OPEN ACCESS Freely available online

Agrotechnology

Review Article

# Climate Change and its Adaptation Option on Agriculture in Ethiopia: A Review

**Abebe Misganaw[1*], Nega Kesete[2], Haimanot Eskezia[1]**

*[1]Department of Plant science, Mekdela Amba University, Tuluawulia, Ethiopia; [2]Department of Natural Resource Management, Mekdela Amba University, Tuluawulia, Ethiopia*

## ABSTRACT

Major contributing factors include increasing atmospheric carbon dioxide, rising temperature and modified frequency of extreme events, possibly leading to more drought and floods. These changes in turn alter the availability of water resources, productivity of grazing lands and livestock, and the distribution of agricultural pests and diseases. Environmental changes, such as changes in rainfall variability, drought, warmer or cooler temperature (lead to change in growing seasons) and land cover change have increased concerns about achieving food security. Africa has been identified as one of the parts of the world most vulnerable to the impacts of climate change. The change in temperature has affected the health, livelihoods, food productivity, water availability, and overall security of the African people. Majority of the Ethiopian economy depends on agriculture which is the most vulnerable economic sector to the impacts of climate change. This seminar paper show reviews the impact of climate change and adaptation strategies on crop production in Ethiopia. Adaptation strategies such as technology development, technology adoption, governmental program and insurance and adjusting farm practice and mitigation strategies such as afforestation/reforestation; agroforestry; soil and water conservation and land rehabilitation; and reducing rate of desertification reducing the impact of climate changes on the world.

**Keywords:** Adaptation strategy; Agriculture; Climate change; Crop production

## INTRODUCTION

Climate change refers to a period where a country or region goes through changing weather or temperature patterns than what is accustomed. It is expected to increase future temperatures, potentially resulting in reduced crop production in many key production regions Tack *et al.*, [1] while demand on food already insecure [2]. Africa is widely held to be highly vulnerable to future climate change [3]. In Ethiopia, the distribution of rainfall varies over the diverse agro-ecological zones that exist in the country . The changing climate is one of the biggest threats to agriculture during the years ahead Kajla *et al.*, [4]; which is also a global environmental threat to all economic sectors, particularly the agricultural sector [5]. In addition, it is representing a significant challenge for delivering grain of consistent quality in the future due to the complex interactions of atmospheric $CO_2$, changing temperature and rainfall patterns on yield and quality [6]. The expected changes in the climate could strongly affect the wheat production worldwide [4]. Trends showed that there are significant increases in water availability with potential benefits for irrigation, as well as increases in variability and flooding Taye *et al.*, [7], Nawaz *et al.*, [8], Kim *et al.*, [9], Kim and Kaluarachchi [10]. Downscaled precipitation and temperature reveal a systematic increase in all future times for both A2 and B2 scenarios. These increases in climate variables are expected to increase mean annual stream flow by 7.1, 9.7, and 10.1 % for A2 scenario and by 6.8, 7.9, and 6.4 % for B2 scenario for 2020s, 2050s, and 2080s, respectively [11]. According to Robinson *et al.*, [12], there will be a potential effect on water flows, crops, infrastructure, and economic output, that, in the absence of adaptation investments; Ethiopia's GDP in 2050 would be up to 10 percent below the counterfactual no climate change baseline. Admassu *et al.*,[13] shows a projected climate effects on key crops in Ethiopia between 2000 and 2050 that yield gains of over 25 percent in much of the eastern highlands and north-central highlands, but large yield reductions and loss of areas suitable for growing maize in the eastern and southwestern parts of central Ethiopia.

Generally, the changing climate imposes an impact in different sectors over the glob since climate change is a cross cutting issues and not bounded by the political boundaries of the different countries. The objective of this review paper is review the Impact of climate change on crop production and their management options.

## REVIEW OF LITERATURE

### Causes of climate change

Driver of climate changes are internal variability within the climate system and external factors. The external causes may be natural or human induced human activity. Human activities because climate change mainly resulted from fossil fuel burning and removal of forests. These contribute to the change by causing changes in Earth's atmosphere in the amounts of greenhouse gases, aerosols (small particles), and cloudiness [14]. At global scale, the main cause of greenhouse gas emissions are from carbon dioxide (70%), primarily from burning of fossil fuel (petroleum) imported from industrialized countries, while the other sources of GHG are methane and nitrous oxide caused by deforestation and agricultural activities, particularly

the use of pesticides [14]. The assessment report by the I PCC (2007, 2013) states with 95% confidence that human influence is the main cause of the observed warming in the atmosphere and oceans and other indicators of climate change and that continued emissions of greenhouse gases will cause further warming and changes in the components of the climate system. The emissions of greenhouse gases are predominantly from high-income countries, while the negative effects of climate change are predominantly in low income countries. This means climate change is generally expected to hit developing countries harder than industrialized countries, since they are less capable of mitigating or adapting to the changes due to their poverty and high dependence on the environment for subsistence [15].

## Impact of climate change on agricultural sector

Climate change influences are more severely felt by poor people who rely heavily on the natural resource base for their livelihoods [14]. Ethiopia is highly affected by climate change due to three main reasons; (i) about 80% of the population is largely depend on rain fed agriculture (ii) low income country (iii) varied geographical locations with different magnitude of climate impacts [16]. Climate change induced El-Nino increase the average temperature and affect rainfall pattern in time and space leading to a recurrent drought which results in food insecurity particularly in dry and semi dry areas of the country [17].

Climate change and its variability are emerging as major challenges to agricultural development with the increasingly irregular and erratic nature of weather conditions placing an additional burden on food security and rural livelihoods [18]. Climate variability has a direct and, in most cases, adverse influence on quality and quantity of agricultural crop production. The climate of an area is highly correlated to the crops cultivated and thus predictability of climate is imperative for planning of farm operations [19]. Global warming refers to observed increase in temperatures over the last 50 years because of increased greenhouse concentrations in the atmosphere [20,21]. Now days the concerns of climate impact on agriculture have been increasing [18]. Agriculture is highly dependent on natural resource such as soil, water and climatic conditions, extreme weather events and climatic conditions have major impacts. Climate change affects crop production through direct impacts on the biophysical growth of crops. Among the various environmental changes brought about by the climate change that limit crop yields, heat and water stresses are considered the most important [22]. Climate change affects agriculture and food production in complex ways of which food production directly through changes in agro-ecological conditions (e.g. changes in rainfall leading to drought or flooding, or warmer or cooler temperatures leading to changes in the length of growing season), and indirectly by affecting growth and distribution of incomes, and thus demand for agricultural products [23]. Climate change is projected to overall decrease in the yields of cereal crop in Africa through shortening growing season length, amplifying water stress and increasing incidence of diseases, which poses huge challenges to the global economy and to social development [24]. Its impacts will disproportionately affect sub-Saharan African countries such as Ethiopia because their economies are highly dependent on climate sensitive activities such as rain agriculture [25]. In Ethiopia, agriculture contributes about 47% of the country's Gross Domestic Product (GDP) and more than 70 million people (85% of the Ethiopian population) depend on agriculture directly or indirectly for their livelihoods [26]. According to Robert J. Hijmans and Temesgen Tadesse a marginal impact analysis of increasing temperature and precipitation across the four seasons (winter, spring, summer and fall) was also undertaken [25]. The results indicated that a unit increase in temperature during summer and winter would reduce net revenue per hectare by US$177.62 and 464.71 respectively,

## Impacts of climate change on crop production

Climate change affects crop production through direct impacts on the biophysical growth of crops. Among the various environmental changes brought about by the climate change that limit crop yields, heat and water stresses are considered the most important [22]. Climate change is projected to overall decrease in the yields of cereal crop in Africa through shortening growing season length, amplifying water stress and increasing incidence of diseases, pests and weeds outbreaks [26]. Among cereal crops, sorghum is cultivated majorly as a rain fed crop; its productivity is significantly influenced by climatic elements [27]. Grain sorghum yield is extremely influenced by crop management practices, growing–season rainfall amount and its distribution, soil water content at planting, plant-available water and other climatic conditions [28]. Global potential of potato yield decreases by 18% to 32 %( without adaptation) and by 9% to 18 %( with adaptation). At high latitudes, global warming will likely lead to changes in the time of planting, the use of later-maturing cultivars, and a shift of the location of potato production. According to Knox *et al.,* [2], climate changes in Africa on production of maize, millet and sorghum yields decline significantly 5%, 9.6% and 14.5%. Temperature rising from optimum range for sorghum production results significantly reduces the sorghum productivity [29]. Tongcheng *et al.,* reported climate change is significantly influence on sorghum productions [30]. Both drought and flooding increase the stress on social institutions, and increase the vulnerability of households, particularly those living close to the poverty line, through loss of assets, impaired health, potential conflicts and animal disease with potential risk for humans. In general, the following process shows how the effect of climate change is channeled to food accessibility which could in turn lead to food in security [31]. Climate change →Low production and productivity → High food prices →Failure to access food→ Malnutrition, Poverty and Disease Starvation in such a way it makes a viscus circles in the living systems of a human being [31].

## Direct impacts of climate change on agriculture

**Changes in mean climate:** Changes in the mean climate away from current states may require adjustments to current practices in order to maintain productivity, and in some cases the optimum type of farming may change. Higher growing season temperatures can significantly impact agricultural productivity, farm incomes and food security [32]. In mid and high latitudes, the suitability and productivity of crops are projected to increase and extend northwards; especially for cereals and cool season seed crops [33-35]. Water is vital to plant growth, so varying precipitation patterns have a significant impact on agriculture. As over 80 per cent of total agriculture is rain-fed, projections of future precipitation change often influence the magnitude and direction of climate impacts on crop production [36].

**Climate variability and extreme weather events**: While change in long-term mean climate will have significance for global food production and may require ongoing adaptation, greater risks to food security may be posed by changes in year-to-year variability and extreme weather events. Historically, many of the largest falls in crop productivity have been attributed to anomalously low precipitation events [37]. However, even small changes in mean annual rainfall can impact on productivity. As current farming systems are highly adapted to local climate, growing suitable crops and varieties, the definition of what constitutes extreme weather depends on geographical location. In many regions, farming may adapt to

increases in extreme temperature events by moving to practices already used in warmer climate, for example by growing more tolerant crops. However, in regions farming exists at the edge of key thresholds increases in extreme temperatures or drought may move the local climate into a state outside historical human experience.

**Extreme temperatures:** Changes in short-term temperature extremes can be critical, especially if they coincide with key stages of development. Only a few days of extreme temperature (greater than 320c) at the flowering stage of many crops can drastically reduce yield. Crop responses to changes in growing conditions can be nonlinear, exhibit threshold responses and are subject to combinations of stress factors that affect their growth development and eventual yield. In the short-term high temperatures can affect enzyme reactions and gene expression. In the long-term these will impact on carbon assimilation and thus growth rates and eventual yield. The rate of photosynthesis and respiration increases with an increase in temperature until a maximum value of photosynthesis is reached. Higher temperature accelerates the evapotranspiration process that creating moisture stress, and shorten the growth period duration of wheat crop, and this becomes more severe regarding yield losses.

**Drought:** There are a number of definitions of drought, which generally reflect different perspectives [38]. It is common to distinguish between meteorological drought (broadly defined by low precipitation), agricultural drought (deficiency in soil moisture, increased plant water stress), hydrological drought (reduced stream flow) and socio-economic drought (balance of supply and demand of water to society [38].The crop water use or evapotranspiration (ET) depends on crop characteristics such as crop ground cover and stomata conductance, and it also depends mostly on atmospheric properties, particularly net radiation and vapor pressure deficit, and air humidity [39].

**Heavy rainfall and flooding:** Crop production can also be impacted by too much water since 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. Indirect impacts include delayed farming operation [40]. The change in rainfall can affect soil erosion rates and soil moisture, both of which are important for crop yields [41]. Thus, increase in temperature along with reduced precipitation will likely result in the loss of arable land in the region due to decreased soil moisture, increased aridity, increased salinity and groundwater depletion [42].The change in rainfall can affect soil erosion rates and soil moisture, both of which are important for crop yields [41].

## Indirect impacts of climate change on agricultural productivity

Pests and diseases: Rising atmospheric $CO_2$ and climate change may also impact indirectly on crops through effects on pests and disease. However, the increasing atmospheric $CO_2$ level does not only contribute to increased crop yields, but is also a major cause of the greenhouse effect. These interactions are complex and as yet the full implications in terms of crop yield are uncertain. Indications suggest that pests, such as aphids Newman [43] and weevil larvae Staley and Johnson [44], respond positively to elevate $CO_2$. Evidence suggests that in Sub Saharan Africa migration patterns of locusts may be influenced by rainfall patterns and thus potential exists for climate change to shape the impacts of this devastating pest. Pathogens and disease may also be affected by a changing climate. This may be through impacts of warming or drought on the resistance of crops to specific diseases and through the increased pathogen city of organisms by mutation induced by environmental stress [45]. Over the next 10-20 years, disease affecting oilseed rape could increase in severity within its existing range as well as spread to more northern regions where at present it is not observed [46]. Changes in climate variability may also be significant, affecting the predictability and amplitude of outbreaks [40].

Mean sea-level rise: Sea-level rise is an inevitable consequence of a warming climate owing to a combination of thermal expansion of the existing mass of ocean water and addition of extra water owing to the melting of land ice [47]. This can be expected to eventually cause inundation of coastal land, especially where the capacity for introduction or modification of sea defenses is relatively low or non-existent. Regarding crop productivity, vulnerability is clearly greatest where large sea-level rise occurs in conjunction with low-lying coastal agriculture. Many major river deltas provide important agricultural land owing to the fertility of fluvial soils, and many small island states are also low-lying. Increases in mean sea level threaten to inundate agricultural lands and salinize groundwater in the coming decades to centuries, although the largest impacts may not be seen for many centuries owing to the time required to melt large ice sheets and for warming to penetrate into the deep ocean [40].

## Yield response in a changing climate

In SSA, climate models predict increased evapo-transpiration and lower soil moisture levels. This would result in drought, some agricultural lands becoming unsuitable for cropping, and some tropical grassland becoming increasingly arid. Lobell *et al.*,[48] exploited historical data from over 20,000 field trials of maize conducted in Africa over the past decade and, they found out that each 'degree day' that the crop spends above 30°C (a unit that reflects both the amount and duration of heat experienced by the plant) depresses yields by 1 percent if the plants are receiving sufficient water. They also revealed that water availability has an important effect on the crops sensitivity; with yields decreasing by 1.7 percent for each degree day spent over 30°C under drought conditions. Thus they indicated that under non-drought conditions 65 percent of the land area in Africa that is under maize cultivation at present would experience yield losses from a uniform 1°C warming. Under drought conditions, 100 percent of the present cultivated area would experience yield losses, with 75 percent of this area suffering yield losses of at least 20 percent. Temperature rise will also expand the range of many agricultural pests and diseases by increasing the ability of pest populations to survive and attack crops thereby causing yield reduction. The climate change will exacerbate drought and land degradation, with estimations of 5 to 8 percent increase (60 to 90 million ha) of arid and semiarid land in Africa [41]. This means that about two-thirds of arable land in Africa is expected to be lost by 2025, land degradation currently leads to the loss of an average of more than 3 percent annually of agriculture GDP in SSA [49].

### Vulnerable groups to climate change in Ethiopia

According to Assefa *et al.*, small- scale, rain fed, subsistence farmers and pastoralists are the most vulnerable groups to climate changes in Ethiopia. They also indicated that climate change impacted regions differently. Regions with arid, semi-arid, and dry sub humid low lands are more vulnerable but low lands have been found less vulnerable to climate change. Diversification of livelihoods, migration, nonfarm activities, and sales of assets, settlement and resettlement activities, and the adoption of improved water management system are few measures that have been taken by households to the impact of climate change. Similarly, Mahmud *et al.*, have studied the different impact of climate change adaptation on food production [50]. Farm households who have adapted to climate change have better food production level than farm households that did otherwise. According to them significant share

of farmers perceived the mean temperature of Ethiopia has increased over the past 20 years. Thus farmers has taken a number of adaptation measures including changing crop varieties, adapting soil and water conservation measures, harvesting water and planning trees and changing planting and harvesting periods. Access to information to future change in climate change, access to agricultural extension and credit services are determinants that made difference on farmers to take adaptation measures [50].

## Adaptation strategies to climate change in Ethiopia

Negative influences of climatic change over sorghum growing areas can be minimized by adapting one or a combination of management practices like adjusting sowing time and application of extra irrigation. Pramod *et al.*, used various adaptation strategies such as change in sowing dates, applying additional irrigation and fertilizer to minimize the yield reduction in wheat [51]. Adem *et al.*, also indicated that supplemental irrigation, sowing date and cultivars showed significant yield increment on chickpea in north Eastern Amhara [52]. Zelalem *et al.*, reported that different sorghum genotypes differed in response to drought stress [53]. Sultan *et al.*, also reported that photoperiod-sensitive traditional cultivars of millet and sorghum that have been used by local farmers for centuries may be more resilient to future climate conditions than modern cultivars bred for their high yield potential [54]. Cunha *et al.*, reported that irrigation is an adaptive strategy to climate change as it supplies water to plants, preventing them to be subjected to water stress [55]. The International Centre for Maize and Wheat Improvement (CIMMYT) has initiated important projects to develop and distribute maize varieties that are able to yield more than the currently available cultivars under conditions of limiting moisture, low fertility and disease or pest pressure while bearing no yield penalty under optimal conditions [56]. Rainwater Harvesting (RWH) is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions. Rainwater harvesting is one of the adaptation strategies on climate change [57].The role of agroforestry in sequestering carbon and contributing to climate change mitigation is well documented 33]. The climate risks identified by EPACC are broadly in the areas of human, animal and crop diseases, land degradation, loss of biodiversity, decline in agricultural production, dwindling water supply, social inequality, urban waste accumulation, and displacement due to environmental stress and insecurity. The program also identifies adaptation strategies and options in the various socioeconomic sectors including cloud seeding, crop and livestock insurance mechanisms, grain storage, societal reorganization, renewable energy, gender equality, factoring disability, climate change adaptation education, capacity building, research and development, and enhancing institutional capacity and the political momentum [58].

Drought mitigation through plant breeding: Drought has always been a great limiting factor to agricultural development in sub-Saharan Africa, particularly in East Africa. The International Centre for Maize and Wheat Improvement (CIMMYT) has initiated important projects to develop and distribute maize varieties that are able to yield more than the currently available cultivars under conditions of limiting moisture, low fertility and disease or pest pressure while bearing no yield penalty under optimal conditions [56].

The role of rain water harvesting: Land degradation has a magnifying effect on climate extremes. In many areas of Africa, crops use a very small proportion of rainwater, the remaining being lost through runoff and deep percolation [57].

Therefore, since climate change is likely to result in reduced or erratic rainfall over large areas of East Africa, techniques that can improve rainwater infiltration or its storage for immediate or future use by crops or livestock are increasingly needed.

**The role of agroforestry:** The role of agroforestry in sequestering carbon and contributing to climate change mitigation is well-documented [33]. What is less understood is its potential for mitigating the negative effects of climate variability and climate change. Agroforestry provides a rich set of promising technologies that can (biophysically and economically) buffer against current climate variability and food or income risks. Trees on farm - Microclimate played reducing heat stress; buffer against crop failure; fencing for allowing off-season farming; micro climate effect; erosion control as well as rotational woodlot -Soil fertility; erosion control and better water infiltration. Domestication of indigenous Economic buffer through production of high value tree products are the major agroforestry contribution in climate change adaptation (fruits, wood, honey, resins, medicine, etc) [40].

## Climate change mitigation measures

There is much concern that the increasing concentration of greenhouse gases in general, and carbon dioxide in particular contributes to global warming by trapping long-wave radiation reflected from the earth's surface. Over the past 150 years, the amount of carbon in the atmosphere has increased by 30%. Most scientists believe there is a direct relationship between increased levels of carbon dioxide in the atmosphere and rising global [59]. One proposed method to reduce atmospheric carbon dioxide is to increase the global storage of carbon in soils. However, soil carbon storage is a win–win strategy. It mitigates climate change by offsetting anthropogenic emissions; improves the environment, especially the quality of natural waters; enhances soil quality; improves agronomic productivity; and advances food security [60]. Soils store 1502 Gt carbon, an amount that is two times greater than the amount found in the atmospheric carbon pool [61]. In addition to carbon storage, the turnover time of organic carbon is important in understanding the role of soils in the global carbon cycle. Thus, soil carbon sequestration through changes in land use and management is one of the important strategies to mitigate the global greenhouse effect. Important land uses and practices with the potential to sequester soil organic carbon include conversion of cropland to pastoral and forestlands, conventional tillage to conservation tillage or no-tillage, and no manure use to regular addition of manure. However, food security needs for the world teeming population make conversion of cropland to forestland unsustainable. Therefore, increased food demands call for management of croplands to ensure food security and at the same time enhanced soil organic carbon sink within the soil to minimized atmospheric emission of $CO_2$.In this case, afforestation and conservation programs have been made in the last three decades [62]. In addition to this, there was a huge areal closure activity in the northern parts of the country for rehabilitating degraded lands, which have their own role in increasing soil carbon stock. The second mechanisms for reducing the emission of greenhouse gases are using lower emitting energy sources. A pilot project to distribute energy-efficient cook stoves was identified as a voluntary offset project that would reduce greenhouse gas emissions, household pollution, and deforestation in the Metekel Zone in the Benishangul-Gumz Regional State in Ethiopia. Voluntary Emission Reduction (VER) projects present companies, governments and organizations with an opportunity to purchase carbon credits. The developers of this project, Carbon Positive Trading (CPT) and The Learning Paper, believed that energy-efficient stoves were an ideal

way of meeting the criteria for a voluntary carbon offset project in Ethiopia [63]. Similar to this area, energy saving stoves was also introduced in different parts of the country before a decade ago. The other mechanism to mitigate climate change worldwide is carbon trading. The current carbon trading is one of the critical practices in the country to mitigate climate change. The Humbo natural regeneration (reforestation) project proposed by World Vision has already been endorsed by Ethiopia's in December 2006 is one example for carbon trading in the country [63].

## CONCLUSION

Climate change affects agriculture and hence food security directly through changing agro-ecological conditions and indirectly by affecting growth and distribution of incomes. Environmental changes, such as changes in water availability and land cover, altered nitrogen availability and nutrient cycling, has increased concerns about achieving food security. These problems are further intensified by climate change. Climate change is one more challenge to reducing poverty, hunger, disease and environmental degradation. Human influence is the main cause of the observed warming in the atmosphere and oceans and other indicators of climate change and that continued emissions of greenhouse gases would cause further warming and changes in the components of the climate system.

Agriculture is highly dependent on natural resource such as soil, water and climatic conditions which extreme weather events and climatic conditions have major impacts. Climate change affects crop production through direct impacts on the biophysical growth of crops through limiting crop yields, heat and water stresses. It affects agriculture and food production in complex ways of which food production directly through changes in agro ecological conditions (e.g. changes in rainfall leading to drought or flooding, or warmer or cooler temperatures leading to changes in the length of growing season), and indirectly by affecting growth and distribution of incomes, and thus demand for agricultural products.

Ethiopia is highly affected by climate change due to three main reasons; (i) about 80% of the population is largely depend on rain fed agriculture (ii) low income country (iii) varied geographical locations with different magnitude of climate impacts. With increasing extremes in rainfall patterns and rising temperatures, there is an impact imposed on the crop production and yields.

## ETHICAL CONSIDERATION

The authors declare that they have no conflict of interest. The review articles also no directly related to human beings. This review articles cannot funded by in any organization. All citation used are acknowledge so the review articles no conflict of interest in all aspects.