental threat of the 21st century.

The aim of this study is to contribute to the few existing literature in Africa, and to the developing countries in general, and in particular; to see what policy response options can be derived from the study to help mitigate the economic effects of CC on agriculture and food security in Nigeria. Experts say severe droughts are likely to be more frequent in Southern Africa, South-East Asia, the Mediterranean and Central Asia. Wetter climates and more floods are predicted for parts of East Africa and Latin America. Agricultural productivity in Africa, Asia and Latin America is expected to decrease by as much as 20%. The geographical boundaries of agro-ecosystems, as well as species composition and performance will change. Marine ecosystems, supplying protein for millions of the poor will continue to experience major migratory changes in fish stocks and mortality events in response to rising temperatures (Fargione, Hill, Tilman, Polasky & Hawthorne, 2008). In addition to longer-term, more permanent shifts in seasonal climatic patterns are near term increases in the frequency and intensity of weather extremes. These are already disrupting agriculture, fisheries, and the natural resource base. Poorer countries with predominantly rural economies and low levels of agricultural diversification are at most risk. They have little flexibility to buffer potentially large shifts in their production bases (ICWG-CC, 2008).

The impact of climate change is vast. One of its threatening sectors is agriculture. Food production is adversely affected. Global warming (climate change) leads to sea-level rise with its attendant consequences, and includes fiercer weather, increased frequency and intensity of storms, floods, hurricanes, droughts, increased frequency of fires, poverty, malnutrition and series of health and socio-economic consequences (von Braun et al, 2008). It has a cumulative effect on natural resources and food production.

Preliminary studies on the vulnerability of various sectors of the Nigerian economy to climate change were conducted by NEST. The sectors evaluated were based on seven natural and human systems identified by the IPCC, and condensed into five. They are:

a. Human settlements and health;
b. Water resources, wetlands, and freshwater ecosystems;
c. Energy, industry, commerce, and financial services;
d. Agriculture, food security, land degradation, forestry, and biodiversity; and
e. Coastal zone and marine ecosystems.

In most countries where agricultural productivity is already low and the means of coping with adverse events are limited, climate change is expected to reduce productivity to even lower levels and make production more erratic. Long term changes in the patterns of temperature and precipitation, that are part of climate change, are expected to shift production seasons, pest and disease patterns, and modify the set of feasible crops affecting production, prices, incomes and ultimately, livelihoods and lives.Given this challenges, this paper examines the impact of climate change on food security and agricultural productivity in Sub Saharan Africa (SSA). The study will further examine measures needed to achieve improve productive base and effective management of natural resources (e.g. land, water, soil nutrients, and genetic resources) and higher efficiency in the use of these resources and inputs for production. It is believed that, putting this in place, mitigation strategies can be attained and food security achieved within the SSA where the challenge of vulnerability and poverty is in the increase.

2.0 Empirical Review

2.1 Climate Change and Agriculture: Global Evidence

Climate change, agriculture and food security is now a subject of global concern. This is evident from the number of empirical literature that is currently available on the subject matter. However, most seem to focus on the industrial countries where the economic impacts are likely to be less harmful because of better adaptation techniques and technology than the developing nations. Notwithstanding, these studies laid the foundation for the increasing number of developing countries studies that are emerging. Adams, et al. (1989, 1990, 1993, & 1999); Parry (1990); Tobey et al. (1992); Easterling et al. (1993); Kaiser et al. (1993); Rosengweig and Parry, (1994); Tim and Li, (1994); Darwin et al. (1995); Watson et al. (1997); Bruce et al. (1996), Reilly, (1994 and 1995); Cline, (1996); Mendelsohn et al. (1994, 1996, & 1999); Mendelsohn and Dinar, (1998); Iglesias and Minguez, (1997); Maddison, (2000) etc., were in the main stream of authors to initially assess the economic impact of CC on agriculture in the industrial countries. Lessons learnt from these earliest applications can be found in the works of Jin et al. (1994); Escano and Buendia, (1994); Amien et al. (1996); Kapetanaki and Rosengweig, (1997); Mathews et al. (1997); Kumar and Parikh, (1998); Sanghi (1998); Mckinsey and Eveson, (1998); Sanghi, (1998); Sanghi et el. (1998); Sanghi and Mendelsohn, (1999); Luo and Lin, (1990); Kumar and Parikh, (2001);

Chang (2002); Kurukulasuriya and Ajwad, (2003); Seo et al. (2005);Fonta, et al etc., for several transitional economies. In Africa, although the literature appears scanty, the subject matter is gradually attracting much attention (Molua, 2002; Watson, 1996 & 1997; Winters et al. 1999; Hassan, 2008). However, it may appear that Downing (1992); Onyeji and Fischer (1994); El-Shaer et al. (1997); Hassan et al. (1998); Hulme and Sheared (1999); Seleka (1999); Molua (2002); Gbetibouo and Hassan (2005); and Deressa et al. (2005), were the first stream of African researchers to measure the economic impact of CC on African agriculture. This was followed by a series of multi-country analyses carried out in 11 African countries, co-coordinated by the Center of Environmental Economics and Policy in Africa, University of Pretoria, in close collaboration with many agencies in the involved countries.

In this series Mano and Nhemachena (2006) finds that when farm revenue in Zimbabwe is regressed against various climates, soil, hydrological and socio-economic variables in a Ricardian framework, the net effect of climate change on agriculture in Zimbabwe is quite significant. Sensitivity analysis of alternative climatic scenarios that is, 2.5^0 C and 5^0 C increases in temperature resulted to decrease in net farm revenues of approximately US$0.3 and US$0.3 billions respectively. In Kenya the results were not much different. Mariara and Karanja (2006) find that climate change also affects agricultural productivity using a seasonal Ricardian analysis. The results showed that increased winter temperatures are associated with higher crop revenue, but increased summer temperatures have a negative impact. Increased precipitation is positively correlated with net crop yield. The result further suggests that there is a non-linear relationship between temperature and revenue on the one hand and between precipitation and revenue on the other. For Cameroon, Molua and Lambi, (2006) finds that a 3.5 per cent increase in temperature associated with a 4.5 per cent increase in precipitation in the absence of irrigation facilities would be detrimental to Cameroon's agriculture, leading to a loss of almost 46.7 per cent in output value. This would negatively affect the economy as a whole, since close to 30 per cent of Cameroon's national GDP comes from agriculture.

In Egypt, empirical results from four variants of the standard Ricardian model showed that a rise in temperature would have negative effects on farm net revenue in Egypt (Model 1). In the second, third, and fourth models, adding the linear term of hydrology, the linear and quadratic terms of hydrology, and the hydrology term and heavy machinery to the analysis improved the adaptability of farm net revenue to high temperature. Marginal analysis indicated that the harmful effect of temperature was reduced by adding the hydrology term and heavy machinery to the analysis. Also, estimates from two climate change scenarios showed that high temperatures will constrain agricultural production in Egypt (Eid et al., 2006). Other studies in this series include (Sene et al. 2006), who assessed the impacts of CC on the revenues and adaptation of farmers in Senegal and finds that farmers have several ways of adapting to climatic constraints in Senegal. These include amongst others diversifying crops, choosing crops with a short growing cycle, weeding early in the north and late in the south, and praying etc. For Seo and Mendelsohn, (2006), using two variants of the standard Ricardian model, results suggest that the livestock net revenues of large farms in Africa fall as temperatures rise but that small farms are not temperature sensitive (Model 1), while in the second model the authors find that higher temperatures reduce both the size of the stock and the net revenue per value of stock for large farms. In Kurukulasuriya and Mendelsohn, (2006), assessing the impact of climate change on African cropland from 11 countries involving over 9000 farmers, the authors find that net farm revenues fall as precipitation falls or as temperatures warm across all the surveyed farms.

In Burkina Faso, Ouedraogo et al. (2006) find that if temperature increases by 1°C, farm revenue will fall by 19.9 US$/ha, while if precipitation increases by 1 mm/month, net revenue increases by 2.7 US$/h using a standard Ricardian model. The elasticity shows that agriculture is very sensitive to precipitation in Burkina Faso. In Ethiopia, the results were not much different, Deressa (2006), also finds that net farm revenue would fall in summer and winter if temperature increases whereas increase in precipitation during spring will increase net farm revenue. Simulation of uniform scenarios that is increasing temperature by 2.5^0C and 5^0C; and decreasing precipitation by 7 per cent and 14 per cent suggest that increasing temperature and decreasing precipitation are both damaging to Ethiopian agriculture. However, the author concludes that decreasing precipitation appeared to be more damaging than increasing temperature. Also in Zambia, Jain (2006), finds that an increase in the November–December mean temperature and a decrease in the January–February mean rainfall have negative impacts on net farm revenue in Zambia, whereas an increase in the January–February mean temperature and mean annual runoff has a positive impact.

It is however; surprising, that despite the vastness, population, and position of Nigeria in the Sub-Saharan region coupled with its different climatic conditions, she was left out of the multi-country studies. Some individual research efforts have however been geared toward ascertaining the impact of CC on Agricultural productivity and profitability in Nigeria. For example, Davis and Sadiq, (2010) carried out a research on the effect of climate change on cocoa yield. The study revealed that there is a weak inverse correlation in rainfall (0.0073), meaning that increase in rainfall result in decrease in yield. While positive weak correlation (0.2196) was established for temperature on yield. The study also revealed a strong positive correlation between yields/pods and temperature. They concluded that a combination of optimal temperature (29°c) and minimal rainfall (900 to 1000mm) will give a better yield and improve production and the economy of both Cocoa farmers and Nigeria at large. Lawal and Emaku, (2007) during their own study on the effect of climate change on cocoa production in Nigeria found out that there is a weak negative correlation for both rainfall and relative humidity on cocoa yield over the years while they established positive correlation for temperature on yield.

On the same study, they found out that the incidence of black pod disease has a positive correlation with temperature and relative humidity but a negative correlation with rainfall. Just like Davis and Sadiq, they concluded that a better yield and reduced incidence of black pod disease on cocoa in Nigeria require an optimal temperature of 29°c and minimal rainfall of 1,125mm and relative humidity of about 74%. . In line with the above findings, Ajayi et al, (2010) revealed that rainfall has a constraining ability on cocoa yield in the core cocoa production areas of Ondo state, Nigeria. They found that Cocoa yield was also shown to be the inverse of annual rainfall level as cocoa yield increased in the early and latter months of the year when the rains are yet to fully come, and suffered in the mid year at the heart of rain season. Contrary to the negative correlation between rainfall and cocoa yield, Omolaja et al, (2009) found that high rainfall and favorable temperature promote flowering intensity of cacao in Nigeria.

3.0 Theoretical framework

Conventionally, there are some models that have been widely used to assess the economic impacts of climate change on agriculture, these are; the Production Function Approach, the Agronomic-Economic Models (AEM), Agro-Ecological Zone Models (AEZM), and the Ricardian Cross-Sectional Model (RM). In the Production function approach, the production function is specified and the yields of different species of crops are examined under different climatic conditions (Reinsborough, 2003). The model assumes that the different species of crop don't have any means of adapting to the changing climate condition. It also assumes that land used in a giving year for a specific crop will be used for that same crop in other years. This makes the model to under estimate the agricultural benefits of the changing climatic conditions.

The AEM employs a combination of: (i) controlled experiments on specific crops grown in field or laboratory settings under different climate scenarios such as temperatures, precipitations, and or carbon-dioxide; (ii) agronomic modeling; and, (iii) economic modeling, to predict climate impacts (Adams and McCarl, 2001). The estimated changes in the experimental crops from the agronomic models are then entered into an economic model to predict crop choice, production, and market prices (Seo et al. 2005). One major advantage of the AEM is that it directly predicts the way climate change affects crop yields since it requires carefully calibrated controlled experiments. However, disadvantages which limits its applicability to the developing countries include amongst others; (i) agronomic estimates do not control for adaptation to changing climates (Mendelsohn and Dinar, 1999); and, (ii) lack of sufficient controlled experiments to determine agronomic responses in several developing countries (Seo et al. 2005). Studies that have adopted this technique include those of: Adams et al. (1989, 1990, 1993, & 1999); Easterling et al. (1993); Kaiser et al. (1993); Rosengweig and Parry, (1994); El-Shaer et al. (1997); Kapentanaki and Rosengweig (1997); Iglesias et al. (1999); Darwin, 1999; Kumar and Parikh (2001) etc.

The AEZM on the contrary, assigns crops to agro-ecological zones as implicit in the name and their crop yields predicted (FAO, 1996). Underlying this model is the simple fact as climate changes, the agro-ecological zones and the crops changes, which makes it possible to predict the effects of alternative climate scenarios on crop yields (Mendelsohn and Dinar, 1999). However, just like the AEZM, changes in the experimental crops derived from the different agro-ecological zones are fed into an economic model to predict rather overall supply and market effects (Darwin et al. 1995). The greatest strength of this model is that it can easily be applied to the developing countries because the geographical distribution of zones in this region is available (Mendelsohn, 2000).

Disadvantages include: (i) it is not clear how tightly climate zones can predict which crops should be grown or what their yields would be (Mendelsohn, 2000); and, (ii) estimates do not control for adaptation to changing climates as the case with the AEZM. For the RM, its theoretical basis is deeply rooted in the famous theory of economic rents by David Ricardo (1815) however, much of its application to climate-land value analysis, draws extensively from the work of Mendelsohn et al. (1994). The RM simple examines how climate in different places affects the net revenue or value of land. As Seo et al. (2005) note, by doing so, the RM accounts for the direct impacts of climate on yields of different crops as well as the indirect substitution of different inputs, introduction of different activities, and other potential adaptation by farmers to different climates. Thus, the greatest strength of the model is its ability to incorporate the changes that farmers would make to tailor their operations to climate change (Mendelsohn and Dinar, 1999). However, despite this major advantage that the RM has over the AEM and AEZM, it has been criticize on grounds that (i) crops are not subject to controlled experiments across farms as the case with the AEM and AEZM, (ii) it does not account for future change in technology, policies and institutions, (iii) assumes constant prices which is really the case with agricultural commodities since other factor determine prices; and, (iv) also fails to account for the effect of factors that do not vary across space such as CO_2 concentrations that can be beneficial to crops (Hassan, 2008 and Fonta, etal 2010).

Despite its major short comings, the RM has been extensively applied in both the developed and developing countries with remarkable success. A few include (Mendelsohn and Nordhaus, 1996; Sanghi et al., 1998; Mendelsohn, 2000, Mendelsohn and Dinar, 1999, 2003; Kumar and Parikh, 2001; Reinsborough, 2003; Gbetibouo and Hassan, 2005; Hassan and Nhemachena, 2008; Deressa et al. 2005; Seo et al., 2005; Sene et al. 2006; Ouedraogo et al., 2006; Mano and Nhemachena, 2006; Deressa and Hassan 2009; Mendelsohn 2010; etc.;).

3.1 Climate change and challenges of food security and agricultural productivity

In 2004 agriculture directly contributed to about 14% of global anthropogenic greenhouse gas (GHG) emissions, according to the Intergovernmental Panel on Climate Change (IPCC, 2007). Agriculture is particularly vulnerable to climate change. Projections to 2050 suggest both an increase in global mean temperatures and increased weather variability, with implications for the type and distribution of agricultural production worldwide (Shaw et al, 2007). Climate change worsens the living conditions for many who are already vulnerable, particularly in developing countries because of the lack of assets and adequate insurance coverage. Climate change impacts the four key dimensions of food security – availability, stability, access, and utilization. Availability of agricultural products is affected by climate change directly through its impacts on crop yields, crop pests and diseases, and soil fertility and water-holding properties. It is also affected by climate change indirectly through its impacts on economic growth, income distribution, and agricultural demand. In addition, stability of crop yields and food supplies is negatively affected by variable weather conditions. Physical, economic, and social access to food would is affected negatively by climate change as agricultural production declines, food prices rise, and purchasing power decreases. Last but not least, climate change poses threats to food utilization through effects on human health and the spread of diseases in geographical areas which were previously not affected. By 2080, agricultural output in developing countries may decline by 20 percent due to climate change, while output in industrial countries is expected to decrease by 6 percent. Also due to climate change, yields in developing countries could further decrease by 15 percent on average by 2080 (FAO, 2008).

According to the United Nations Joint Press Kit for Bali Climate Change Conference, 2007, the following impact and projections were stated with specific focus to SSA,

i. **Climate change will increase hunger and malnutrition:** Climate change will worsen the living conditions of farmers, fishers and forest-dependent people who are already vulnerable and food insecure. Hunger and malnutrition will increase. Rural communities dependent on agriculture in a fragile environment will face an immediate risk of increased crop failure and loss of livestock. Mostly at risk are people living along coasts, in floodplains, mountains, dry lands, and the arctic. In general, poor people will be at risk of food insecurity due to loss of assets and lack of adequate insurance coverage.

ii. **Climate change will particularly affect vulnerable people and food systems:** More frequent and more intense, extreme weather will have adverse immediate impacts on food production, food distribution infrastructure, on livelihood assets and opportunities in both rural and urban areas. Changes in mean temperatures and rainfall, increasing weather variability and rising sea levels will affect the suitability of land for different types of crops and pasture, the health and productivity of forests, the incidence of pests and diseases, biodiversity and ecosystems.

Loss of arable land is likely due to increased aridity, groundwater depletion and the rise in sea level.

iii. **Agriculture contributes to climate change:** Greenhouse gas emissions from the food and agriculture sector contribute over 30 percent of the current annual total emissions (deforestation 17, 4 percent, agriculture 13, 5 percent).

iv. **Sustainable forest management:** Around 13 million hectares of forests are annually being lost due to deforestation, according to FAO. Reducing forest degradation and deforestation helps to protect water and soil resources as well as biodiversity and it contributes to the reduction of greenhouse gas emissions. Climate change will also affect the health of forests through an increase of forest fires and pests and diseases. Without economic or other incentives and political will, it will be difficult to stop deforestation and forest degradation.

v. **Fishing and aquaculture are threatened by climate change:** Climate change is having an impact on oceans, seas, lakes and rivers and on the animals and plants that are found in them. Climate change will affect about 200 million people and their families worldwide who live by fishing and aquaculture. Some fish resources will become less abundant while important species may move to other areas where they are less available to the fishers. This will make it harder for many fishing communities to continue to make a living from fish or to provide fish for feeding their families. Coastal communities may also be displaced by rising sea levels and will be forced to find new places to live and new ways to earn a living.

vi. **New patterns of pests and diseases will emerge:** Humans, plants, livestock and fish will be exposed to new pests and diseases that flourish only at specific temperatures and humidity. This will pose new risks for food security, food safety and human health.

Obviously, climate change is no longer a problem to be faced in the future; it is a reality that is seriously affecting the Earth already, especially challenging agricultural productivity and food security in developed and developing economies of the world and thus requires urgent attention. Shah et al (2007) have argued that disruptions or declines in global and local food supplies due to climate change can be avoided through more efficient irrigation and watershed management, improved land cultivation and livestock management and the development of crop varieties and breeds that are adapted to changing climatic conditions. Plant and animal biodiversity increases resilience to changing environmental conditions and stress (drought, salinity, flooding). Land use for livestock production, including grazing land and cropland dedicated to the production of feed, represents approximately 70 percent of all agricultural land in the world (UNDP, 2007).

Climate change and energy: critical implications for food security

Climate change and energy are two major factors redefining the world food equation and having an enormous impact on the food security of poor people. Climate change is now not only a better-understood scientific fact, but also a phenomenon which has already affected global temperatures, regional weather patterns, and physical and biological systems. Attributed directly or indirectly to human activity, climate change puts additional pressure on already over-exploited natural resources. It negatively affects crop yields, stability of food supplies, and the ability of people to access and utilize food in many parts of the developing world. Although rich countries are responsible for most greenhouse gas emissions (GHGs) the impact of climate change is expected to be most severe in developing countries and on poor people. Low-income communities depend directly on agriculture, forestry, fisheries, aquaculture, and climate-sensitive resources. They also have inadequate complementary services, such as health, education, and insurance services.

Bryant et al (2000) stated that the risks climate change poses on food security are particularly pressing at a time of high oil prices, at levels surpassing $130 a barrel in May 2008 (IFAD, 2008). High fuel prices make agricultural production more expensive by raising the cost of fertilizers, irrigation, and transportation. With high oil prices, calls for increased energy efficiency, and government biofuel subsidies, agriculture-based energy production has surged. Farmers have switched massively to production of crops for ethanol and biodiesel. The increased level and volatility of agricultural prices is negatively impacting the purchasing power and the food security of the poor (von Braun, 2007). Food security depends on availability of food, access to food, and utilization of food (FAO, 2000). Food availability refers to the existence of food stocks for consumption. Household food access is the ability to acquire sufficient quality and quantities of food to meet all household members' nutritional requirements. Access to food is determined by physical and financial resources, as well as by social and political factors. Three facets of the food system need to be met in order for food security to be realized. Each of these facets can be impacted by climate variability, and these impacts are:

Food availability

Climate variability directly affects agricultural production, as agriculture is inherently sensitive to climate conditions and is one of the most vulnerable sectors to the risks and impacts of global climate change (Parry et al., 1999). Many factors impact the type of policies implemented at a national level (such as domestic politics, redistribution of land/wealth, exchange rates, and trade issues, etc.). Climate variability should be factored into these policies, as these policies can impact the availability of staple foods, for example, by providing incentives to grow crops appropriate for the climate conditions.

In the case study sites, the two major forms of agricultural production are arable and pastoral farming. Because of the limited amount and uneven distribution of rainfall in time and geographic scope at the study sites, rainfall represents the most limiting factor for agricultural and livestock production. Its consequences are well known to local populations: the drying out of water sources, scarcity of grazing land, shortage of dairy products, and loss of wild plants for gathering, migration of grazers, bad harvests, and livestock losses, among others. For instance, it has been estimated by the World Bank that around 10% of the population of Sub-Saharan Africa is primarily dependent on their animals, whereas another 58% depend on varying degrees of their livestock (Arnell et al., 2002; Devereux and Edwards, 2004). Increasing population pressures interacting with declining rainfall and reduced pasture has already begun to impact the livestock sector negatively. Rangeland condition is directly affected by the climate and in turn, directly affects the quality and quantity of small and large stock and associated livelihood activities (Ziervogel, et al, 2006).

Production of food and other agricultural commodities may keep pace with aggregate demand, but there are likely to be significant changes in local cropping patterns and farming practice. About 50 percent of total crop production comes from forest and mountain ecosystems, including all tree crops, while crops cultivated on open, arable flat land account for only 13 percent of annual global crop production. Production from both rainfall and irrigated agriculture in dry land ecosystems accounts for approximately 25 percent, and rice produced in coastal ecosystems for about 12 percent (Millennium Ecosystem Assessment, 2005).

Furthermore, the “greenhouse fertilization effect” will produce local beneficial effects where higher levels of atmospheric CO2 stimulate plant growth. This is expected to occur primarily in temperate zones, with yields expected to increase by 10 to 25 percent for crops with a lower rate of photosynthetic efficiency (C3 crops), and by 0 to 10 percent for those with a higher rate of photosynthetic efficiency (C4 crops), assuming that CO2 levels in the atmosphere reach 550 parts per million (IPCC, 2007); these effects are not likely to influence projections of world food supply, however mature forests are also not expected to be affected, although the growth of young trees stands will be enhanced (Tubiello, et al,2007 and Norby et al, 2005).

The impacts of mean temperature increase will be experienced differently, depending on location (Leff, Ramankutty and Foley, 2004). For example, moderate warming (increases of 1 to 3 ºC in mean temperature) is expected to benefit crop and pasture yields in temperate regions, while in tropical and seasonally dry regions, it is likely to have negative impacts, particularly for cereal crops. Warming of more than 3 ºC is expected to have negative effects on production in all regions (IPCC, 2007). The supply of meat and other livestock products will be influenced by crop production trends, as feed crops account for roughly 25 percent of the world’s cropland.
For climate variables such as rainfall, soil moisture, temperature and radiation, crops have thresholds beyond which growth and yield are compromised (Porter and Semenov, 2005).

On the other hand, cereals and fruit tree yields can be damaged by a few days of temperatures above or below a certain threshold (Wheeler *et al.*, 2000). In the European heat wave of 2003, when temperatures were 6 ºC above long-term means, crop yields dropped significantly, such as by 36 percent for maize in Italy, and by 25 percent for fruit and 30 percent for forage in France (IPCC, 2007). Increased intensity and frequency of storms, altered hydrological cycles, and precipitation variance also have long-term implications on the viability of current world agro ecosystems and future food availability.

Food accessibility

Food accessibility refers to a situation whereby food is allocated through markets and non-market distribution mechanisms. Factors that determine whether people will have access to sufficient food through markets are considered to include income-generating capacity, amount of remuneration received for products and goods sold or labour and services rendered, and the ratio of the cost of a minimum daily food basket to the average daily income.

Non-market mechanisms on the other hand, include production for the farmer's own consumption, food preparation and allocation practices within the household, and public or charitable food distribution schemes. For rural people who produce a substantial part of their own food, climate change impacts on food production may reduce availability to the point that allocation choices have to be made within the household. A family might reduce the daily amount of food consumed equally among all household members, or allocate food preferentially to certain members, often the able-bodied male adults, who are assumed to need it the most to stay fit and continue working to maintain the family. Non-farming low-income rural and urban households whose incomes fall below the poverty line because of climate change impacts will face similar choices. Urbanization is increasing rapidly worldwide, and a growing proportion of the expanding urban population is poor (Ruel *et al.*, 1998). Allocation issues resulting from climate change are therefore likely to become more and more significant in urban areas over time. Urban agriculture has a limited ability to contribute to the welfare of poor people in developing countries because the bulk of their staple food requirements still need to be transported from rural areas to the Urban Centers (Ellis and Sumberg, 1998). If climate change creates other more urgent claims on public resources, support for food distribution schemes may decline, with consequent increases in the incidence of food insecurity, hunger and famine related deaths.

Food affordability

In many countries, the ratio of the cost of a minimum daily food basket to the average daily income is used as a measure of poverty (World Bank Poverty Net, 2008). When this ratio falls below a certain threshold, it signifies that food is affordable and people are not impoverished; when it exceeds the established threshold, food is not affordable and people are having difficulty obtaining enough to eat. This criterion is an indicator of chronic poverty, and can also be used to determine when people have fallen into temporary food insecurity, owing to reduced food supply and increased prices, to a sudden fall in household income or to both. The incomes of all farming households depend on what they obtain from selling some or all of their crops and animals each year. Commercial farmers are usually protected by insurance, but small-scale farmers in developing countries are not, and their incomes can decline sharply if there is a market glut, or if their own crops fail and they have nothing to sell when prices are high.

Most food is not produced by individual households but acquired through buying, trading and borrowing (Du Toit and Ziervogel, 2004). Climate impacts on income-earning opportunities can affect the ability to buy food, and a change in climate or climate extremes may affect the availability of certain food products, which may influence their price. High prices may make certain foods unaffordable and can have an impact on individuals' nutrition and health. Changes in the demand for seasonal agricultural labour, caused by changes in production practices in response to climate change, can affect income-generating capacity positively or negatively. Mechanization may decrease the need for seasonal labour in many places, and labour demands are often reduced when crops fail, mostly owing to such factors as drought, flood, frost or pest outbreaks, which can be influenced by climate.

Local food prices in most parts of the world are strongly influenced by global market conditions, but there may be short-term fluctuations linked to variation in national yields, which are influenced by climate, among other factors. An increase in food prices has a real income effect, with low-income households often suffering most, as they tend to devote larger shares of their incomes to food than higher-income households do (Thomsen and Metz, 1998).

When they cannot afford food, households adjust by eating less of their preferred foods or reducing total quantities consumed as food prices increase. Given the growing number of people who depend on the market for their food supply, food prices are critical to consumers' food security and must be watched. Food often travels very long distances (Pretty *et al.*, 2005), and this has implications for costs. Increasing fuel costs could lead to more expensive food and increased food insecurity. The growing market for biofuels is expected to have implications for food security, because crops grown as feedstock for liquid biofuels can replace food crops, which then have to be sourced elsewhere, at higher cost.

Food preference

Food preferences determine the kinds of food households will attempt to obtain. Changing climatic conditions may affect both the physical and the economic availability of certain preferred food items, which might make it impossible to meet some preferences. Changes in availability and relative prices for major food items may result in people either changing their food basket, or spending a greater percentage of their income on food when prices of preferred food items increase.

In southern Africa, for example, many households eat maize as the staple crop, but when there is less rainfall, sorghum fares better, and people could consume more of it. Many people prefer maize to sorghum, however, so continue to plant maize despite poor yields, and would rather buy maize than eat sorghum, when necessary.
The extent to which food preferences change in response to changes in the relative prices of grain-fed beef compared with other sources of animal protein will be an important determinant of food security in the medium term. Increased prices for grain-fed beef are foreseeable, because of the increasing competition for land for intensive feed grain production, the increasing scarcity of water and rising fuel costs (FAO, 2007). If preferences shift to other sources of animal protein, the livestock sector's demands on resources that are likely to be under stress as a consequence of climate change may be contained. If not, continued growth in demand for grain-fed beef, from wealthier segments of the world's population, could trigger across-the-board increases in food prices, which would have serious adverse impacts on food security for urban and rural poor.

Food utilization and nutritional value

Food insecurity is usually associated with malnutrition, because the diets of people who are unable to satisfy all of their food needs usually contain a high proportion of staple foods and lack the variety needed to satisfy nutritional requirements. Declines in the availability of wild foods, and limits on small-scale horticultural production due to scarcity of water or labour resulting from climate change could affect nutritional status adversely. In general, however, the main impact of climate change on nutrition is likely to be felt indirectly, through its effects on income and capacity to purchase a diversity of foods. The physiological utilization of foods consumed also affects nutritional status, and this – in turn – is affected by illness (World Bank Poverty Net, 2008). Climate change will cause new patterns of pests and diseases to emerge, affecting plants, animals and humans, and posing new risks for food security, food safety and human health. Increased incidence of water-borne diseases in flood-prone areas, changes in vectors for climate-responsive pests and diseases, and emergence of new diseases could affect both the food chain and people's physiological capacity to obtain necessary nutrients from the foods consumed.

Malaria in particular is expected to change its distribution as a result of climate change (IPCC, 2007). In coastal areas, more people may be exposed to vector- and water-borne diseases through flooding linked to sea-level rise. Health risks can also be linked to changes in diseases from either increased or decreased precipitation, lowering people's capacity to utilize food effectively or often resulting in the need for improved nutritional intake (IPCC, 2007). Where vector changes for pests and diseases can be predicted, varieties and breeds that are resistant to the likely new arrivals can be introduced as an adaptive measure. A recent upsurge in the appearance of new viruses may also be climate-related, although this link is not certain. Viruses such as avian flu, ebola, HIV/AIDS and SARS have various implications for food security, including risk to the livelihoods of small-scale poultry operations in the case of avian flu, and the extra nutritional requirements of affected people in the case of HIV-AIDS (FAO, 2008).

The social and cultural values of foods consumed will also be affected by the availability and affordability of food. The social values of foods are important determinants of food preferences, with foods that are accorded high value being preferred, and those accorded low value being avoided. In many traditional cultures, feasts involving the preparation of specific foods mark important seasonal occasions, rites of passage and celebratory events.
Food safety may be compromised in various ways. Increasing temperature may cause food quality to deteriorate, unless there is increased investment in cooling and refrigeration equipment or more reliance on rapid processing of perishable foods to extend their shelf-life. Decreased water availability has implications for food processing and preparation practices,particularly in the subtropics, where a switch to dry processing and cooking methods may be required. Changes in land use, driven by changes in precipitation or increased temperatures, will alter how people spend their time. In some areas, children might have to prepare food, while parents work in the field, increasing the risk that good hygiene practices may not be followed.

Food system stability

Many crops have annual cycles, and yields fluctuate with climate variability, particularly rainfall and temperature. Maintaining the continuity of food supply when production is seasonal is therefore challenging. Droughts and floods are a particular threat to food stability and could bring about both chronic and transitory food insecurity. Both are expected to become more frequent, more intense and less predictable as a consequence of climate change. In rural areas that depend on rainfall for agricultural production, changes in the amount and timing of rainfall within the season and an increase in weather variability are likely to aggravate the precariousness of local food systems.

Stability of access: As already noted, the affordability of food is determined by the relationship between household income and the cost of a typical food basket. Global food markets may exhibit greater price volatility, jeopardizing the stability of returns to farmers and the access to purchased food of both farming and non-farming poor people. *Food emergencies*: Increasing instability of supply, attributable to the consequences of climate change, will most likely lead to increases in the frequency and magnitude of food emergencies with which the global food system is ill-equipped to cope. Climate change might exacerbate conflict in numerous ways, although links between climate change and conflict should be presented with care. Increasing incidence of drought may force people to migrate from one area to another, giving rise to conflict over access to resources in the receiving area. Resource scarcity can also trigger conflict and could be driven by global environmental change. Grain reserves are used in emergency-prone areas to compensate for crop losses and support food relief programmes for displaced people and refugees. Higher temperatures and humidity associated with climate change may require increased expenditure to preserve stored grain, which will limit countries' ability to maintain reserves of sufficient size to respond adequately to large-scale natural or human-incurred disasters.

Threats of climate change for developing countries and food insecure people

Emissions of GHGs between 2000 and 2006 have increased on average by 3.1 percent per annum, compared to 1.1 percent in the previous decade, and are likely to continue to grow rapidly in view of high economic growth and lack of effective mitigation strategies (Garnaut Climate Change Review 2008). There is high confidence that natural systems are affected by changes in climate, especially by rising temperatures (IPCC 2007). The effects of climate change are heterogeneous and region-specific. Some positive effects of climate change such as CO2 fertilization of plants could contribute to increasing food production and security. Climate change could lead to increased water stress, decreased biodiversity, damaged ecosystems, rising sea levels, and potentially, to social conflict due to increased competition over limited natural resources. Small-holder agriculture, pastoralist, forestry, and fisheries and aquaculture are among the systems most at risk (FAO 2008).

The threats of climate change are more severe in developing countries, partially due to geography. Many low-income countries are located in tropical and subtropical regions, which are particularly vulnerable to rising temperatures, and in semi-desert zones, which are threatened by decreasing water availability. By 2080, agricultural output in developing countries may decline by 20 percent due to climate change, while output in industrial countries is expected to decrease by 6 percent (Cline, 2007). Also due to climate change, yields in developing countries could further decrease by 15 percent on average by 2080 (Fischer et al. 2005). Taking into account the effects of climate change, the number of undernourished people in Sub-Saharan Africa may triple between 1990 and 2080. Climate change shocks also erode the long-term opportunities for human development and could exacerbate inequalities within countries (UNDP 2007).

Climate change impacts the four key dimensions of food security – availability, stability, access, and utilization (e.g. Schmidhuber and Tubiello 2007). Availability of agricultural products is affected by climate change directly through its impacts on crop yields, crop pests and diseases, and soil fertility and water-holding properties. It is also affected by climate change indirectly through its impacts on economic growth, income distribution, and agricultural demand (Schmidhuber and Tubiello 2007). In addition, stability of crop yields and food supplies is negatively affected by variable weather conditions. Physical, economic, and social access to food would is affected negatively by climate change as agricultural production declines, food prices rise, and purchasing power decreases. Last by not least, climate change poses threats to food utilization through effects on human health and the spread of diseases in geographical areas which were previously not affected.Current responses to climate-change threats—particularly those affecting agriculture in developing countries and hence, the majority of the rural poor—underestimate the gravity of the situation. The existing climate risk management options can have substantial benefits for some cropping systems if climate change is moderate, but will not be efficient if climate change is severe (Howden et al. 2007).

Poor and food-insecure people have often failed to receive the benefits of current climate change science. The ability of the poor to take advantage of climate change mitigation and adaptation technologies is also linked to their education, cultural practices, skills, and access to financial assets, as well as to the existence of supporting institutions and the relevance and applicability of technologies to their particular needs. It is important to maximize small farmers' knowledge, which is often marginalized by large-scale efforts to promote agricultural production. Small farmers are often at a disadvantage due to economies of scale. Horizontal cooperation schemes and scale-neutral technologies are some of the ways to overcome these barriers for small farmers.

The costs to adapt to climate change can also include opportunity costs if new technologies and land use practices are changed, and can reduce farm incomes.

3.4 Impact of climate change on cultivable land cereal production potential on currently irrigated land and production potential on current rain-fed grass/scrub/woodland

About 128 million ha of all currently cultivated land in SSA is suitable for grain maize production with a production potential of 882 million tones under current climate conditions and high levels of input (see Table 1). The result of the HadCM3 climate change projection for 2080 indicates that SSA would lose 11% of its potentially cultivable land and 7% of its grain maize production potential, compared with current climate conditions, even under the assumption of CO_2 fertilization and adaptation of the best and most productive grain maize varieties. The trend of loss of cultivable land is same in all the areas identified (in Table 1).

The total land area comprising grass, scrub and woodland in SSA is estimated at 988 million has with a production potential 0f 2.67 billion tones of biomass (see Table 2). According to the HadCM3 climate change projection, the impact of climate change in 2080 would result in an increase in SSA's pasture production potential of about 2%. Southern Africa, with current pastures of around 162miilion ha, would lose approximately 14% of its cultivable land and 20% of its pasture production potential in 2080. Livestock is an important component of food consumption and of livelihoods in most SSA countries, and meat and dairy demand is projected to increase by more than threefold by the 2080s (Shah, 2008). The results highlight the need for grain-based livestock feed and this may not be viable in some SSA countries through domestic production alone.

With these and other indicators (see Shah, et al 2008), the number of undernourished in the developing world is estimated at 820 million, equivalent to 17% of the total population of 4.1billion. SSA has the highest prevalence of undernourishment with some 32% of the total population deprived of access to food (see Table 3). Some fairly unambiguous conclusions emerge from the analysis of climate change impacts on the prevalence of hunger. First, climate change will most likely increase the number of people at risk of hunger. Second, the importance and significance of climate change impact on the level of undernourishment depends entirely on the level of economic development assumed in those countries.

Biofuels linkages with climate change and agriculture

Agriculture is part of the problem and part of the solution of the climate change problem. Land use change and agriculture add to nearly one third of greenhouse gas emissions, but they also offer opportunities for carbon mitigation through carbon sequestration and biofuel production. Biofuel production increases the linkages between the energy and agriculture sectors, influences and is influenced by political, social, economic, and environmental change, and impacts households, businesses, and the private sector (von Braun, et al 2008). Biofuels have raised hopes for reducing greenhouse gas emissions, mitigating climate change on a global or regional scale, and reducing the environmental risks to food security. Yet, biofuel expansion also adds to the greenhouse gas emissions problem through the conversion of forest and grassland land to energy crop production. With land-use change, increased world corn-based ethanol production doubles emissions over 30 years and increases green-house gas emissions for 167 years (Searchinger et al. 2008). For palm biodiesel produced in Indonesia or Malaysia, the payback period to the carbon debt from land conversion is 423 years (Fargione et al. 2008).On the positive side, biofuels could benefit poor people through raising agricultural incomes, creating additional rural jobs in crop harvesting and processing, and utilizing marginal lands and crop residues.

The extent to which these potentials are realized depends on the farmers' ability to access to information and markets, produce at competitive prices and sufficient economies of scale, and afford new biofuel sources. However, economies of scale in ethanol production—at least to date—favor large scale farms, while the existing subsidy regimes and import restrictions undermine the comparative advantage of developing countries. For developing countries and poor people, the competition between agricultural production for food and for energy also creates new food security risks in the four dimensions mentioned above – availability, stability, access, and utilization. In terms of food availability, biofuels could unduly divert land and water resources, capital, and political attention, away from the production of food. In the largest ethanol producer, the United States, a third of the domestic corn produced is being used for ethanol production. Rising demand of biofuel feedstocks also puts strong upward pressure on agricultural commodity prices and thus, on access to food. Further, stability of food supplies is put at risk as volatile energy prices translate into larger food-price fluctuations, to which poor people have little capacity to adjust.

Incorporating actual biofuel investment plans, IFPRI's global scenario analysis projects that biofuel expansion may result in price increases of 26 percent for maize and 18 percent for oilseeds by 2020.1 These increases in crop prices are also accompanied by a net decrease in calorie consumption in all regions. The largest decrease is in Sub-Saharan Africa, where calorie availability is projected to fall by more than 8 percent if biofuels expand drastically. In addition, the pressure biofuels put on water for household use could pose health risks and undermine food utilization (Searchinger et al, 2008). At the same time, however, local biofuel production could provide cleaner and cheaper cooking and heating alternative fuels and have positive health consequences for the poor. Whether expanded biofuel production is an environmentally sustainable source of energy depends on the choice of feedstock, cultivation practices, technologies employed, and the security, trade, and environmental policies that are adopted. For example, current public policies, which support uncompetitive biofuel production with distorting subsidy regimes implicitly, act as a tax on basic food, which constitutes a large share of the expenditures of the poor (von Braun, et al 2008). Biofuel technology will be an important area for sharing innovations between industrialized countries and developing countries in the future that could serve global sustainability. As the majority of patents in biofuels are held by the private sector, this is also a promising area for public–private partnerships.

4.4 Policy direction

Agriculture is important for food security as it produces the food people eat; and (perhaps even more important) it provides the primary source of livelihood for 36 percent of the world's total workforce (FAO 2008). Preserving and enhancing food security requires agricultural production systems to change in the direction of higher productivity and also, essentially, lower output variability in the face of climate risk and risks of an agro-ecological and socio-economic nature. In order to stabilize output and income, production systems must become more resilient, i.e. more capable of performing well in the face of disruptive events. More productive and resilient agriculture requires transformations in the management of natural resources (e.g. land, water, soil nutrients, and genetic resources) and higher efficiency in the use of these resources and inputs for production. Transitioning to such systems could also generate significant mitigation benefits by increasing carbon sinks, as well as reducing emissions per unit of agricultural products.

In achieving this, von Braun et al (2008) disclosed that a rapid, coordinated, and multidisciplinary response is needed to respond to climate change and other emerging risks. It should be adapted to location-specific circumstances and incorporate the effects on food security of non-climatic factors such as high energy prices, high food prices, and biofuel production. The approach should combine adaptation strategies, which reduce the vulnerability of poor people to climate change and other shocks, and mitigation strategies, which moderate the impact of climate change after it has occurred. For example, for agriculture, the IFPRI's global scenario analysis is based on the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) directed by Mark Rosegrant.

More fundamentally, policy direction for climate change mitigation and improved sustained food security and agricultural productivity must among other things include improved land management, adjustment of planting dates, and introduction of new crop varieties, while the mitigation options include improved energy efficiency and crop yields, and land management techniques to increase carbon storage (IPCC 2007). Building on the fundamentals of good development policy is essential but not enough to ensure food security under new climate change challenges and threats. On a broad scale, von Braun (2008) noted that the adaptation strategies that are extensions of good development policy include,

i) promoting growth and diversification of production and livelihood systems;
ii) investing in research and development, education and health;
iii) creating markets in water and environmental services;
iv) improving the international trade system;
v) enhancing resilience to disasters and improving disaster management; and
vi) promoting risk-sharing, including social safety nets and weather insurance.

Effective adaptation and mitigation strategies, however, must also go beyond good development policy, be proactive, and explicitly target the impacts of climate change and energy (biomass) developments on the poor. As the global food equation is changing as a result of energy shortage and climate change, the world is not only confronted with agriculture and energy policy issues, but also with broader social, environmental, and security issues.

The needed response involves a combination of science, institutional, and policy innovations, which should be taken into account in global, regional, and national strategies, and should have three main elements. These elements, von Braun et al (2008) stated are:

1. ***A science and technology strategy*** for mitigating climate change and accelerating agricultural productivity to maintain and improve food security. Yet, investments in science and technology have been sorely neglected in recent decades. For climate change mitigation, the technological innovations needed include early warning systems for droughts, floods, and other natural disasters, better soil and water management, and seed varieties more resistible to adverse climatic conditions. For adaptation and long-term productivity, biodiversity should also be maintained and enhanced, for example through newly founded gene banks. Carbon sequestration, a process that removes carbon dioxide from the atmosphere, should be encouraged for mitigating the increase of carbon concentration. Also, more support should be given to developing clean bioenergy technologies that do not compete with food production. To achieve long-term agricultural growth and build a more resilient food system that can meet ongoing and future challenges, developing country governments should also increase their medium- and long-term investments in agricultural research and connect to international science and knowledge-sharing systems. In addition, new approaches to scientific partnerships should be developed and expanded. Co-funding and cooperation among public institutions, foundations, and private enterprises should play an important role in building and advancing the scientific base.

2. ***Markets and trade policy strategy***, which calls for global institutional arrangements of carbon and biofuels trading, as well as micro-level design of markets in the two sectors. As a first step, developed countries should eliminate domestic biofuel subsidies and open their markets to biofuel exporters for biofuels from sustainable production. In view of the high food prices, measures to make more agricultural products available for food and feed include freezing biofuel production at current levels, reducing it, or imposing a temporary moratorium for biofuels based on grains and oilseeds. Transparent and equitable standards of carbon and biofuels trading are needed, including sustainability and performance based standards rather than technology-based standards that will quickly become outdated. Post Kyoto Protocol rules of access must change to include activities important for developing countries such as avoiding deforestation, soil carbon sequestration, and mitigating methane and nitrous oxide. The Clean Development Mechanism rules should be refined to encourage small farmer participation. In addition, existing regulations which impose high costs on developing carbon markets in poor countries should be changed and streamlined. Ongoing climate change initiatives, such as the Bali Action Plan, should lead to a new binding international climate change agreement with appropriate carbon-trading and carbonoffset policies (e.g. cap-and-trade and carbon-tax instruments). A global emission trading system should include the right economic incentives for engaging small farmers in developing countries in climate change mitigation and adaptation. Farmers' organizations should cooperate at the national and international level to link small farmers to global carbon markets (IFAD 2008). Ensured by efficient contracts, the private sector and small farmers can engage in mutually-beneficial projects in carbon sequestration and decentralized bio-energy crop production.

3***. An insurance and social protection strategy for the food insecure poor*** to respond to the growing complexities of food system changes. To reduce the vulnerability of poor households to adverse climate and energy price shocks and to prevent new households from falling into poverty, there is an increased need to strengthen public and market-based social protection mechanisms. Examples of social protection policies include social safety nets (such as conditional or unconditional cash transfers, public works and school feeding programs, subsidies on items consumed by the poor, microcredit, and crop insurance), health insurance, and social security. In addition, the triggers of emergency agencies to respond to crises should be improved. New and innovative insurance mechanisms and private-public partnerships should also be introduced at a larger scale to expand coverage among the poor. Insurance and social protection must be adjusted to the individual circumstances of each country and should be supported by investment in rural infrastructure and services, and good governance. On an appropriate time scale, the actions needed to address the acute and long-run price crisis issues may be broken down into an emergency package and a resilience package (von Braun, et.al. 2008).

5.4 Conclusion

Within contemporary global challenge of climate change and its adverse effect on food security and agricultural productivity, measures must be taken towards adaptation and mitigation. One successful path to tread is to boost agricultural production.

Projections based on population growth and food consumption patterns indicate that agricultural production will need to increase by at least 70 percent to meet demands by 2050. Most estimates also indicate that climate change is likely to reduce agricultural productivity, production stability and incomes in some areas that already have high levels of food insecurity. Developing climate-smart agriculture is thus crucial to achieving future food security and climate change goals. Each country should develop and implement a viable national action plan, which takes into account future development paths, expected climate change impacts, and adaptation and mitigation costs. National governments can play a crucial role in assisting with climate mitigation and adaptation in five major ways: provide information and advice about climate risks and available strategies, provide guidance and training on design and implementation of measures, promote desirable adaptation measures through public policy, mandate adaptation to safeguard public health and safety and institutionalize adaptation capacity and policy and promote interdepartmental cooperation (Yohe, Burton, and Rosegrant, 2008).

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Table 1: Impact of climate change on cultivable land cereal production potential on currently irrigated land

	Current climate			HadCM3 A2 2080s			CSIRO A2 2080s		
	Area min ha	Prod min tons	Yield t/ha	Area	Prod	Yield % Change	Area	Prod	Yield % Change
Sub –Saharan Africa	128	882	6.9	-11	-7	5	-23	-20	4
Eastern Africa	52	348	6.7	-5	5	11	-27	-22	8
Middle Africa	17	117	7.0	-3	-3	1	-7	-7	-7
Western Africa	50	350	7.0	-15	-13	2	-18	-15	4
Southern Africa	9	67	7.4	-44	-45	-2	-61	-63	-6
Developed	229	1503	6.6	40	14	-18	50	38	-8
Developing	342	2471	7.2	-1	2	3	-10	-9	1
World	571	3975	7.0	16	7	-8	14	9	-4

Note: results include CO_2 fertilization and assume rational adaptation and transfer of crop types **Source:** Fischer et al, 2008

Table 2: Impact of climate change on cultivable land and production potential on current rain-fed grass/scrub/woodland

	Current climate			HadCM3 A2 2080s			CSIRO A2 2080s		
	Area min ha	Prod min tons	Yield t/ha	Area	Prod	Yield % Change	Area	Prod	Yield % Change
Sub –Saharan Africa	988	2,670	2.7	0	2	3	-1	1	1
Eastern Africa	436	1,311	3.0	2	4	4	1	4	4
Middle Africa	216	866	4.0	-1	4	5	1	4	4
Western Africa	175	260	1.5	3	4	5	-5	-6	-6
Southern Africa	162	233	1.4	-14	-20	-19	-13	-15	-15
Developed	1,624	3,178	2.0	4	5	5	11	13	13
Developing	2,258	7,687	3.4	-1	1	1	1	2	3
World	3,882	10,865	2.8	0	2	2	4	5	5

Source: Fischer et al, 2008

Table 3: Impact of climate change on world food system indicators, people at risk of hunger (million people)

	Year 2000	A2r 2080 without CC	A2r 2080 HadCM3	A2r 2080 HadCM3, mitigation
Latin America Africa	57	23	30	26
Sub-Saharan Africa	188	410	450	430
Southern East Asia	42	5	5	5
South Asia	312	43	45	44
East Asia	42	5	.5	5
Developing	821	554	622	588

Source: Fischer et al, 2008