Review of Impact of Climate Change on Food Security in Africa

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Abstracts
Food Security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. African continent is found to be the most susceptible and vulnerable places to climate change impacts, which is marked as the most food insecure region in the world, because of its reliance on climate sensitive and vulnerable economic sectors (rain fed agriculture) and its lower financial, technical, and technological capacity to adapt the climate change risks, and climate change is considered as posing the greatest threat to agriculture production and food security in the 21st century, particularly, in many of the poor, agriculture-based countries of Africa. Climate change affects food security in various ways: through impacting on all four components of food security (availability, accessibility, affordability, utilization and nutritional value and food system stability), through impacting on crop production and yield, through impacting on water availability, through impacting on fisheries production, through impacting on agricultural pests (weed, insect and disease pests), and through impacting on livestock production. African continent specially, Sub-Saharan African region is found to be the most drought prone area in the World. The severity of climate change extreme events/or drought induced food insecurity and malnutrition in Africa is emphasized. In Africa, food insecurity and malnutrition became chronic induced by repeatedly occurring drought. Due to climate change extreme event/or drought drive food crises/hunger many Africans were badly affected For instance, more than 100 million people were affected by drought driven hunger in Africa. So, Africa especially, Sub-Saharan Africa is marked as the most food insecure region in the world, and has the highest proportion of food insecure people, with an estimated regional average of 26.8% of the population undernourished and this rates could be over 50%. Moreover, the risk of hunger will increase by 10-20% in 2050. Similarly, in Africa, due to climate change impacts, the number of malnourished children is projected to be increased in 2030 and 2050 from the baseline (33 million) to 42 million and 52 million respectively. Thus, climate change impacts on food security has to be taken as key issue and impact reduction strategy options have to be implemented.
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1. INTRODUCTION

Climate change represents a major threat for the coming decades, particularly in Africa than any other continent. Climate change is considered as posing the greatest threat to agriculture production and food security, particularly in many of the poor, agriculture-based countries of Africa, due to their low capacity to effectively cope with a possible adaptation mechanisms to decrease in yields among others (Shah *et al*., 2008; Nellemann *et al*. 2009). Farming techniques are also relatively primitive, the majority of the continent is already arid and the smallholder systems that dominate the agricultural landscape have very limited capacity to adapt (Muller *et al*., 2015). (World Bank, 2009). Some regions in Africa have become drier during the last century (e.g., Sahel) and it is projected that the continent will experience a stronger temperature increase trend than the global average (Boko *et al*. 2007).

Due to its largely adverse effects on African agriculture, climate change is expected to have a negative impact on food security (Niang *et al*., 2014). Chronic drivers, which include poverty, environmental stressors, the absence of property rights, and poor market access, create a vulnerable environment where short-term drivers (e.g., food price increases) stress the communities. Food insecurity results from a complex interaction of multiple stressors (socioeconomic and environmental) over long time periods and with sudden shocks (Akrofi *et al*, 2012).

On the other hand, in sub-Saharan Africa, climate change /extreme droughts already impede people's ability to grow food and rear livestock. Pastoralists and agro-pastoralists will need to adapt to changes in water regimes in order to maintain their food security and well-being (Kebede *et al*., 2011). Beyond increases in temperature, climate change in sub-Saharan Africa is expected to cause changes in rainfall intensity (Songok *et al*., 2011a), increases in the incidence of extreme events such as droughts and floods (Richard *et al*., 2001), increases in desertification, and alterations in certain disease vectors causing changes in the spatial and temporal transmission of infectious diseases (Chen *et al*., 2006). Drought resulted in agricultural losses and is major driver of food insecurity in Africa. Climate change has had caused significant food insecurity, malnutrition and affecting the life of African people and its trend is increasing in 21th century (IPCC, 2007b). In general speaking, climate change is found to be the main driver of food insecurity and malnutrition in Africa, implying that badly affecting African agriculture and food security. Therefore, the objective of this paper is to review impact of climate change on food security and to review the severity of food insecurity and malnutrition due to climate change impacts, and to set a future line works/or measures to reduce climate change risks on food security in Africa.

2. REVIEW OF LITERATURE

2.1. Impact of Climate Change on Food Security

2.1.1. Food Security and its Dimensions

Food security could be defined as follow, food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996). Food security depends on availability of food, access to food, and utilization of food (FAO, 2000). The common definition of food security rests on three pillars: food availability, food access, food utilization (Ericksen *et al.* 2011) and their stability. Indicators used to measure food availability include crop production and/or food production indices, livestock ownership indices, and national food balance sheets (Renzaho and Mellor, 2010).

Food availability: The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food). Food availability is also a result of domestic production, distribution, storage, import and export. Food availability is the amount of total physical quantities of food available in a country or an area in the form of domestic production, import, exchange, processed and stocks after deducting the total exports (Mayo, 2008). Food availability is probably most frequently used as a measurement of food security. Access to food: Access to food means one's capacity to safeguard the entitlements to food. Access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet. Entitlements are defined as the set of all commodity bundles over which a person can establish command given the legal, political, economic and social arrangements of the community in which they live (including traditional rights such as access to common resources).

Access to food is "the set of alternative commodity bundles that a person can command in society by using the totality of rights and opportunities that he or she faces" (Sen, 1984). Food accessibility is a measure of the ability to secure entitlements, which are defined as the set of resources (including legal, political, economic and social) that an individual requires access food. Food utilization: It is utilization of food through adequate diet, clean water, sanitation and healthcare to reach a state of nutritional well-being where all physiological needs are met. Food utilization is "the nutritional value of the diet, including its composition and methods of preparation; the social values of foods, which dictate what kinds of food should be served and eaten at different times of the year and on different occasions; and the quality and safety of the food supply, which can cause loss of nutrients in the food and the spread of foodborne diseases if not of a sufficient standard" (FAO (2008a). In brief, it is an individual's food utilization refers to the personal capacity to get benefits from the food consumed (Ericksen, 2008).

Food stability: To be food secure, a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) or cyclical events (e.g. seasonal food insecurity). The concept of stability therefore refers to the availability, access and utilization dimensions of food security. All dimensions of food security are thus closely intertwined with agriculture production, which are both source of food and source of income for rural households.

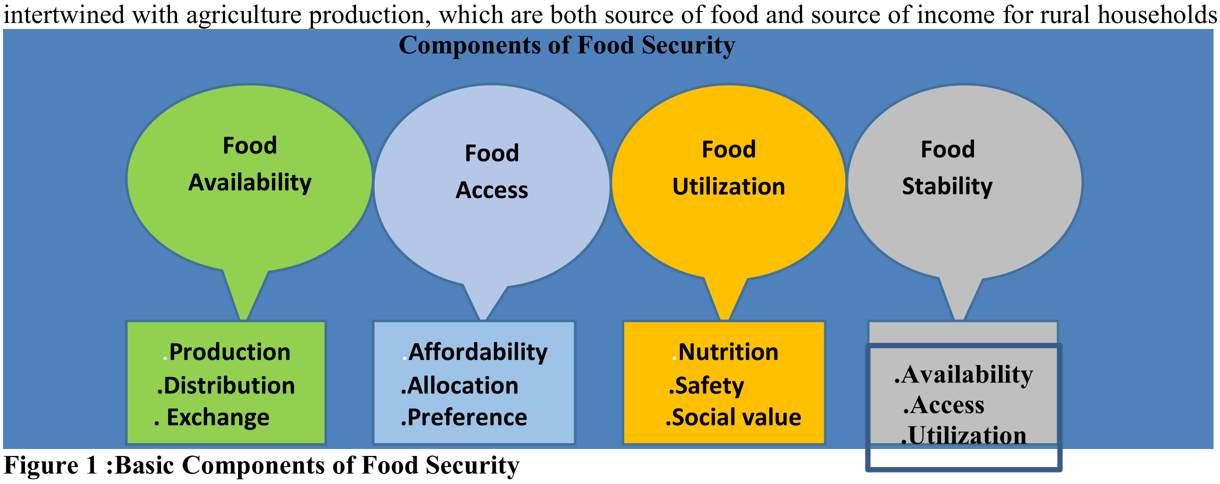

Figure 1 :Basic Components of Food Security

2.1.2. Climate Change Affects Basic Components of Food Security

Food security vulnerability to climate change depends not only on the intensity of the shock but also on the vulnerability of the food system (and its subcomponents, the relationships between them) to the particular shock, i.e. the propensity or predisposition of the system to be adversely affected (IPCC, 2012). Focusing on the "food security vulnerability" to climate change, meaning the propensity of the food system to be unable to deliver food security outcomes under climate change, and food security vulnerabilities to climate change encompass the environmental (productive), economic and social dimensions (FAO,2016).

As a result of the cascading impacts and specific vulnerabilities to food security description, climate change impacts four dimensions of food security: availability, access, utilization and stability (FAO 2011) directly and indirectly. As noted by Porter *et al*., (2014), there is much less quantitative understanding of how non-production components of food security will be affected. A review of peer-reviewed journal papers on food security and climate change since 1990 showed that they were mainly about availability, 70 percent, access, utilization and stability being represented by11.9 percent, 13.9 percent and 4.2 percent, respectively, of the papers (Wheeler and von Braun, 2013). All dimensions of food security are affected by climate change, food security depends not only on the direct impact of climate change on food production, but also (and critically so) on human development, economic growth, trade flows, and food aid policy (Keane *et al*., 2009). Climate change has major implications on food security and livelihoods (Thompson and Scoones, 2009). Climate change affects food security, water availability, and productivity levels in Africa (Hope, 2009). Climate change is expected to affect all of the components that influence food security: availability, access, stability and utilization (FAO/WFP, 1010).

The food systems on which food security depends are subject to climatic and other various risks. These risks can impact directly the four dimensions of food security and nutrition (food availability, access to food, utilization, and food stability). IPCC (2012). Vulnerability can be defined as vulnerability of "what" (here: the food system and its components) to "what" (here climate risks and all the sets of risks, or a change such as influenced by climate change in the context that they shape existing risks) (Carpenter *et al*., 2001)..

2.1.1.1. Potential Climate Change Impacts on Food Access

The impact of climate change on food accessibility often depends on distinct factors such as the functionality of food markets, the affected geographical environment (Hertel & Rosch, 2010) and differences in socioeconomic factors (Reidsma *et al.*, 2010). Increased exposures to climate change events result in reducing people's entitlement to food, hence challenge their food security (FAO (2008a), Change in the levels and volatility of food prices is a key determinant of food access. The increased level and volatility of agricultural prices is negatively impacting the purchasing power and the food security of the poor (von Braun, 2007). Given the hypothesis that climate change will be a contributing factor to food price increases, and hence its affordability, the vulnerability of households to reduced food access depends on their channel of food access (medium evidence, medium agreement). Households into five main categories of food access, indicating their relative impacts of food price increases. Concerning about the impact of increased food prices on poverty and food security arises due to the high share of income that poor consumers spend on food, thus generating a disproportionately negative effect of price increases on this group (FAO, 2011). A study by the World Bank estimated a net increase of 44 million people in extreme poverty in low and middle income countries as a result of food price increases since June 2010 (Ivanic *et al*., 2011).

The distribution of net food buyers and net food sellers varies considerably across countries and can be expected to change with the process of economic development (Zezza *et al*., 2008; Aksoy *et al*., 2010; FAO, 2011). Climate change will affect food accessibility by influencing food allocation. Food is allocated through markets and non-market distribution mechanisms. For rural communities in Africa who produce a substantial part of their own food and also non-farming low-income rural and urban households. Climate change impacts on food production may reduce availability to the point that allocation choices have to be made within the household (Mendany *et al*., 2006). Climate change will also affect affordability by affecting income and also ability of people to choose the food they want to eat (prefer ability) (FAO, 2008a).

In regions with high food insecurity and inequality, increased frequency of droughts will particularly affect poorer households and may disproportionately affect women, given their vulnerability and restricted access to resources (IPCC, 2014b). Climate change will particularly put at high risk indigenous peoples, who depend on the environment and its biodiversity for their food security and nutrition – specifically those living in areas where significant climate change impacts are expected such as mountain regions, the Pacific islands, coastal and other low-lying areas, and in the Arctic (IPCC, 2014b). Access to aquatic foods will be affected by changes in livelihoods and catching or culture opportunities combined with transferred impacts from other sectors (i.e. increased prices of substitute foods), competition for supply and information asymmetries. Impacts may also arise from rigid management measures that control temporal and spatial access to resources. Climate change can also have remote impacts on the food security of people distant from the initial shock, particularly through food price increases and volatility. Without considering effects of CO_2, changes in temperature and precipitation will contribute to increase global food prices by 2050 (Nelson *et al*., 2014a).

2.1.1.2 Potential Climate Change Impacts on Food Availability

Impacts of climate change on major crop yields is probably the food security-related issue on which there are the most studies, with two decades of work since the global assessment of (Rosenzweig and Parry,1994) including major studies by Parry *et al*., (2005), Cline (2007), IBRD/WB (2010) and Rosenzweig *et al*, (2014). 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**).** Availability of aquatic foods will vary, positively and negatively, through changes in habitats, stocks and species distribution (Barange and Perry, 2009). Marine fish availability in the tropical belt and along coastal regions across the globe is predicted to decrease substantially (Cheung *et al*., 2010). Global temperatures of 4 degree centigrade or more, combined with increased food demand, would pose large risks to food security globally and regionally (Porter *et al*., 2014).

Food availability is the channel which climate changes directly affects food security (Thompson *et al*., 2010). The impacts of climate change on food availability will be experienced differently, depending on location. For example, moderate warming (increases of 1 to 3 ºC) is expected to benefit crop and pasture yields in temperate regions, while in African tropical and seasonally dry regions, it is likely to have negative impacts, particularly for cereal crops. IPCC (2007) warming of more than 3 ºC is expected to have negative effects on production in all regions. As reported by FAO (2008a), 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. Projections vary according to the scenario used, the model and time scale. There is, however, consistency on the main orientations: yields are more impacted in tropical regions than at higher latitudes and impacts are more severe with increased warming. Importantly, many of the areas where crop yields are expected to decrease are also areas that are already experiencing food insecurity.

2.1.1.3. Potential Climate Change Impacts on Food Utilization

Climate change impacts on food utilization by declining the availability of wild crops and the production of small-scale farmers. Potential impacts of climate change on nutrition have been much less studied. Several climate change impact pathways can be identified. As mentioned above, climate change will impact livelihoods and income of small-scale food producers and also, through food price increases and volatility, the livelihoods of poor net food buyers, constraining these populations to reduce their food consumption in quantity and quality. They are also likely to reduce health expenditures with potential effects on nutrition. In a literature review on climate change and its impacts on childhood undernourishment among subsistence farmers in low-income countries, Phalkey *et al*., (2015). Lloyd, Kovats and Chalabi (2011) projected a relative increase in moderate stunting from 1 to 29 percent in 2050, with severe stunting increasing from 23 to 62% (Central Africa). Rationing consumption to prioritize calorie- rich, but nutrient poor foods is another common response (Bloem *et al*., 2010). The effects are a decrease in dietary quality as well as quantity, which are magnified by pre-existing vulnerabilities and lead to long term loss of health, productivity capacity and low incomes (medium evidence; medium agreement) (Bloem *et al*., 2010; Alderman, 2010; Brinkman *et al*., 2010; Campbell *et al*., 2010; Sari *et al*.,2010).

Studies also point to changes in the nutritional quality of foods (reduced concentration in proteins and in some minerals like zinc and iron), due to elevated CO_2, particularly for flour from grain cereals and cassava (Porter *et al*., 2014). This effect does not necessarily translate into impacts on nutrition, as it is generally combined with increased yields which themselves can increase food intake, often the main concern (Porter *et al*., 2014). However, some authors (Myers *et al*., 2014) note that in some countries populations receive 70 percent of iron or zinc from C3 grains or legumes and that, in countries where proteins are mainly of plant origin, a decrease of protein content could have serious health consequences. According to WHO (2014) climate change is projected to increase diarrheal diseases, impacting mainly low-income populations. Climate change also has an impact on food safety, particularly on the incidence and prevalence of food-borne diseases. Tirado *et al.* (2010) reviewed the potential impacts on food contamination at various stages of the food chain and described adaptation strategies and research priorities to address food safety implications of climate change. Continuously rising temperatures also support the spreading of the organism responsible for producing the toxin that causes Ciguatera Fish Poisoning (CFP), which occurs in tropical regions and is the most common non-bacterial food-borne illness associated with the consumption of fish (IPCC, 2013). The Food Research International journal recently published a special issue on climate change impacts on food safety (Uyttendaele and Hofstra, 2015), which tackled this topic from various perspectives. Overall, the reviews conclude that climate change could reduce food safety and that more research is required to get a better understanding of the problems and to set up adaptation strategies.

2.1.1.4. Potential Climate Change Impacts on Food Stability

Climate change extreme evens found to affect food stability reported by many authors. Climate-induced events such as floods and droughts will be more frequent and extreme due to climate change (Kundzewicz *et al*., 2007), have negative impact on food stability. According to Reilly & Willenbockel (2010); Parker *et al*., (2019), climate change events create critical threats to the stability of food systems, especially for households with limited capacity in their food consumption, for instance, temperature increases and a sharp decline in rainfall in the semi-arid zone of Northern Nigeria caused to drop crop and livestock productivity. It further contributes to loss of farm and grazing lands while intensified the water scarcity, which negatively affected livelihood, household income while artificial food shortages, malnutrition and diseases (Jibrillah *et al*., 2018). According to IPCC (2012), there is increasing evidence of and confidence in the effect of climate change on increasing the incidence and frequency of some types of climate extreme events and this will have significant impacts on food security. Recent experiences of global climate patterns affecting food security indicate the potential nature and magnitude of increased variability. The degree to which these price increases affected domestic consumers and poverty depended on national responses in importing countries, although a significant net negative effect on poverty was found (Ivanic *et al*., 2011). According to FAO (2008) stability of food supply will be impacted by changes in seasonality, increased variance of ecosystem productivity, increased supply risks and reduced supply predictability issues that may also have large impacts on supply chain costs and retail prices. Increased climate variability, increased frequency and intensity of extreme events, as well as slow ongoing changes, will affect the stability of food supply, access and utilization.

2.1.3. Climate Change Affects Food Security through Impacting on Crop production

Climate change affects crop production through direct impacts on the biophysical factors such as plant growth and the physical infrastructure associated with food processing and distribution (Schmidhuber and Tubiello, 2007). With increasing frequency of droughts and floods associated with climate change, agricultural production will decline and the state of food insecurity and malnutrition will increase (Kumsa, and Jones, 2010). It is estimated that African farmers are losing about US$28 per hectare per year for each 1°C rise in global temperature (Kumssa and Jones, 2010).

Boko *et al*., (2007) have indicated that three of the five regions shown to be at risk of flooding in coastal and deltaic areas of Africa. In Kenya, losses for mangoes, cashew nuts and coconuts could cost almost US$500 million for a 1 m sea-level rise (Republic of Kenya, 2002). In Guinea, between 130 and 235 Km^2 of rice fields (17% and 30% of the existing rice field area) could be lost as a result of permanent flooding, depending on the inundation level considered (between 5 and 6 m) by 2050. In Uganda, crop production has been negatively impacted by climate hazards and disasters; an average of 800,000 ha of crops are destroyed annually by climate-related effects, resulting in losses exceeding US$47million (NEMA, 2008). During the 1997/1998 due to flood impacts, 300 ha of wheat were lost (MWE, 2012). Further flood disasters hit the Teso area (Eastern Region), leading to rotting cassava, and sweet potato tubers and groundnuts worth over US$3.1 million.

Huq *et al*., (2004) mentioned that crops such as rice, wheat, beans, maize and potatoes are highly affected and other crops like millet, which resist high temperature and low levels of water may be less affected. Biophysical impacts of climate change on food crops critical for food security: maize, common bean, cassava, sorghum, yam, finger millet, pearl millet, groundnut, and banana were found to be most negatively impacted (Ramirez-Villegas *et al*., 2015). High temperature stress during reproductive processes can affect sorghum substantially as the reproductive processes are more sensitive to high temperature stress compared to vegetative processes of development (Downes, 1972, Craufurd *et al*., 1998). Prasad *et al*., (2006), growth temperatures of 40/30°C (day/night) delay panicle exertion by about 30 days, while panicle exertion is completely inhibited at growth temperature of 44/34°C. Temperatures above 35˚C and below 10-15˚C cause damage to banana plant tissue and distort flowering emergence and bunch filling, and temperatures below 2- 3˚C for several days are lethal to the plant, which does not recover (Ramirez *et al*., 2012). In Kenya, crop failure during 2014/2015 cropping year due to rain fall scarcity has led to reduction in crop (wheat, maize, sorghum, and others) production 10% lower than last five years in average (Table1) (FAO, 2015). According to Li *et al*., (2009) the areas of major crop production (barley, maize, rice, sorghum, soya and wheat) have all experienced an increase in the area affected by hydrological drought which renders them sensitive to weather variability in the future.

Table 1: Cereal crops affected due to climate change in Kenya

Types of cereals	2009-2013 Average	2013	2014 estimate	Change 2014/2013
		000 tones		
Maize	3255	3391	2750	-19
Wheat	385	486	4500	-7
Sorghum	146	139	120	-14
Others	235	292	285	-2
Total	4021	4308	3605	-16
		Percentage change calculated from uni rounded data		

Source: (FAO, 2015)

2.1.4. Impact of Climate Change on Crop Yield

There are different climate change driven environmental changes/or stresses to impact crop yield in Africa, which is in agreement with the idea of Prasad *et al., (*2008) who reported that among the possible environmental changes, heat and water stresses are the most important. Again, heat stress during crop development leads to fewer and smaller organs, reduced light interception due to shortened crop life, and altered carbon-assimilation processes including transpiration, photosynthesis, and respiration (Stone, 2000). Heat stress during flowering and grain filling stages results in decreased grain count and weight, resulting in low crop yield and quality (Craita and Gerats, 2013). Plants close their stomata as a response to increased evaporative demand, reducing their photosynthesis rate and increasing vulnerability to heat injury (Lobell and Gourdji, 2012). Even short-duration heat shock can reduce crop yield substantially, especially if it coincides with the reproductive stage (Teixeira *et al*., 2013). Water stress leads to shortening of the crop reproduction stage, reduction in leaf area, and closure of stomata to minimize water loss, reducing crop yields (Barnabás *et al*., 2008). Water stress also increases pollen sterility, which reduces grain yield and quality (Alqudah *et al*., 2011).

The impact of these stresses on crop yield has been studied widely. As various studies showed that a large negative sensitivity of crop yields to extreme daytime temperatures around 30 °C to 34°C depending on the crop and region (FAO, 2016). Maximum daytime temperature accelerates crop maturity, resulting in reduced grain filling, while higher minimum nighttime temperatures increase respiration losses. The episodic heat waves also have a strong negative impact on yields, particularly when they occur during sensitive phenologic stages, such as during reproductive growth causing increased sterility or during seedling emer-gence, which affects crop stand establishment (Jon Padgham, 2009). Th**e** response of crops to climate change is genotype-specific. Recent results also confirm the damaging effects of elevated tropospheric ozone on crop yields, with estimates of losses for soybean, wheat and maize in 2000 ranging from 8.5 to 14 %, 4 to 15 %, 2.2 to 5.5 %, respectively (Porter *et al*., 2014). Climate change is projected to decrease the yields of cereal crops in Africa overall through shortening growing season length, amplifying water stress, and increasing diseases, pests, and weeds *(*Vrieling *et al*..2013). In Africa, crop yield reductions due to climate change impacts for extended years, for instance, the analysis of actual climate change impacts on value of crop yield associated with a range of climate shocks for five African countries for varying past ten years is mentioned below (Table 2).

Table 2 Analysis of the actual impacts on crop yields

Countries	Weather/Climate variable or shock	Impact on the value of crop production
Ethiopia	Rainfall-growing season	+ (7–8) %
	Temperature-growing season	+ (10–60) %
Malawi	Rainfall-growing season	+ (16–20) %
	Dry spells-growing season	– (10) %
Niger	Rainfall-growing season	+ (64–84) %
	Late onset of rain	– (42–51) %
United Republic of Tanzania	Within season rainfall variation	– (8–15) %
	Too hot growing season (>30 °C)	– (14–25) %
Zambia	Rainfall-growing season	+ (5–10) %
	Late/false onset of rains too hot growing season (>28 °C)	Decreases the + impact of inorganic fertilizers by 50% Nullifies the + impact of improved seed

Source: Arslan *et al*. (2015); Asfaw, Coromaldi and Lipper (2015)

According to IPCC (2007), average global temperature increased between 1.8 and 4.0 oC during the period of 1980 to 1999 and expected to increase between 1.1 and 6.4 oC during the 21st century. Global warming to some extent could reduce markedly crop productivity in equatorial and tropical countries (Vose *et al*, 2005 and Tang *et al*, 2013). The occurrence **of** prolonged drought is found to cause crop failure in Africa. For instance, as evidenced by the Ministry of Disaster Management and Refugees Affairs (MIDIMAR), Rwanda has continuously experienced impacts caused by increase in temperature translated into droughts events, occurred and lasts for a long period (10) years from 1910 up to 2014. The prolonged droughts occurred in the years resulted in crop failure and food shortage where the worst situation of lacking food was recorded in December 1989. In this period, there was risk of crop failure and about 237 people died due to famine in Rwanda in different Zones (MIDIMAR, 2015) (Table 3).

Table 3: Historical drought events in Rwanda (1910 up to 2014)

Event period	Affected Zone of Rwanda	Death	Damages
1910	Kibungo/ Zaza	0	
1976-1977	National	0	Famine, crop failure
October 1984	National	0	Famine, food shortage
December,1989	Gikongoro[5] Gitarama and Butare	237	Famine, crop failure
1996	Gikongoro	0	Famine, Food shortage
November 1999-Early 2000	Umutara, Kibungo, Kigali (Central), Gitarama, Butare and Gikongoro	0	Famine, Food shortage
March 2003	Kigali Rural (Gashora and Bugesera), Kibungo, Umutara, Butare, Gikongoro and Gitarama	0	Crop failure
February 2005	National	0	Famine, crop failure
March - September 2006	Kibungo, Umutara, Bugesera, Butare, Gikongoro and Gitara	0	Famine, Food shortage
June 2014	Bugesera and Kayonza Districts	o	Crop failure

Source: (MIDIMAR 2015)

For Africa, most of the evidence reviewed projected a yield reduction of up to −40%, across all crop types and sub-regions, although there was a large magnitude of variation in the reported impact. Only a small number (n = 9) of studies accounting for around 30 observations reported yield increases, mainly for maize grown in East, West and Northern Africa. Most evidence in the scientific literature relates to maize (n = 106). Rice, sugarcane and yams account for only 6 of 162 observations for Africa despite the fact that these crops collectively account for 27% of the total cropped area, (FAO 2010). The estimated mean yield change for West Africa (−12.5%) and central Africa has by far the fewest estimates of climate change impacts on crop productivity (Knox *et al*., 2012); (FAO 2010). The projected impacts are also crop and region specific. For example in Africa, previous work on climate change impacts indicates that crops with significant yield reductions include maize (-5 %), sorghum (-14.5 %) and millet (-9.6 %) and wheat (−17%), yields are set to decline significantly, whereas rice and cassava yields are projected to not be significantly impacted during the 21st century (Knox *et al*., 2012) (Table 4).

Table 4 : Summary of reported impacts of climate change on yield (mean and median changes %) for all crops, by sub-region in Africa (Notes: n = Number of reported mean yield changes, which may include several from the same source for different countries or time

Crop	Number	Mean variation (%)	Crops with significant variation	Number	Mean variation (%)	Crops with non-significant Variation[1]	Number
			Wheat	37	-12.1		
			Maize	129	-7.2	Rice	43
All crops	257	-7.7	Sorghum	23	-13.0	Cassava	8
			Millet	9	-8.8	Sugarcane	7
			Wheat	20	-17.2	Rice	5
			Maize	106	-5.4	Cassava	7
Africa	163	-7.7	Sorghum	13	-14.6	Sugarcane	3
			Mille	8	-9.6		
Central Africa	14	14.9	Maize	8	-13.1	Wheat	2
East Africa	35	0.4				Wheat	2
		(NS)				Maize	29
North Africa	22	0.8				Wheat	10
		(NS)				Maize	12
Sahel	24	11.3	Maize	13	-12.6	Sorghum	3
			Millet	6	-10.6		
Southern Africa	33	-11.0	Maize	24	-11.4	Wheat	2
						Sorghum	3
						Sugarcane	2
West Africa	34	-12.5	Maize	19	-7.4	Wheat	3
						Sorghum	5
						Cassava	4

Source: (Knox *et al.*, 2012)

On the other hand, crop production losses for the certain crops is projected to be increased in 2050. Schlenker and Lobell (2010) use a new analytical approach utilizing historical crop production and weather data to generate a model of yield response to climate change at the country level for several key African crops. Summary of their findings for median production losses in key crops across the continent by 2050 are maize, sorghum, millet, groundnuts and cassava (Table5).

Table 5 : Summarizes their findings for median production losses in key African staple crops across the continent by 2050

Types of crop	Average % production loss predicted by 2050
Maize	22 %
Sorghum	17%
Millet	17 %
Groundnut	18 %
Cassava	8 %

Source: (Schlenker and Lobell, 2010); (FAO 2010)

2.1.5. Impact of Climate Change on Fisheries Production

Climate change affects food security through impacting on fisheries production in diverse ways in Africa. The key variables or drivers of interest to this sector include changes in water temperature, precipitation, salinity, river flow, nutrient levels, lake levels, storm frequency and intensity, and flooding (Lehodey *et al*., 2006, Brander, 2007). Increase in the frequency and severity of extreme events, such as floods and storms, will affect fishing operations and infrastructure (Adger *et al.,* 2005). Edwards and Richardson (2004), Hall-Spencer *et al*., (2008) reported that changes in water quantity and quality will affect productivity, as well as the distribution and abundance of aquatic competitors and predators. In areas that experience water stress and competition for water resources, aquaculture operations and inland fisheries production will be at risk (Peters *et al*, 2014).

Increased precipitation also results in high levels of eutrophication, resulting in an increase in primary production, including algal production, which compete for oxygen with fish and are a major cause of spontaneous fish kills and stunted growth (Ficke, 2007). Further, increased nutrients will lead to changes in the abundance and distribution of exploited species and assemblages (Lehodey *et al*., 2006, Dulvy *et al.,* 2008), and may affect the capture of fish juveniles and fry from the wild for aquaculture use. Kalff (2000), Ficke *et al.* (2007) mentioned that the probability of higher temperatures and increased biological oxygen demand, it is possible that levels of dissolved oxygen will decrease, leading to negative impacts to aquaculture and food security within the basin. .

Fisheries make particular contributions to food security and more than 90% of the people engaged in the sector are employed in small scale fisheries, many of whom are found in the poorer countries of the world (Cochrane *et al*., 2011). Impacts of climate change on fisheries will be felt most acutely in Africa (Allison *et al*., 2009). The study by Cheung *et al*.(2010) shows that yield potential could in fact increase by 16% off the eastern and south-eastern coasts of Sub-Saharan Africa (Madagascar, Mozambique, Tanzania, and Kenya), but that closer to the coastline the direction of change is reversed and yield potential changes by -16% and -5%. Significant adverse changes in maximum catch potential are projected of -16 to -5% for the Red Sea, as well as off the coast for Namibia, -31 to -15% for Cameroon and Gabon, and up to -50% along the West African coast from Gabon up to Mauritania and along the Mediterranean coast (Cheung *et a*l. 2010). Authors (Cheung *et al*., 2011) find that due to climate change impacts, acidification and reduced oxygen content lowered the estimated catch potentials by 20–30% relative to the results of the previous study.

The deep African lakes of East Africa could be particularly vulnerable (Ndebeli-Murisa *et al,*.2010).With lakes such as Chilwa, Kariba, Malawi, Tanganyika and Victoria contributing more than 60% of dietary protein consumed in bordering rural communities (Ndebeli-Murisa *et al* 2010), climate change impacts on freshwater fisheries would have serious implications for human populations. In East African Rift Valley areas, impacts of climate change on fisheries has been demonstrated for Lake Tanganyika (O'Reilly *et al*., 2003) that productivity of fish in Lake Tanganyika might have decreased by as much as 20% over the past 200 years. Recent declines in fish abundance in East African Rift Valley lakes have also been linked to climatic impact on lake ecosystems (O'Reilly, 2007). As reported by WWF (2006) climate change impacts fisheries in East Africa, because many tropical fish have a critical thermal maxima beyond which they are unable to survive.

2.1.5. Impact of climate Change on Livestock Production

Climate change affects livestock and livestock production in Africa. For instance, in various Sub-Saharan Africa countries, 20% to 60% losses in animal numbers were recorded during serious drought events in the past two or three decades. In South Africa, Niang *et al*. (2014) reported that dairy yields may decrease by 10 to 25 percent under certain climate change scenarios. Another case study reported by the same authors estimated a 23 percent rise in the cost of supplying water to animals from boreholes in Botswana. Climate change affects all classes of livestock. Average, minimum, and maximum and seasonal variations are crucial for livestock growth, regeneration, and survival. Very high temperatures, beyond 30°C, affect pasture quality, optimal animal physiology and regulate climate-related parasites and diseases. The negative effects of increased temperature on feed intake, reproduction, and performance on various livestock species is reasonably well understood, for example, cattle, sheep, goats, pigs, and chickens, perform best at temperatures between 10°C and 30°C. But for each 1°C increase above that, all species reduce their feed intake by 3–5 percent (Rojas-Downing *et al*., 2015). According to Thornton *et al*. (2009), this will have far-reaching effects on the quality and quantity of livestock species. Increase in temperatures will also have widespread negative impacts on forage quality and thereby affect livestock productivity (McMichael *et al.,* 2007). The East African region is prone to periodic extreme changes in the weather including occasional flooding and prolonged dry spells all of which can result in famine and other stresses (EAC, 2006). Heat distress suffered by animals will reduce the rate of animal feed intake and result in poor growth performance (Rowlinson, 2008). Water stress and increased frequency of drought will lead to loss of livestock and associated resources. This will result in food insecurity and conflicts. According to Vitali *et al*., (2009), heat stress in dairy cows can be responsible for increases in mortality and economic losses. It affects a wide range of parameters in poultry (Feng *et al*., 2008a). An increase in temperature tends to reduce animal feeding and growth rates (André *et al*., 2011, Renaudeau *et al*., 2011).

As reported by Sellers (1984), climate variability and change has facilitated the recent and rapid spread of the blue tongue virus, an important ruminant disease observed in Africa. Ticks that carry zoonotic diseases (diseases that can be transmitted from animals to people) have also likely changed distribution as a consequence of past climate trends. Meta-analyses conducted by (Tomley and Shirley, 2009) suggest that around 20 percent of ruminants (25 percent of young and 10 percent of adult animals) in Africa and more than 50 percent of poultry die prematurely each year; at least half of those deaths are due to infectious disease. Climate change can exacerbate disease in livestock. Thornton *et al*. (2014) reported that among 65 animal diseases identified as most important to poor people, 58% are climate-sensitive. Moreover, models predict changes in priority diseases such as trypanosomosis, which costs farmers in East Africa $2 billion a year; East Coast Fever, which kills one animal in Africa every 30 seconds; and Rift Valley Fever (RVF), which reduced exports from Africa by 75%. Climate change affects livestock and pasture in Africa. In the arid and semi-arid zones of Africa are an estimated 50 million pastoralists and agro-pastoralists that constitute one of the poorest and most vulnerable population sub-groups (Rass, 2006). Pastoralists obtain more than 50% of their total gross income from mobile livestock rearing on communal pastures; and agro-pastoralists between 25% and less than 50% from livestock and more than 50% from cropping activities (Swift, 1988).

Climate change extreme/or droughts in Africa, illustrate the potentially large effects of local and/or regional climate variability on livestock (IPCC, 2007). Repeatedly occurring drought had caused livestock mortality in Africa. One obvious consequence would be rangeland degradation involving reduced forage productivity and quality, and lack of resilience to drought, which could lead to massive livestock loss (Table 6) (FAO, 2008b).

Table 6: Impacts of droughts on livestock numbers in selected African countries, 1981 to 1999

Years	Location	Livestock losses
1981- 1984	Botswana	20 % of national herd
1982-1984	Niger	62 % of national cattle herd
1983-1984	Ethiopia (Borana Plateau)	45-90 % of calves, 45 % of cows, 22 %of mature males
1991	Northern Kenya	28 % of cattle; 18 % of sheep and goats
1991-1993	Ethiopia (Borana) 2002	42 % of cattle
1993	Namibia	22 % of cattle 41% of goats and sheep
1995-1997	Greater Horn of Africa (average of 9 pastoral areas)	20 % of cattle; 20 % of sheep and goats
1995-1997	Southern Ethiopia	46 % of cattle; 41% of sheep and goats
1998-1999	Ethiopia (Borana)	62 % of cattle

Source: IPCC, 2007

Impacts of climate change on animal health are also documented, especially for vector borne diseases, rising temperatures increasing winter survival of vectors and pathogens. Outbreaks of Rift Valley fever in East Africa are also associated with increased rainfall and flooding due to El Niño-Southern Oscillation events (Lancelot *et al*., 2008; Rosenthal, 2009; Porter *et al*., 2014).

Thresholds for livestock vulnerability to climate change could be exceeded in the future. In the tropics and sub-tropics temperatures frequently rise above the “comfort zone” of 10°C–20°C (FAO 2009), and therefore, livestock are adapted to these higher temperatures. Heat stress can occur when temperatures are above 25°C for dairy cattle, when combined with high humidity, low air-flow, and direct sun light (Barman *et al.* 1985, Hahn 1999). In beef cattle the threshold temperature above which dry matter intake is adversely affected is 30°C with a relative humidity of below 80 percent, and if the relative humidity is above 80 percent the threshold temperature drops to 27°C (Hahn 1999). Due to climate change or due to high temprature projected impacts on livestock in Africa under future scenario is presented in the (Table 7).

Table 7: Projected impacts for livestock in Africa under future scenario

Sub-region	Climate change impacts	Scenarios
Botswana	Cost of supplying water from boreholes could increase by 23 percent due to increased hours of plumping under drier and warmer conditions	A2, B2 2050
Lowlands of Africa	Reduced stoking of dairy cows, a shift from cattle to sheep and goats, due to high temperature	A2, B2 2050
Highlands of Africa	Livestock keeping could benefit from increased temperatures	A2, B2 2050
East Africa	Maize stover availability per head of cattle may decrease due to water scarcity	A2, B2 2050
South Africa	Dairy yields decrease by 10–25 percent	A2 2046–2065 and 2080–2100

Source: (Niang *et al.* 2014)

2.1.6. Climate Change Affects Food Security through Impacting on Water Availability

In Africa, climate change affects food security through impacting on water availability. It is nearly 51% of the population in sub-Saharan countries lack access to a supply of safe water and 41 % lacks adequate sanitation. In Africa, nearly 330 million of these people live in rural areas. In almost all rural communities in Africa, it is primarily women and girls, who collect water, protect water sources, maintain water systems, and store water. Without access to sufficient and reliable water for productive uses in and around the household, people are excluded from a range of options that would otherwise enable them to secure their sources of food and income. The water sector is strongly influenced by, and sensitive to, changes in climate (including periods of prolonged climate variability). Two-thirds of rural Africans and a quarter of urban dwellers in Africa lack access to clean, safe drinking water (Simms, 2005). About 25% of the contemporary African population experiences high water stress while 69% of the population lives under conditions of relative water abundance (Vörösmarty *et al.*, 2005; IPCC, 2007). However, this relative abundance does not take into account other equally important factors such as access to clean drinking water and sanitation, which effectively reduces the quantity of freshwater available for human use.

According to UNEP (2003), about 1,100 million people do not have access to clean drinking water, and contaminated water is the cause of 5 million death every year, with the majority of these in the cause of 5 million deaths every year, with the majority of these in sub-Saharan Africa. Specifically, 14 countries in Africa are already experiencing water stress; another 11 are expected to join them by 2025, at which time nearly 50 per cent of Africa's predicted population of 1.45 billion people will face water stress or scarcity. Changes in temperature, precipitation and sea levels are expected to have severe consequences for the availability of water in Africa (IPCC, 2007). This is of particular concern to Africa, where much of the population relies on surface water for their different livelihoods activities (De Wit, 2006). Boko *et al*., (2007) reported that a 3°C temperature increase could lead to 0.4 - 1.8 billion more people at the risk of water stress. Climate change is also expected to reduce water quality, posing risks to drinking water quality even with conventional treatment (Jimenez Cisneros *et al*., 2014). Water stress will affect between 75-250 million persons, 50% reduction on rain fed irrigation, loss of coastal lands, and Arid and Semi-Arid Lands (ASALs) increase by 8% while adaptation costs swallowing up to 10% of GDP (IPCC 2007). FAO (2009) predicted that water demand will increase by 40% across Africa by 2030. UN (2014) Africa is found to be the second driest continent with ASALs covering approximate 66%.

Climate change is adding significant uncertainty to the availability of water in many regions in the future. It will affect precipitation, runoff and snow/ice melt, with effects on hydrological systems as well as on water quality, water temperature and groundwater recharge. The impacts of changed rainfall patterns on water quality have not been sufficiently studied; heavy rainfall may well increase pollutant loadings, which would impact the quality of raw water for agriculture, industries and other uses as well as for drinking purposes, exacerbating existing access and quality problems, even with conventional treatment (Jiménez Cisneros *et al*., 2014).

2.1.7. Climate Change Affects Food Security Indirectly through Effecting on Agricultural Pests

Climate change affects indirectly food security through impacting on agricultural pests (weed, insect and disease pests). Climate change induces agricultural pest occurrence, multiplication and crop infestation then results in crop failure and terminus crop yield losses in Africa, because of climate is being favorable for agricultural pests. As the climate warms, it is expected that the range of agricultural pests may expand, as the ability of pest populations to survive the winter and attack susceptible crops increases. Studies suggest that pests, such as aphids (Newman, 2004) weevil larvae (Staley and Johnson, 2008) respond positively to higher carbon dioxide concentrations. Increased temperatures in winter also reduce the mortality of aphids enabling earlier and potentially larger dispersion (Zhou *et al*., 1995). In Sub-Saharan Africa, evidential research shows that migration patterns of locusts may be influenced by rainfall patterns; therefore, climate change may impact the distribution of this pest (Cheke and Tratalos, 2007). The risk of increased aflatoxin contamination in some areas due to changing rainfall patterns may restrict the area over which certain crops like maize can be grown. According to Lewis *et al*., (2005); Cotty and Jaime-Garcia, (2007), maize is a staple for millions of people in Africa but it is susceptible to climate influences as exemplified by recent experiences with aflatoxins in Kenya.

The potential changes in temperature, rainfall and wind patterns associated with climate change was expected to have a dramatic effect on Desert Locust in Africa, the most dangerous of all migratory pests (Cressman, 2013). The greatest impacts will be caused by warmer temperatures and increased rainfall in desert areas extending from West Africa to the Horn of Africa. According to the Ugandan Agricultural Census, in Uganda, climate change caused 1.3 million agricultural households to experience food shortages through pests or diseases damage (UBOS and MAAIF, 2011). Dugje *et al*., (2006); Stringer *et al*., (2007); Vasey *et al*., (2005) reported that the parasitic weed (*Striga hermonthica)* and related Striga species constrained in dry land areas of Sub-Saharan Africa which was occurred on more than 40 million hectares of maize, millet, sorghum, and upland rice areas. In these areas, the weed robs the crops water and nutrients, causing stunting and wilting; yield losses are often in excess of 50%. Striga infestations causes US$7 billion in annual yield loss in Africa and directly affect the livelihood of 100 million people and lead to abandonment of Land (Dugje *et al*., 2006; Stringer *et al*., 2007).

Striga is a parasitic weed that infests approximately 158,000 hectares of arable land in the Lake Victoria Basin (LVB). With regard to insect pests, stem borer (*Busseola fusca*) seriously limit yields by infecting the crop throughout its growth. The yield losses caused to maize vary widely and range from 20 to 40 percent in East Africa depending on the agro-ecological condition, crop cultivar, agronomic practice, and intensity of infestation (Kodjo *et al*. 2013). Climate is one of the abiotic factors that define ecological suitability for individual species and thus dictate composition of pest communities in different regions (Kodjo *et al*. 2013). Unfortunately, temperature, which is one of the important climatic variables that directly affect herbivorous insects, is predicted to increase by 1.4°C–5.8°C toward the year 2100. This change could profoundly affect population dynamics and status of cereal stem borer (Kodjo *et al*.., 2013). Increased climate variability associated with climate change trends may result in higher pre-harvest levels of fungal diseases and their associated mycotoxins posing both economic and health risks due to accelerated infestation of mycotoxigenic fungi (Dinesh *et al*. 2015), and a summary of climate change and crop diseases for selected crops (from most to least sensitive crops, they are: arabica coffee, robusta coffee, rice, maize, East African highland banana, beans, sorghum, sweet potatoes, and cassava) is presented in the (Table 8).

Table 8: Potential impacts of climate change on crop disease (Dinesh *et al*. 2015)

Types of crops	Potential impacts of climate and diseases
Coffee	Rising temperatures and erratic rainfall increase the risk of disease and pest infestations.
Rice	Two major diseases (blast and bacterial leaf blight) affect rice yields and are significantly aggravated by weather conditions such as higher temperatures, air humidity, or soil moisture.
Maize	Aflatoxin contamination represents a serious threat to human health and the marketing of maize and will likely worsen if dry season rainfall increases.
East African highland banana	While banana is less vulnerable to increasing temperatures than coffee, the potential impact of pests and diseases on the crop is significant.
Beans	Beans are vulnerable to fungal and viral diseases when excessive rain falls during critical growing periods
Multiple grains	Erratic rain could increase post-harvest storage losses of crops typically dried in the sun (maize, beans, coffee, rice, etc.), due to increased pests and rotting.
Sorghum and maize	Coupled with irregular precipitation, increased temperatures could result in the proliferation of striga, a parasitic weed that affects sorghum and maize, which is prevalent in areas with degraded soils.
Sweet potatoes and cassava	Both crops grow well at temperatures much higher than current ones, but are also vulnerable to pests and disease.

Source: (Dinesh *et al*. 2015).

2.1.8. Severity of Food Insecurity and Malnutrition Due to Climate Change Extreme Events/or Drought

Climate change extreme events /drought causes extreme food insecurity and malnutrition situations and affected so many Africans due to repeatedly occurrence of drought, again, there is huge number of food in secure and malnourished people in this region which is in line with the idea of authors (Schlenker and Lobell, 2010) who reported that climate change made African continent to have the highest proportion of food insecure and malnourished population in the World. The IPCC notes that food insecurity and undernutrition linked to extreme climatic events may be one of the most important consequences of climate change due to the very large number of people that may be affected (Confalonieri *et al*, 2007). For instance in Ethiopia and Kenya, two of the world‘s most drought-prone countries, studies have found that children aged five or less born during a drought are respectively 36 and 50 per cent more likely to be malnourished that children not born during a drought (Watkins K., 2007). In Niger, children aged two or less born in a drought year were 72 per cent more likely to be stunted (Watkins K., 2007). As reported by Emergency Events Database (EM-DAT), more than 100 million people were affected by drought driven hunger in Africa (Anne Bourke, 2011). According to the Ugandan Agricultural

Census, in Uganda, 1.8 million agricultural households were experienced food shortages due to drought (UBOS and MAAIF, 2011). Kenya was affected by drought seven times over 1991-2008, which affected about 35.7 million people. Ethiopia also experienced six drought times over 1983-2008, which affected about 41.3 million people. Other African countries were also affected by drought several times (Table 9) (IPCC, 2007).

Table 9: Major African drought over 1980-2008 as reported on EM-DAT, 2009, (Adopted from Anne Bourke, 2011).

Country names	Years	Affected people nearest (0.1 mn)
Kenya	2008	1.4
	2005-06	3.5
	2004	2.3
	1999-02	23
	1997-98	1.6
	1994-95	1.2
	1991-92	2.7
Ethiopia	2008	6.4
	2003-04	12.6
	1997	1.0
	1989-94	6.5
	1987	7.0
	1983-84	7.8
Sudan	2000-01	2.0
	1991-92	8.6
	1987	3.5
	1983-85	8.4
Eritrea	2008	1.7
	1999-03	2.3
	1993	1.6
Somalia	2008	3.3
	2000-01	1.2
	1987	0.5

Source: (Anne Bourke, 2011)

Drought has been found to cause severe detrimental impacts on nutrition in African countries (Fuentes and Seck, 2007), for instance, in Ethiopia, children who were born in an area affected by a drought were 35.5% more likely to be malnourished and 41% were more likely to be stunted, in Kenya, children who born in drought-prone areas were 50.4% likely to be stunted and 71.1% likely to be severely stunted, in Niger, the chance of being malnourished was more than doubles for children between the ages of one and two who were born during a drought. Children born during a disaster, irrespective of the location were up to 55.5% likely to be undernourished**.** Of the top ten disasters in East Africa between 1970 and 2003, most were caused by droughts (1969, 1979, 1980, 1984, 1989, 1990, 1992, 1999 and 2000), which is in similarity with report of (World Bank, 2007) that the greatest numbers of people were affected by drought in 1999-2000, of which 4.4 million people were in Kenya and 14.2 million people were in other East African countries

In other years, also drought caused food security crises in East African countries. In Ethiopia, since (1953-2011) twelve major drought-induced food security crises have been occurred, as Woldeamlak (2009) mentioned, 'once every three or four years is a drought year.' In addition, due to drought effect the Demographic Health Survey (DHS) highlighted that 44 % of Ethiopian children were stunted (low height-for-age), 21% were severely stunted, 10 % of children were considered to have low weight-for-height (wasting), and 29% of children were considered as underweight (low weight-for-age). Under nutrition is predominantly rural: stunting, wasting, and underweight rates were higher in rural (46%, 10%, and 30% respectively) compared to urban (32%, 6%, and 16%) areas (CSA, 2011). As estimated by FAO/WFP, there were similar results in Ethiopia: over 41% of the population was considered to be undernourished, and 7.6 million (or 11% of the rural population) were considered chronically food insecure, meaning each year they are relying on resource transfers to meet their minimal food requirements (FAO/WFP, 2010). About 2.2 to 6.4 million additional people were found to be food-insecure or not able to meet their food needs in the short term due to transitional factors (FAO/WFP, 2012). Major drought-related food security crises occurred in several drought years in Ethiopia (Table 10**)** (FAO/WFP, 2012).

Table 10: Chronology of drought-related food security crises since (1953-2011) in Ethiopia

Food security crises years	Major incidences
1953	Food security crisis in Wollo and Tigray
1957/58	Food security crisis in Tigray, Wollo, and south-central Shewa. About 1 million Farmers in Tigray might have been affected, with about 100,000 were displaced.
1962/66	Many parts of the northeastern Ethiopia suffered from droughts and Food Security crisis. Tigray and Wollo were severely hit
973/74	This was one of the most significant food security crises which affected parts of Eastern Harare SNNPR and the Bale lowlands. About 100,000 to 200,000 people died as a result of this extensive crisis.
1977/78	Most parts of the Wollo were severely hit by food security crisis owing to erratic Rainfall, pest damage, and frost actions. About 500,000 farmers were affected
1984/85	Most parts of Ethiopia including relatively food secure areas like Walaita, Kambata and Hadiya were affected by severe food insecurity. Drought and crop diseases were the main drivers of the food security crises in this case, it is estimated that over 1,000,000 people died.
1987/88	Tigray, Wollo and Gonder were severely affected due to drought and civil wars.
1990/92	Rain failure and regional conflicts resulted in approximately 4,000,000 people were affected.
1993/94	widespread food insecurity, but few deaths or cases of displacement were reported because of early responses by the government and international aid organizations
2003/04	Over 13 million people affected, but the response mitigated the worst potential outcomes
2008/09	Almost 3 million people were affected.
2011	Severe food security crisis occurred in the southeastern lowlands. This was linked to Unprecedented drought.

[Source: Compiled from Markos (1997), Webb *et al.* (1992), Cochrane (2011)]

Sub-Saharan Africa (SSA) is marked as the most food insecure region in the world (UNDP, 2012). WFP (2011) notes that risk of hunger will increase by 10-20% in 2050. Sub-Saharan Africa region has the highest proportion of food insecure people, with an estimated regional average of 26.8% of the population undernourished in 2010 - 2012, and where rates over 50% can be found (FAO *et al*., 2012). As revealed by UNECA (2013) due to climate change impacts 24 million malnourished children located in Sub Saharan Africa among other climate related variables. Similarly, Eastern, Central, Southern and Western Africa regions became second global hunger index. (FAO, 2015) reported that in present years. The number of malnourished children in Sub Saharan African (SSA) countries has also worsened due to global climate change. For instance, (figure 2) shows that the number of malnourished children in Sub Saharan African is projected to be about 1 million more in 2030 and 600,000 more in 2050 due to climate change relative to no climate change scenario. On other hand, another projection shows that the number of malnourished children in 2030 and 2050 will be increased from the baseline (33 million) to 42 million and 52 million respectively (Figure 3).

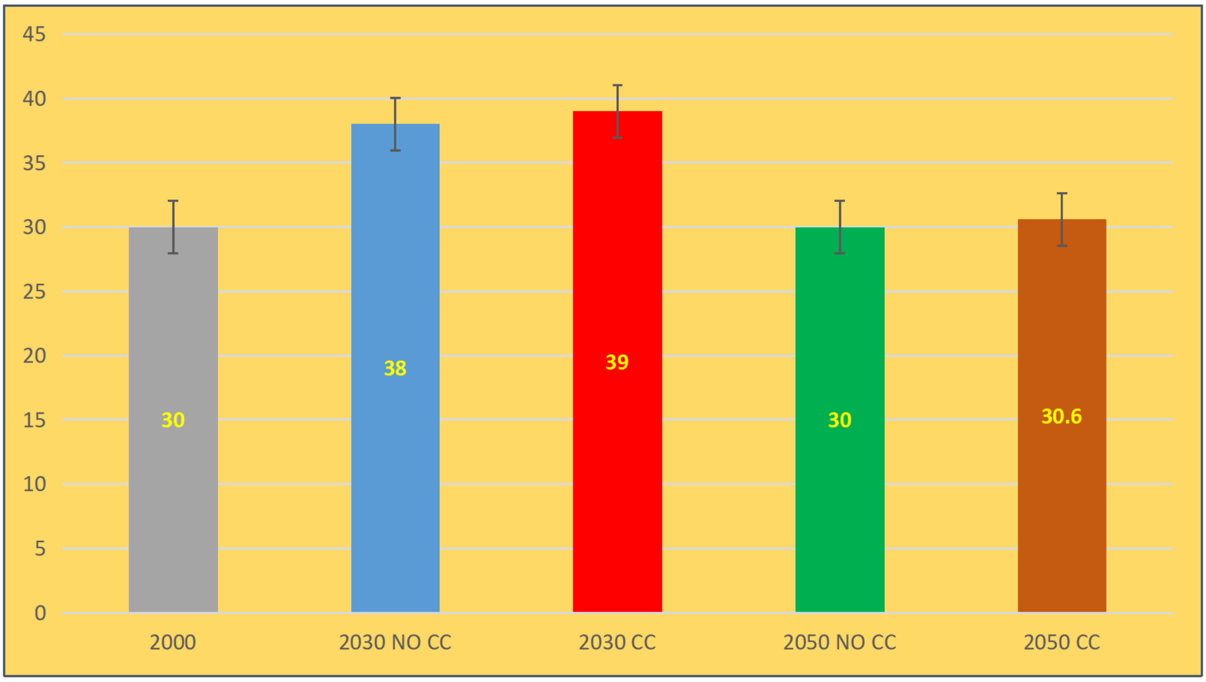

Figure 2: Impact of climate Change on Child malnutrition in SSA (Million Children)
Source: own calculations from (Ringler *et al.*, 2010)

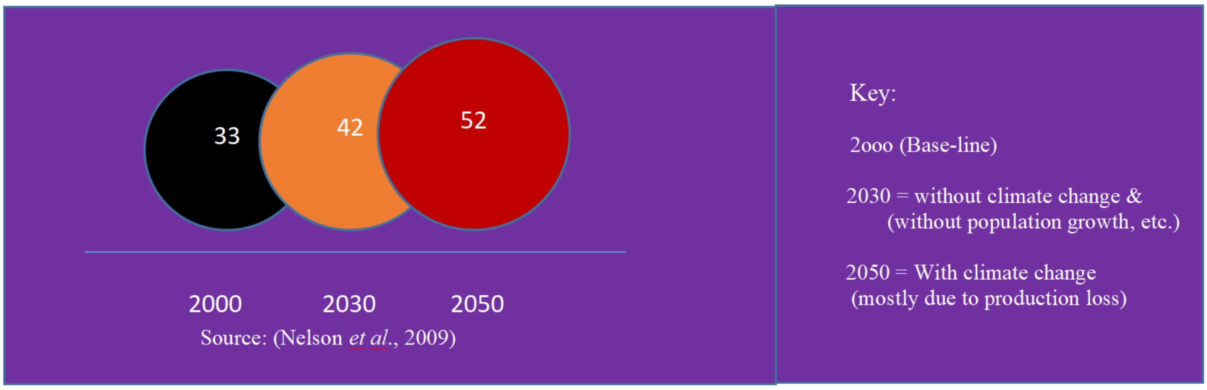

Figure 3: Number of malnourished children in Sub - Saharan Africa (million)

3. CONCLUSION AND RECOMMMENDATIONS

This paper reviews impact of climate change on food security and severity of food insecurity and malnutrition in Africa. Based on the climate change impact indices, African continent is found to be the most susceptible and vulnerable places to climate change impacts and became the most food insecure region because of their reliance on climate sensitive and vulnerable economic sectors (rain fed agriculture) as well as their lower financial, technical, and technological capacity and primitive farming techniques to adapt. In Africa, climate change is found to negatively affect all classes of food security in diverse ways. Climate change has prevalent, multi-faceted and temporal impacts on food security, implying that climate change negatively affects all four dimensions of food security (availability, accessibility, utilization, and stability). Therefore, climate change does not only affect food availability, but other dimensions are also highly susceptible.

Climate change affects food security through impacting on crop production and yield. Climate change affects crop production through direct impacts on the biophysical factors such as plant growth and the physical infrastructure associated with food processing and distribution.). Crop production has been negatively impacting by climate hazards and disasters; an average of 800,000 ha of crops are destroyed annually by climate-related effects, resulting in losses exceeding US$47million. Climate change affects all classes of livestock. Average, minimum, and maximum temprature and seasonal variations are crucial for livestock growth, regeneration, and survival. Very high temperatures, beyond 30°C, affect pasture quality, optimal animal physiology and regulate climate-related parasites and diseases. Climate change exacerbate disease in livestock. Among 65 animal diseases identified as most important to poor people, 58% are climate-sensitive. Changes in priority diseases such as trypanosomosis, which costs farmers in East Africa $2 billion a year; East Coast Fever, which kills one animal in Africa every 30 seconds due to climate change impact.

Climate change affects water availability and quality in Africa. Due to climate change, it is estimated that nearly 51% of the population in sub-Saharan countries lack access to a supply of safe water and 41 % lacks adequate sanitation. Two-thirds of rural Africans and a quarter of urban dwellers in Africa lack access to clean, safe drinking water. Climate change affects food security through impacting on fisheries production in diverse ways. Climate change influences fisheries through different pathways, including changes in water temperature, precipitation, salinity, river flow, nutrient levels, lake levels, storm frequency and intensity, and flooding.

Climate change affects indirectly food security through impacting on agricultural pests (weed, insect and disease pests). As the climate warms, it is expected that the range of agricultural pests (weed, insect and disease pest) get expand, as the ability of pest populations to survive the winter and attack the susceptible crops and causes a great yield loss. The other thing is about the severity of climate change extreme events/or drought induced food insecurity and malnutrition in Africa. In Africa, food insecurity and malnutrition became chronic induced by repeatedly occurring drought. Due to climate change extreme event/or drought drive food crises/hunger many Africans were badly affected For instance, more than 100 million people were affected by drought driven hunger in Africa (Anne Bourke, 2011). So, Africa especially, Sub-Saharan Africa is marked as the most food insecure region in the world, and has the highest proportion of food insecure people, with an estimated regional average of 26.8% of the population undernourished and this rates could be over 50%, and the risk of hunger will increase by 10-20% in 2050. Similarly, in Africa, due to climate change impacts, the number of malnourished children is projected to be increased in 2030 and 2050 from the baseline (33 million) to 42 million and 52 million respectively. Therefore, in order to reduce negative impacts of climate change on food security, African governments should strive to implement the following future line works.

- Increasing resilience of food security in the face of climate change calls for multiple interventions, from social protection to agricultural practices and risk management.
- Set up the National Adaptation Plan process under the UNFCCC provides the opportunity to integrate food security and nutrition as a key objective
- Promoting technological strategies (investment in research and development of stress tolerant and widely adapted crop varieties, water management in agriculture with water storage and improve access to irrigation water and natural resource management options).
- Policy options (finance, weather index insurance, strategic food reserves, etc.)
- Capacity building (institutional plus physical infrastructure including water storage, irrigation systems, food storage, processing, forecasting and disaster preparedness).
- Improve clean and safe drinking water availability through climate change impacts reduction options
- Coordination and mainstreaming of climate change into agricultural extension
- Promote implementation of climate-smart and conservation agriculture
- Income diversification within and outside of agriculture (improving income of the farmers)
- Implementing climate change impact reduction strategies on fisheries production
- Research should be conducted on negative impacts of climate change
- Tentative short term training have to be given for farmers and extension workers on negative climate change impacts and how to implement coping mechanisms and adaptation strategies
- Modernizing African agriculture through the use of improved management practices and technologies
- Drought tolerant and fast maturing food crops should be developed by research and popularize them
- Promote implementation of irrigation fed agriculture rather than rain fed agriculture
- Improving public awareness and understanding about current climate change situations and its potential negative impacts
- Climate change and disaster risk management
- Promote agricultural pest (weed, insect and disease pest) management strategy options
- Selection and breeding of livestock to adapt to climate change impacts and improve livestock grazing management systems
- Promoting use of adaptation strategies and coping mechanisms in agricultural production systems
- Promoting diversification and inter cropping of crops
- Environmental conservation

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Acronyms used in the document

CFP	Ciguatera Fish Poisoning
CSA	Central Statistics Authority
EAC	East African Community
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
I FPRI	International al Food Policy R research Institute
IPCC	Intergovernmental panel on Climate Change
LDCs	Least Developed Countries
MWE	Ministry of water and Environment
MAAIF	Ministry of agriculture Animal husbandry and Fisheries
NEMA	National Environment Management Authority
UBOS	Uganda Bureau of Statistics
UN	United Nation
UNDP	United Nation Development Program
UNEP	United Nations Environment Programme
UNECA	United Nations economic commission for Africa
UNFCCC	United Nations Framework Convention on Climate Change
WFP	World Food Programme
WWF	World Wide Fund for Nature