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Impact of Climate Change on Crop Yield with Special Reference to Food Security in Ethiopia: Review Article

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Abstract
This review was designed to address the impact of climate change on crop yield with special reference to food security in Ethiopia. The challenge of climate change and global warming is enormous in Ethiopia due to widespread poverty, land use change, erosion and deforestation and farm residues that underpin agricultural production and its variability will likely have a major influence on national level of food security. Future climate projections suggest that atmospheric carbon dioxide rising via agriculture 80%, temperature will increase up to 3 ^{o}C but the precipitation may increase or decrease depending on the location thus one said flooding other said drought, on other said relative humidity and evapotranspiration depend on temperature anomaly. Thus fluctuation of climate elements causes the crop yield reduction though direct (physical growth and development) and indirect (soil temperature and water scarcity) impact, whereas the impact of topographic and crop photosynthesis variation on crop yield becomes regular. Consequently, could reduce crop production in 2050-2100 even if diverse climate scenario, under same climate scenario the population is expected to doubled from 87.9 to 188 million in 2050. Thus cause increment of more food to feed those people. on other hand, increase food demand. The projection of climate change affect the requirements of Food and Nutrition hence malnourished rise from 1.5million to 2.02 million person and average person food consumption requirement decline from 2,212 kcal per day to 506 kcal per day in 2050 likewise food supply decrease..
Keywords: Climate Change, Population Growth, Crop Yield, Food Security

1. Introduction

Ethiopia, with a total area of 1,127,127 km^2 (CSA, 2009) has a population of 87.9 million, out of which 85% live in rural areas (CSA, 2014). The country has diverse topographic features which encompass high mountains, deep gorges, flat-topped plateaus and rolling plains. The physical conditions and variations in altitude have resulted in a great diversity of climate, soil and vegetation and land use practices (Asrat, 1992). The climate of Ethiopia is mainly controlled by the seasonal migration of the Inter-tropical Convergence Zone (ITCZ) and associated atmospheric circulations as well as by the complex topography of the country. It has a diversified climate ranging from semi-arid desert type in the lowlands to humid and warm temperature type (NMSA, 2001). Ethiopia is characterized by diverse topography. The great East African Rift Valley (which runs northeast to southwest across Ethiopia), the mountains and highlands to the right and left of this Rift Valley, and the lowlands surrounding these mountains and highlands in every direction can be described as the country's main topographical features. The diverse topography and various atmospheric systems affecting the Ethiopian climate, in turn, resulted in varying climatic conditions across the country (NMSA, 1996).

The causes of climate change can be divided into two categories, human and natural causes. It is now a global concern that the climatic changes occurring today have been speeded up because of man's activities. Thus, has resulted in increases in globally-averaged mean annual air temperature and variations in regional precipitation and these changes are expected to continue and intensify in the future (Solomon et al., 2007). While it is poses a huge challenge to Ethiopia and its people. The country is faced with increasingly unpredictable rains, and sometimes the complete failure of seasonal rains – problems which are linked to climate change. It is a country with large differences across regions which are reflected in the country's climate vulnerability. The lowlands are vulnerable to increased temperatures and prolonged droughts which may affect livestock rearing. The highlands may suffer from more intense and irregular rainfall, leading to erosion, which together with higher temperatures leads to lower total agricultural production.

Global food security threatened by climate change is one of the most important challenges in the 21st century to supply sufficient food for the increasing population while sustaining the already stressed environment R. Lal, *et al.*, 2005. Food security is highly sensitive to climate risks in Ethiopia (WFP, 2014). This climate change will reduce crop yields and in turn will increase the price of food that force people to change production and consumption patterns and directly will reduce calorie intake European Commission (DG ENV, 2009). Different studies indicated this problem will increase in the future Akram AK., *et al*, (2006), due to climate change with population growth which are contributing the great share of the problem (Lloyd S. *et al*., 2011). So climate change is undermining current efforts to address food security (UNSSCN, 2010).

Different literatures indicate the impact of climate change on food security and malnutrition is highest among Ethiopia, where most of the population depends on agriculture base economy activities that is sensitive to climate. However, according to the Federal Democratic Republic of Ethiopia in 2012 report shows a faster Gross

Domestic Product (GDP) growth in Ethiopia from 1990 to 2010, while this condition creates a great opportunity to improve living standards of the population including food security. The climate change in Ethiopia has been receiving dedicated interest among state in recent times. But it is worth noting that an extensive review on food security implications of climate change on crop yield and also adequate amount of research is not done on the problem to provide verification. In light of above idea, this paper reviews literatures on impacts of climate change on crop yield and food security Ethiopia, to characterize and synthesize current understanding of the problem, and low resolution priorities for future research. Therefore Climate change for Ethiopia food security implies that role of agricultural production are presented. Finally mitigation technologies and practices, strategy for crop yield for implications of food security are discussed. This review addresses the potential impacts of climate change on crop yield with specific reference to food security. Considerable gaps remain in knowledge of how agricultural systems will be affected.

2. Results and Discussion

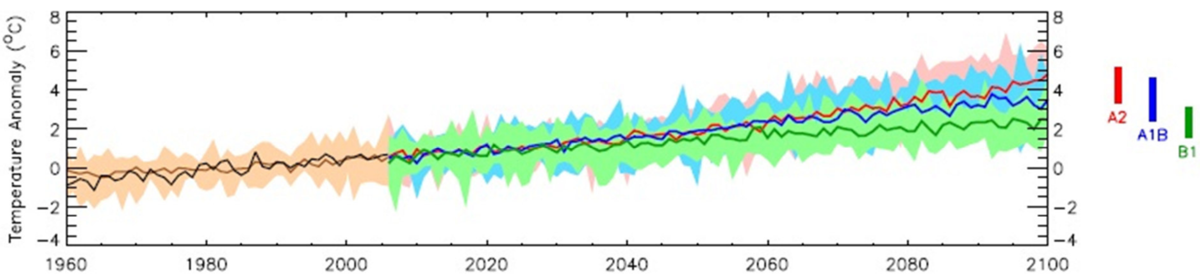
2.1 Effects of Climate Change on Elements of Atmosphere

2.1.1 Changes in Mean Temperature and Precipitation

Increased temperature and changing rainfall patterns will have an impact on lives, livelihoods, and production of food. Those forecasting for most regions of the world as a result of climate change, while the impacts of mean temperature increase will be qualified differently, depending on location furthermore it is expected that country at low latitude (tropical and sub tropical region were water availability is low would generally be at risk of decreased crop yield at even 1-2^{o}C of warming (FAO,2008b) However, high temperature during the reproductive phase is associated with a decrease in yield due to a decrease in the number of grains and kernel weight, In addition to high temperatures, the number of ovules that are fertilized and develop into grain decreases (Schoper *et al.,* 1987a and b). It is clear that changes to the variability of temperature, separate to changes in mean seasonal temperature, affect the yield of annual crops.

Although Temperature determines the duration of a crop's growing season and controls its phenological development and water requirements. precipitation are highly complex due to the varied topography of the country thus the seasonality, duration, and regularity of rainfall vary by both latitude and longitude(WFP’ 2015), while it provides the critical input for crop growth, water. However better yields are obtained in the dry season when temperatures are lower and pest problems are fewer. An increase in precipitation would help increase the area of this crop and its yield, but an increase in temperature promotes sterility and yields would be reduced (S.X. Sinha, *et al.*, 2006). All rural livelihood systems in Ethiopia are highly sensitive to climate given the dependence of cropping, pastoral and agropastoral communities on rainfall. Recent climate trends show that rainfall is decreasing in the south-central, southeastern, and northern parts of the country, while the western parts of the country have been receiving more rainfall potentially increasing the magnitude of droughts and floods (WFP, 2015). The distribution of these variables during the period of crop growth is also critical. As a result, larger areas can be brought under cultivation at the climatic margins. But, in the existing crop belts, the growing season duration will be reduced and productivity (crop yield) losses will result (S.X. Sinha, *et al*., 2006). Some crops may also be forced out of cultivation to be replaced by others. However, Safeguarding food security in the face of climate change also implies avoiding the disruptions or declines in global and local food supplies that could result from changes in temperature and precipitation regimes.

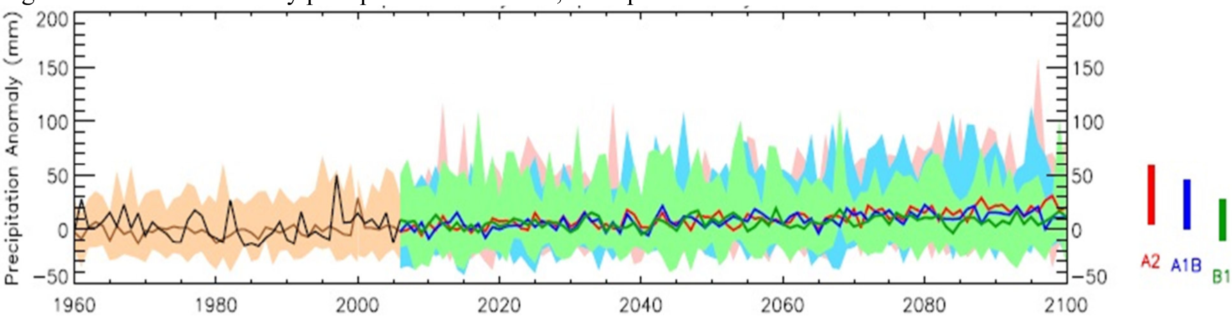
Figure 1. Mean temperature anomaly, Ethiopia 1960-2100.



Source: UNDP Climate Change Country Profiles Ethiopia. School of Geography and the Environment, Oxford University. Accessed Feb. 27, 2012 at http://country-profiles.geog.ox.ac.uk

Ethiopia is experiencing the effects of climate change. Besides the direct effects such as an increase in average temperature or a change in rainfall patterns, (FDRoE 2011), Over the last decades, the temperature in Ethiopia increased at about 0.2° C per decade. The increase in minimum temperatures is more pronounced with roughly 0.4° C per decade Marius Keller, (2006). According to ACCRA, (2011) the mean annual temperature in Ethiopia have increase by between 0.5 and 1.3 ºC On another hand as shown above figure Ethiopia mean temperature will be 3.5 ºC in 2100 figure 1 UNDP , 2012. Consequently the 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). However highest yields in C3 crops are obtained around a mean daily temperature of 15^{o}C and in C4 crops around 30^{o}C **(**Sinha S., *et al*. 2006**)**. Whereas the temperature optima for vegetative growth and the reproductive phases are often different although an increase of temperature beyond a mean of 22 ºC causes sterility in rice resulting in reduced grain yield, though it has no effect on photosynthesis and also In wheat, an increase in mean temperature above 16 ºC results in a decrease in grain weight and a poor yield. A higher temperature significantly reduces tillering, which is essential to building shoot population (Sinha S**.** *et al.,* 2006).

Figure 2: Trends in monthly precipitation anomalies, Ethiopia 1960-2100



Source: UNDP Climate Change Country Profiles Ethiopia. School of Geography and the Environment,Oxford University. Accessed Feb. 27, 2012 at http://country-profiles.geog.ox.ac.uk

Ethiopia has diverse topography thus causes various distribution of rain fall that lead to drought and other flood. Similarly this trend of above figure shows the values of recent past and projected future precipitation are anomalies (Figure 2). However precipitation remained fairly stable over the last 50 years when averaged over the country Marius Keller, (2006). although the Afar region have become increasingly vulnerable to flood risk as a result of more intense rainfall in shorter periods and land degradation (DRMFSS, 2012), also water logging expected, in fact water logging is inhibiting plant growth and development leading to reduced gas exchange between root tissues and the atmosphere and also deficit of essential macronutrients (nitrogen, phosphorous and potassium) and an accumulation of toxic nutrients (iron and magnesium) resulting from decreased plant root uptake and changes in redox potential (Armstrong and Drew, 2002). Drought is one of the major risks in Tigray Region for example currently in Raya Azebo Wereda Tigray Region estimated that 72% households in this wereda are vulnerable to drought risk. Drought occurred several times (DRMFSS, 2012). The future changes in precipitation and temperature as projected by various global climate models are summarized in Figure 2. Most of the global climate models project an increase in precipitation in both the dry and wet seasons. Studies with more detailed regional climate models, however, indicate that the sign of the expected precipitation change is uncertain. The temperature will very likely continue to in-crease for the next few decades with the rate of change as observed

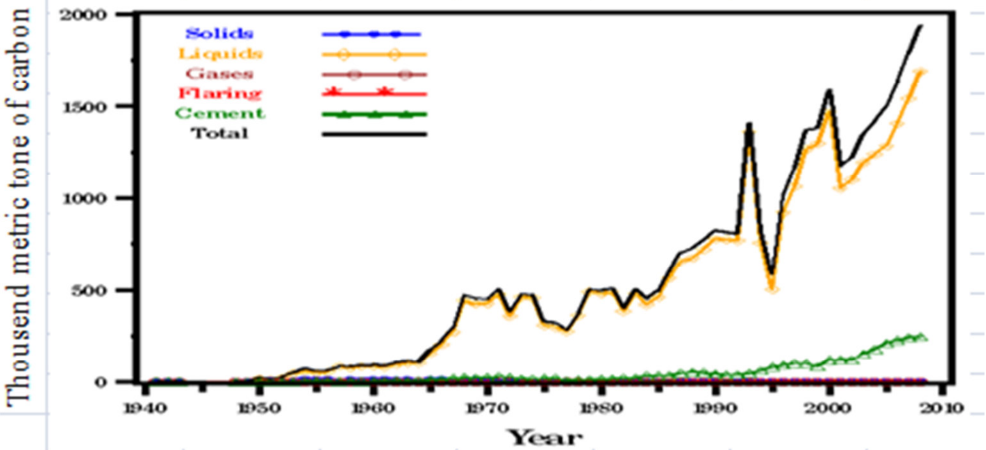
The supply of meat and other livestock products will be influenced by crop production trends, as feed crops account for roughly 25 percent of the world‘s cropland. For climate variables such as rainfall, soil moisture, temperature and radiation, crops have thresholds beyond which growth and yield are 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 Ethiopia, Droughts impair agricultural productivity and may lock subsistence farmers into poverty traps, whereas recurrent flooding can have long-term negative effects on agricultural GDP by directly damaging crops and by destroying roads, IFPRI, 2011. While excess much water, Heavy rainfall events leading to flooding can wipe out entire crops over wide areas, and excess water can also lead to other impacts including soil water logging, anaerobicity and reduced plant growth (Falloon & Betts, 2016). likewise in east Africa and its heart land in the Ethiopia high land, rain fall and run off are expected to increase with risks of more extensive and severe flooding(FAO,2011).Our analysis can therefore support decision making by identifying development strategies that offer the highest resilience to future climate change (IFPRI, 2011).

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^{0}C and 5^{0}C; 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.

2.2 Changing on Concentration of atmospheric Co_2

Carbone dioxide ($CO_{2)}$ concentration in the atmosphere has increased by 31% since the beginning of the

industrial era, from 280 to 360 ppm (IPCC, 2001). Anthropogenic emissions of CO_2 originate primarily from the burning of fossil fuels and deforestation in tropical regions (FAO, 2003). However Ethiopia's green house gas (GHG) emissions are dominated by agriculture, which contributes 80% of the total GHG emissions (Marius Keller, 2009). While forest is fundamental to the survival and livelihood of the majority of people in rural Ethiopia, especially small scale farmers. These resources are under intense pressure from population growth and in appropriate farming and management practices (FAO, 2003). In fact, Compared to other countries, Ethiopia's emissions are very low Sector wise (Marius Keller, 2009). As well as the forests resources of Ethiopia store 2.76 billion tons of carbon (about 10 billion tons of CO_2) in the aboveground biomass, which will be released to the atmosphere in 50 years, if the deforestation continues at the present rate of about 2% (ECRN and UNDP, 2010).
Figure 3. Per capita CO_2 Emission Estimates for Ethiopia CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2008



Source: Carbon Dioxide Information Analysis Center (CDIAC), 2012

Despite the fact that as above figure shown the emission of CO_2 for Ethiopia in the atmosphere are higher than they have been at any time before 1995 however In 1971, CO_2 levels exceed 505 thousand metric tons of carbon. Whereas total fossil-fuel emissions of CO_2 were consecutively rise about 1938 thousand metric tons of carbon in 2008. Thus shows amazingly constant relationship with fossil-fuel burning, and fossil-fuel emissions stay in the air. On other hand according to FDRE (2011), the GHG emissions 150 Mt CO2 emissions in 2010 which is rise to 400 Mt CO2 emissions in 2030. Different studies as show that the climate changes envisage in the next century are mostly attributed to the increasing concentration of CO2 (Wittwer, 1986, Markley and Hurley, 1983). Reaching today's level of 400 ppm of atmospheric carbon dioxide, and atmospheric CO2 could hit 600 ppm by 2100, globally (Midgley,200l). Whereas CO_2 emissions from people burning fossil fuels are the driving force behind climate change and have risen atmospheric CO_2 concentration and Earth has warmed (NASA, 2016). In light of above idea atmospheric CO2 has increased burning fossil fuels, deforestation, and biomass, as well as land-use changes and other industrial (cement). It is the reference in Ethiopia clear, thus enhance the greenhouse effect, blocking heat from escaping into space and contributing to the warming of Earth's lower atmosphere with the intention of were temperature rise. However, Gifford (1987), made a more cautious assessment of CO2 effects by including temperature change as an additional component.

2.1.3 Changing on Relative humidity and Evapotranspiration

Evapotranspiration (ETo) is an important agro-meteorological parameter for climatological and hydrological studies (Isikwue B., *et al.*., 2015). Temperature is strongly and positively correlated with ETo but relative humidity were negatively correlated with ETo. However, Rising temperature, rising potential evapotranspiration rates and declining rainfalls conspire to increase the severity, frequency and duration of droughts (FAO, 2011). The relationship between evaporation and evapotranspiration with weather parameters and have shown that weather parameters may have positive or negative correlation with evapotranspiration and can significantly influence it depending on the climatic conditions of the different location observed (Isikwue, B. C, *et al.*, 2015). While as blow shown on Ethiopia climatic graph, average temperature, day length (hours) and wind speed inversely proportional to relative humidity. Despite the fact that wind speed, sunshine hours, mean air temperature were positively correlated with evaporation, while relative humidity was negatively correlated with evaporation (Isikwue, B., *et al.*, 2015).

It is expected that country at low latitude (tropical and sub tropical region) were water availability is low would generally be at risk of decreased crop yield at as result of increase evapo-transpiration and lower soil moisture level Bals *et al.*., (2008) thus phenomenon would result in some of agriculture land in sub Sahara Africa. In fact Ethiopia characterizes in diverse topography and various atmospheric systems, therefore, Relative humidity between 20 and 40% prevailed over north of Ethiopia while Relative humidity between 40 and 60%

was experienced over parts of, parts of Ethiopia (ACMAD, 2015). However ET increases with the relative humidity gradient. In fact, circulation modeling show increased annual mean rainfall and an increase in evapotranspiration to the year 2050, as the relative humidity of the air rises, ET rates fall. Very high or very low RH is not conducive for high grain yield. Under high humidity, RH is negatively correlated with grain yield of maize. The yield reduction was 144 kg/ha with an increase in one per cent of mean monthly RH. Similarly, wheat grain yield is reduced in high RH (TUNA, 2016). On other hand the highest decrease in wheat yield occur due to high evapotranspiration in between 2070-2099 (Kourosh E. *et al,* 2012).

2.2 Effects of Climate Change on Crop Yield

2.2.1 Climate Change on Crop Growth and Development

The projection of climate change in Ethiopia influence crop physiological trend through anomaly of climate elements accordingly a recent analysis of more than 20,000 historical maize trial yields in Africa over an eight year period combined with weather data showed for every degree day above 30 °C grain yield was reduced by 1 % and 1.7 % under optimal rainfed and drought conditions, respectively (Lobell *et al.,* 2011).While drought negatively affects all stages of maize growth and production, the reproductive stage, particularly between tassel emergence and early grain-filling, is the most sensitive to drought stress (Grant *et al.,* 1989). Humidity can also affect plant turgor pressure, which is an indicator of the amount of water in plant cells. When humidity is low, moisture evaporates from plants very quickly that lead plants to wilt rapidly while humidity and temperature are both high, plants can get overheated because transpiration is reduced, thus restricting evaporative cooling. Humidity can also affect the fruit set of some plant species.

Temperatures are expected to increase in Ethiopia in all seasons with on average 1°C by 2030, 2°C by 2050, and 3°C by 2080 (compared to 1975) m.e.r, 2015. In fact thus temperature optima for vegetative growth and the reproductive phases are often different (FAO, 2011). While in wheat an increase in mean temperature above 16 °C results a decrease in grain weight and poor yield. A higher temperature significantly reduces tillering, which is essential to building shoot population (Sinha S., *et al*. 2006). On other hand an increase of temperature beyond a mean of 22deg.C causes sterility in rice resulting in reduced grain yield, though it has no effect on photosynthesis. (Sinha S., *et al*. 2006). While drought stress during this period results in a significant reduction in grain yield, associated with a reduction in kernel size (Bolaños and Edmeades, 1993). The susceptibility of maize to drought stress is generally attributed to its separation of male and female flowers (Grant *et al.,* 1989). Through phonological effect atmospheric CO_2 increases those increments of atmospheric CO_2 concentrations can also directly affect plant physiological processes of photosynthesis and transpiration (Field *et al*. 1995). In fact CO_2 increase amount of grain and decrease the quality of that grain in future. The crops having a high growth rate in the preflowering phase usually deplete soil moisture, which is necessary to normally complete the grain development phase (Sinha S., *et al*., 2006). On other hand an increase in the concentration of atmospheric CO_2 significantly stimulates the growth and development of plants while dramatically enhancing their efficient use of water (Sherwood B., 2001). But the concentration of atmospheric CO2 predicted for the year 2100 will have major implication for plant physiology and growth (Daniel R., 2010)

2.3 Climate Change on Crop yield and its component

Climate change will affect agriculture through higher temperatures, greater crop water demand, more variable rainfall and extreme climate events such as heat waves, floods and droughts. According to world Band document (2011), Marginal areas, where low yields and poverty go hand in hand, may become even less-suited for agriculture as a result of land degradation through deforestation, wind and water erosion, repetitive tillage and overgrazing.

As different studies point to severe crop yield reductions in the next decades in Sub-Saharan Africa particularly rural households thus are highly dependent on agriculture and farming systems are highly sensitive to climate change. The changes in crop production related climatic variables will possibly have major influences on regional as well as global food production (M.G. Abraha, and M.J. Savage, 2006). However the Climate change factors might be varies as plants are classified on phases of photosynthetic pathways. In this preview four crops are chosen as important hence Wheat, teff, sorghum and maize are the four major crops of the country accounting for about 80.24% of its total grain crops production in 2009/2010 (CSA, 2009).

The following observations are relevant for assessing the effects of climate change, including carbon dioxide (CO_2) concentration, on crop yields. The levels of CO_2 in the atmosphere are higher than they have been at any time in the past 400 thousand years. The CO_2 levels were around 200 parts per million (ppm), and, the CO_2 around 280 ppm. In 2030, CO_2 levels surpassed 400 ppm, as NASA, (2016). While the effect of elevation CO_2 on different crops yield are vary (Figure 6). Consequently, the CO_2 has no impact on maize (has different physiology) because it is C4 photosynthesis crop to grow. Likewise the yield of maize will increase under the future climate, but the rate of change may remain the same in the 2030 and 2050 for emission scenarios Gebre H., *et al*., 2014. More over according to Zerihun study shows that maize yield has increased over 50 percent over 28 years Zerihun G., 2012. On the other hand, with CO_2 fertilization, the yield of maize will increase with no considerable difference between the emission scenarios and period of analysis (Table 1) (Gebre H., *et al*., 2014).

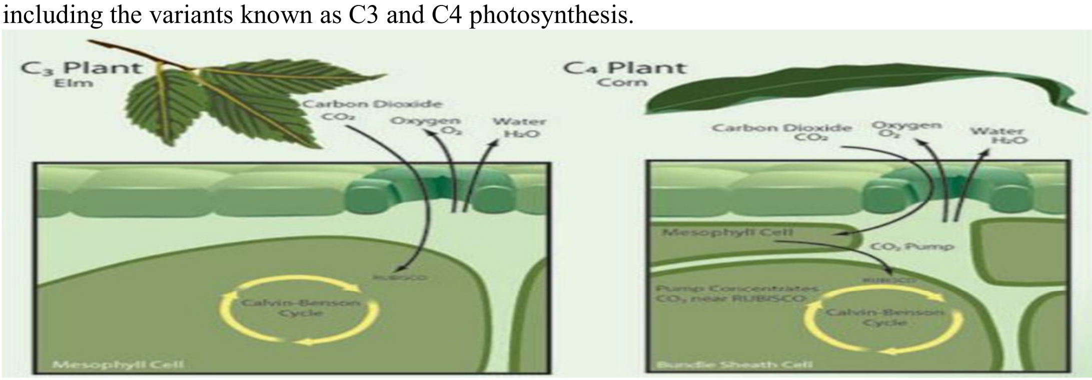
Table 1. Changes in seasonal (kiremt) rainfall and temperature and yields of maize and sorghum under the future climate with and without CO2 fertilization under A2 and B1 emission scenarios at Mekelle station

	Yield change (kg/ha)					
	Without CO_2 fertilization			With CO_2 fertilization		
Period	CO2 (ppm)	Maize	Sorghum	CO2 (ppm)a	Maize	Sorghum
baseline(kg/ha)	360	3812	3067	360	3812	3067
2030-A2	360	12.7	11.4	470	7.2	21.9
2030-B1	360	11.3	-2.7	450	10.9	7.5
2050-A2	360	12	3.6	549	14	34.2
2050-B1	360	10.6	4.6	502	14.8	16.9

Source: Gebre H., *et al*., 2014

The effect of elevation CO2 on plant are not uniform, same species particularly those that utilize the C4 variant photosynthesis show less of respond to elevated CO2 than do the other types of plants. Therefore the elevation of carbon dioxide in atmosphere can act negative impact that lead to more drought trash, via rise temperature and more air pollution. High concentration of CO_2 cause stimulate photosynthesis, mean that more CO_2 take in plant were as stimulation in photosynthesis at elevation of CO_2 decrease yield, because, the plant reproductive require sensitive to temperature thus air temperature negatively affect seed set and pollen viability (Figure 5) in 2100. In addition to rising CO2 over next century is likely to affect both agricultural production food quality (Daniel R., 2010). The Climate projections for Africa (IPCC 2007), include a likely average temperature increase of 1.5 to 4°C in this century, higher than the global average. However moderate temperature rises, warming and drying could reduce crop yields by 10– 20 percent by 2050 in Africa (Jones and Thornton, 2009). whereas In Ethiopia Temperatures are expected to increase in all seasons with on average 1°C by 2030, 2°C by 2050, and 3°C by 2080 (compared to 1975) (m.e.r, 2015). While according to Lobell and Burke (2010), suggested that an increase in temperature of 2 °C would result in a greater reduction in maize yields within Saharan Africa. In fact the temperature optima for vegetative growth and the reproductive phases are often different (FAO, 2011).

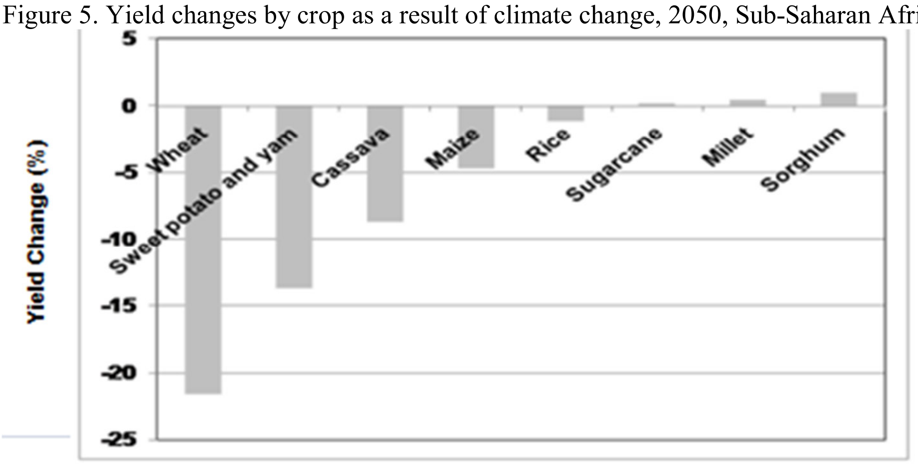
Figure 4: Each plant species utilizes one of several distinct physiological variants of photosynthesis mechanisms, including the variants known as C3 and C4 photosynthesis.



Source: Daniel R. 2010.

The amount of rainfall during the growing season is projected to increase under both the A2 and B1 scenarios (Table 1), on other hand the positive changes in the yield of maize and sorghum under future climate could be due to this moderate increase in rainfall during kiremt (Gebre H., *et al*., 2014). The effects of precipitation for Amhara and Oromia region shows negative effects on teff and wheat yields. Similarly, it has a negative relative effect on maize yield for both the Amhara and SNNP regions (Zerihun G., 2012). However, the response of sorghum yield will depend on emission scenarios and period of analysis. By the 2030, sorghum yield will increase (11.4 %) under the A2 emission scenario but will decrease (2.7 %) under the B1emission scenario (table 1) (Gebre H., *et al*., 2014). Whereas The studies about wheat production affected by climate change are mainly concerned with future CO_2 concentrations while climate change impacts on wheat yield in Ethiopia, results show that the elevated CO_2 level can reduce the median wheat yield by about 25% (figure 1) (IFPRI,2010).

Figure 5. Yield changes by crop as a result of climate change, 2050, Sub-Saharan Africa (percent change)

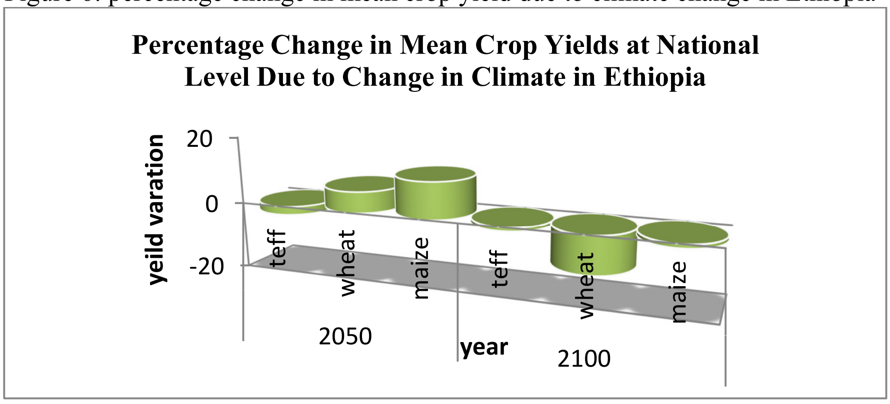


Source: IFPRI (International Food Policy Research Institution), 2010.

The assessment based on a pessimistic assumption about global warming, estimates that by the 2080s world agricultural productivity will decline by 3-16 percent. The loss in Africa could be 17-28 percent (Cline 2007). The figure of presents expected changes in yields as a result of climate change in 2050 for selected crops grown in Sub-Saharan Africa. Negative yield impacts are projected to be largest for wheat, followed by sweet potato, whereas overall yields for millet and sorghum are projected to be slightly higher under climate change, thus probably given their higher tolerance to higher temperatures and drought stress. Although negative impacts are largest for wheat, gives changes in crop yields for major crops grown in Sub-Saharan Africa by agroecological zone. Interestingly, yield impacts are quite heterogeneous across crops and zones, IFPRI, 2010. However, the studies that were taken by Zerihun G., 2012 place three cereal crops: teff, maize, and wheat were relative risk in yields measured shows large variability between crops and zones and no crop or zone has consistently positive or negative results. Among the crops, the Eastern zones show projected yield increases for four out of the five crops.

Cereal production growth in Sub-Saharan Africa is projected to decline by 3.2 percent as a result of climate change, with declines in yield growth of 4.6 percent, despite the fact that the results extrapolated by Zerihun G., 2012 at the national level show that average teff and wheat yields will decrease, and maize yield will increase in 2050 but in 2100 all the three crop yields will drop (Figure 7) implying that in the long run the negative impacts of climate change will worsen. Among staple crops, negative yield impacts are projected to be largest for wheat, followed by sweet potato, whereas overall yields for millet and sorghum are projected to be slightly higher under climate change (Figure 6), (IFPRI, 2010).

Figure 6: percentage change in mean crop yield due to climate change in Ethiopia



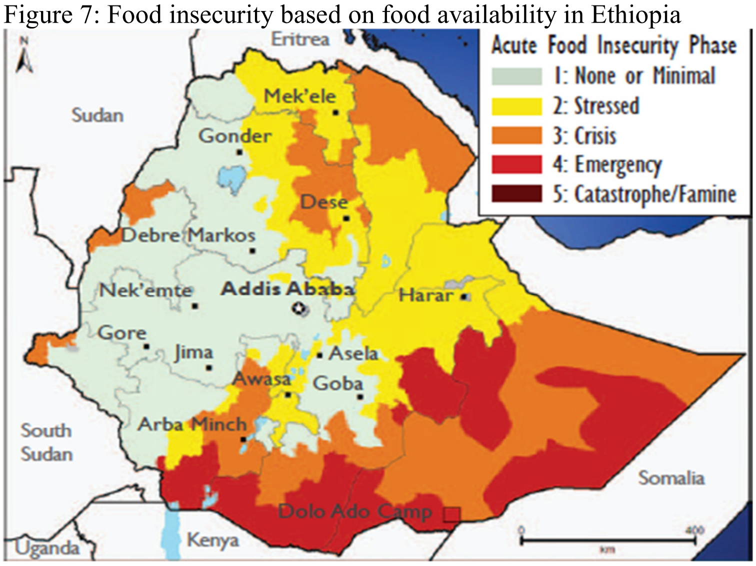
Source : Zerihun G., 2012.

Ethiopia with various topography, therefore according to Zerihun G. studies during the year 2050 maize yield will increase by around 48 percent in Oromia region and teff yield also shows an increase of around 2 percent in SNNP region. On the other hand the precipitation remained fairly stable over the last 50 years when averaged over the country (Marius Keller, 2006). According to FAO, Further productivity increases may occur in the coming century; in the order of 30% or more where plant nutrients and moisture are adequate (FAO, 2011). Whereas the results extrapolated to the national level show that average teff and wheat yields will decrease and this implies that according to Dawit W. *et al*. (2015), by 2030, the production of maize and wheat is projected to be about 10.3 and 13.4 percent lower with and without CRGE scenario respectively than what it would be in the baseline. The result indicated that maize and wheat production will decrease from baseline 16.39 billion to 14.70 and 14.19 billion Birr with and without CRGE by 2030, respectively. Similarly, if there are no CRGE interventions CO_2 emissions induced decline in agricultural factor productivity that leads to 7.9 percent decrease in teff production. Under the implementation of CRGE, the impact of CO_2 emissions on teff production lowers to 6.1 percent (table 1), (Dawit W. *et al*, 2015). While in 2100 all the three crop yields (maize, sorghum and teff) will drop implying that in the long run the negative impacts of climate change will worsen unless appropriate measures are taken. However all the regions will experience a drop in crop yields both in 2050 and 2100, when, compared with the recent average crop yield (Zerihun G., 2012).

3 Climate Change Impacts on Food Security

The increasing year-to-year variability and increases in droughts, heavy precipitation and temperature events, those lead to lowers agricultural production with corresponding negative effects on food security (Breed for all, 2009). Food security is highly sensitive to climate risks in Ethiopia (IFPRI, 2010). While According to WFP Ethiopia remains one of the world's most food-insecure countries, where about one in three people live below the poverty line despite the fact that in 2014, assisted 6 million vulnerable people with food and special nutritional assistance (WFP, 2016). However, historical and more recent climate-related events such as the 2008/2009 and 2011 food security crises in the Horn of Africa have highlighted the impact of droughts and floods on food production, access to markets, and income from agricultural activities (IFPRI, 2010). Thus, even though mean changes in the global climate resulting from a doubling of CO2 concentration can be anticipated, the specific changes in the annual variability of climate are uncertain during the period when the doubling is occurring. But, keeping with the complex, non-linear and multiple feedback characteristics of the climate system, it is likely that the next 50 to 100 years will experience chronic and severe climate variability.

Figure 7: Food insecurity based on food availability in Ethiopia



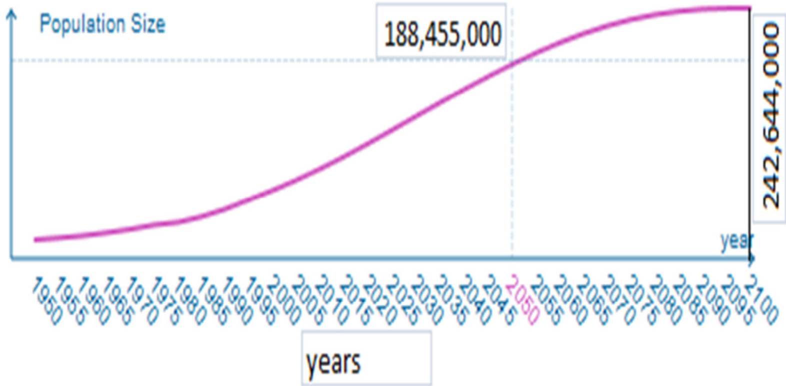
Source: USGS (2012)

Climate change has adverse effect on food security thus increase poverty and hunger, while food insecurity is not a recent occurrence in Ethiopia were as it has historically vulnerable for food insecurity. Production of key crops is not increasing fast enough to keep up with the country's high population growth: per capita cereal production has been estimated to decline by 28% between 2009 and 2025(USGS et al. (2012). Food insecurity is highest in the east of the country or in parts of central Ethiopia, depending on the method used to measure it. However, an integrated vulnerability assessment on climate change effects in Ethiopia's regional states found that the top four vulnerable states are Afar, Somali, Oromia, and Tigray (Map set 1). While the country were heavily dependent on agriculture bases is clear. In fact increased annual climate variability of total food production as well as the regional share of production are the determinants of food security (IFPRI, 2010). This overall projection translates into much more severe losses in certain places and the events: pests and diseases; droughts, heat stress and floods and also soil quality has been decreasing for several decades thus lead to Chronically poor crop performance (World Bank, 2010). Through decline of crop yield in 2050, maize, rice, and wheat prices are expected to be 4%, 7%, and 15 % higher, respectively, compared with the historic climate scenario. Whereas the net cereal imports in Eastern Africa will experience large increases 15 %t in as a result of significant maize yield declines (IFPRI, 2010). In addition to climate change, yields in developing countries could further decrease by 15 percent on average by 2080 (FAO, 2008).

3.1 Population Growth and Food Production

Ethiopia will have more than 87.9 million Population, with growth rate of 2.2% per year in 2014 projected to be 120 million people by 2030 ((FDRoE), 2015) Rapid population growth has a negative impact on human development, provision of basic services and poverty eradication; these effects are magnified and become more urgent in the context of climate change. Reducing the rate of population growth has long been a development goal because of the detrimental effect of rapid population growth on economic development (Judith S. *et al*. 2016). Rapid rates of population growth in sub-Saharan Africa are impeding its ability to even contain the number of people living in extreme poverty. Thus lead rise food production therefore to meet the projected demand production in Africa would have to increase almost fivefold (S.X. Sinha, *et al*. 2006). However in 2014, Ethiopia assisted 6 million vulnerable people with food and special nutritional assistance (WFP, 2016), and also poverty was 29.6 % in 2010/11, 250 million people went hungry in 2010, almost a third of the population (World Bank 2010).

Figure 8: Population of Ethiopia from 1950 and 2100



Source: United Nations, Department of Economic and Social Affairs (UNDES), Population Division. World Population Prospects, 2015.

As above figure shows that Ethiopia will have 188.46 million Population on 2050 and people will reach 242.64 by 2100 million (Figure 3). Therefore food production must increase. However, food production in any given year is affected most directly by the values of the critical climate elements (temperature, radiation, precipitation, etc.) during the year (Garcia, 1981). In addition to population growth in Ethiopia is resulting in soil degradation, dwindling land holdings and low agricultural productivity, which increases pressure on poor people to move either to environmentally marginal or urban areas thus lead to vulnerable and more likely to exploit new resources in an unsustainable way, leading to a vicious cycle of poverty and degradation (Judith S. *et al*. 2016)

The effects of rapid population growth in developing countries under different scenarios (involving, for example, population structure, water availability, food and shelter requirements and labour markets) to support better adaptation strategies (Judith S. *et al*. 2016). Although Ethiopia climate condition on total cereal production dynamic the regions of high variability also have low average crop yields. In addition to population growth is often mentioned as a contributing factor to food insecurity in developing countries (Scott M. and Ellen S., 2012).

Food production in different regions must increase substantially if each region has to meet its requirements. On other hand additional demand for land will come from increasing food requirements as a result of a rising global population and an increasingly affluent (WFP, *et al*., 2009).

3.2 Requirements of Food and Nutrition

The developing world about 1 billion people are experiencing some form of shortage in food supply (FAO, 2009). While the evidence is that climate change will increase this tendency and will increase the risk of hunger and malnutrition (WFP, *et al*., 2009). Similarly, the impacts of the scenario with climate change include changes in area and yield expansion, higher food prices, small changes in net cereal trade, slightly reduced calorie availability, and growing childhood malnutrition in Sub-Saharan Africa (IFPRI, 2010). On other hand Climate change directly affects food and nutrition security of millions of people (UNSCN, 2010). While, climate change in Ethiopia with medium fertility scenario the number of malnourished rise to 2.02 million in 2050 whereas No climate change with medium fertility scenario the number of malnourished decline to 1.5milion on same decade. On other hand climate change with low fertility, the malnourished become 0.98milion (Scott M. and Ellen S., 2012).

According to World Population Prospects there will be Rapid population growth in Ethiopia (UNDES, 2015). In addition to the demand of such a large population will put huge additional pressure on food production systems. In fact Food requirements are influenced by population size and structure as is food consumption.

Regardless of climate change, demand for food will increase. Therefore in Ethiopia, food consumption is lowest, on another hand Ethiopian needs an average person food requirement about 2,212 kcal of energy per day however the effect of climate change will affect food consumption those lead to 506 kcal of energy per day in 2050 (Scott M. and Ellen S., 2012). The consequences of the increasing CO2/decreasing nitrogen relationship are worrisome. Elevated CO_2 lowers protein concentrations in wheat grain, rice grain, potato tuber and barley by about 8%, wheat alone provides 21% of protein in the human diet. Therefore researchers expect that protein available for human consumption may diminish by about 3% as atmospheric CO_2 continues to climb in the next few decades (Facts, Figures & the Future 2014).

3.3 Supply and Demand of Food

Food supply is directly dependent on ample fertile land, fresh water, energy, plus the maintenance of biodiversity. As the human population grows, the requirements for these resources also grow (David P. *et al*., 1996). Thus Availability of agricultural products is affected by climate change. While, stability of crop yields and food supplies is negatively affected by variable weather conditions (Greg E., *et al*., 2011). It is result that the Climate change a significant factor on the supply side of the food security issue, and population growth, a significant factor affecting demand in Ethiopia (Scott M. and Ellen S., 2012).

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