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Review Article

Analyzing Impacts of Climate Variability and Changes in Ethiopia: A Review

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Abstract: Climate change is a global problem of this century but its impact is higher in low-income countries like Ethiopia, which has limited capacity to cope with the effects because the country's economy is based on agriculture that directly affected by the impact of climate change. Subsequently, Ethiopia has been facing severe droughts at least twice per decade and several sever flood hazards. Most of the studies confirmed that the country's annual temperature is increasing with about 0.37˚C whereas the rainfall has no clear trend and there is high variability with the rising frequency of floods and droughts. The climate changes projection indicated increasing in temperature by 2.2°C and 3.3°C in 2050 and 2090 respectively, but the rainfall trend is uncertain. The drought between 1900 and 2010 killed over 400,000 and exposed 54 million people for starvation and in 2004, 2005, 2008, 2016, and 2017; about 8, 6.3, 11.6, 18, and 8.5 million people respectively, need food aid. The flood in 2006 damaged crops on 1907 hectares and declined productivity by 20%; whereas about 15,600 livestock died and 199,902 people need humanitarian support. The heavy floods resulted in a loss of 1.5 billion tone topsoil which estimated to US$ 106 million. By 2050 climate change will reduce the Ethiopian GDP by 8-10% and 2.4 million people become food unsecured. To mitigate and adapt the impact of climate change the government has implemented the Climate-Resilient Green Economy Strategy since 2011 under which different development activities such as SWC, afforestation, and agroforestry practices, and fodder banks establishment in different localities. The country also implementing different international agreements as tool to fight climate change. Studies have shown that there are hazards of climate change therefore; the government should implement climate-smart practices in all sectors, access to relief funds, and precise early warning systems.

Keywords: Climate Change, Drought, Ethiopian, Extreme, Impact, Hazard, Variability

1. Introduction

1.1. Background

The world's climate has already changed and will continue to change dramatically, and the change is manifested in the recurrent drought, floods, and famine that have threatened millions of people and livestock in recent decades [58]. The average global surface temperature is predicted to increase by 2.8°C during this century [37]. Such global warming would alter the natural climate and environmental systems, leading to increased frequency of extreme weather events such as droughts, storms, flooding, rising sea levels, reversal of ocean currents and changes in precipitation patterns [89]. This induced significant social, economic, and environmental impacts in the form of forced migration, conflict, crop failure, and environmental degradation. Now it is considered a global event with growth, poverty, food security, and stability implications [58]. The global climate change and the associated weather extremes continued posing a considerable challenge in the world mainly in developing countries. However, developed countries have not resisted its devastating effects, and they are not committing their pledges to reduce Greenhouse gas (GHG) emission [37].

Ethiopia had been known for its diversified climate in different sizes and diversity of major agro-ecological zones which is suitable for the support of different plant and animal species [30]. However, nowadays the country is most

vulnerable to climate variability due to its dependency on smallholders and subsistent farmers who completely based on rain-fed agriculture that affected by climate variability. Studies argue that climate change will be a major challenge to the country's efforts towards achieving food security and sustainably exit from poverty. The agriculture sector which contributes more than 45% of GDP, 80% to the labor force, and 85% to foreign exchange earnings is highly susceptible to climate change [47]. For instance, the flood of 2006 affected 719 human lives, displaced about 242,000 people, severely damaged infrastructures and houses, and caused property loss worth more than a million USD and the droughts occurred from 2004 - 2017 has been affected about 53.1 million people in the country [10, 39].

In Ethiopia, agriculture and energy are the dominant sectors that emit most of the GHGs, approximately 85% and 15% respectively [15]. However, Ethiopia's contribution to the global GHG emission is negligible due to its lower economic activity. But, climate change affects the production and productivity of the agricultural sector by decreasing soil fertility, increasing pests and crop diseases, and aggravating lack of access to inputs and improved seeds and frequent drought and floods. Above all, low irrigation scheme, poverty, high population pressure, lack of institutional capacity make the country critically affected by climatic variability [11, 44]. As [67] mentioned drought is the single most destructive climate-related natural hazard in Ethiopia.

Hydrologically, Ethiopia is classified into three main seasons; such as “Bega” from October to January, “Belg” from February to May, and “Meher” from June to September. “Meher” is the main rainy season when most of the agricultural activities are carried out whereas the “Bega” is the dry season when harvesting is conducted and “Belg” is a short rainy season especially in the southern and southwestern part of the country that has been used for the production of early maturing crop and for the regeneration of grasses and water bodies for domestic and wild animals. Local peoples believe that when there is good rain during “Belg” season; it is an indicator of a good year for agricultural production. However, due to climate variability and changes, the rain during the “Belg” season has been unpredictable and completely terminated from in many parts of the country [64].

According to the study by the Ethiopian Panel on Climate Change [26], over the past 50 years, there has been a warming trend in the annual temperature of the country. The minimum temperature is increased by approximately 0.4°C per every ten years and it is projected that the mean annual temperature will increase with the range of 0.9 to1.1°C by 2030. Hence, it has a devastating effect on humans and environmental functions. For instance, the impact of climate change affected the endemic species of the country. For instance in Bale Mountains National Park, the change in climate condition has made a suitable environment for domestic dogs to encroach in the habitats of Ethiopian Wolf and the domestic dogs have been transmitting rabies to the endemic Ethiopian Wolf. Furthermore, the domestic dogs also breed with the wolves and resulted in the loss of species endemism; this discouraged the tourist that visits the area to enjoy the unique beauty of the Ethiopian Wolf [26].

Ethiopia is categorized under the countries most vulnerable to climate variability and change and it is frequently facing climate-related hazards, commonly drought and floods [16]. Since the early 1980s; the country has suffered seven major droughts and many severe floods occurred in different parts of the country [78]. To reverse the impacts of climate variability and change the country have been working on climate change mitigation and adaptation measures. The measures include the use of different early maturing crop varieties, implementation of forestry and agroforestry practices, soil and water conservation, early and late planting, expansion of irrigation schemes, drought-tolerant animal species and changing livestock husbandry styles and implementation of international conventions [65]. However, the ability of smallholder farmers in developing countries to cope with the effects of climate change is impacted by limited capacity, few alternative sources of income, lack of expertise, and lack of appropriate public policies and financing [19]. Thus, the purpose of this paper is to analyze the effects of climate change in Ethiopia and make available to the users and researchers.

1.2. Trends of Climate Change in Ethiopia

Ethiopia's climate is typically tropical in the south−eastern and north−eastern lowland regions, but much cooler in the highland regions of the country. The mean annual temperatures had been around 15-20°C in high altitude regions, whilst 25-30°C in the lowlands. Though, recently the temperature is increasing dramatically throughout the country hence the national average temperature is increased by 1°C since the 1960s [28]. Moreover, the number of hot days and nights in a year is increasing over time. But, the trend of observed mean annual rainfall didn’t indicate any clear trends [77]. The country's long-term climate-related to changes in precipitation patterns, rainfall variability, and the temperature has increased the frequency of droughts and floods [79, 71]. According to [20, 6], at the national level, the average precipitation rate was 2.04 mm per day in 1961-1990 but it will decrease to 1.97 mm per day in 2070-2099. As [49] mentioned, rainfall variability greater than 30% is risky for farmers who depend on crop production.

Studies showed that Ethiopia's contribution to global GHG emissions is insignificant and it was estimated to release about 150 Mt CO_2 equivalents (CO_2e) in 2010 and will increase to 400 Mt CO2e in 2030 under climate change scenario [15]. However, the contribution is less than 0.3% of the global emissions [9] from which per capita emissions is less than 2 tons CO_2e are modest compared with the more than 10 tons per capita on average in the European Union and more than 20 tons per capita in USA and Australia [83]. Nevertheless, the country is characterized by seasonal and inter-annual variability in rainfall and the annual rainfall variability in many parts of the country remains above 30% [57]. The parts of the country that experience higher variability are also characterized by a higher probability of crop failures. Areas

where previously know with Belg season rain suffers from greater rainfall variability and unpredictable.

The analysis of long-term gridded rainfall data shows no significant change in simulated to mean annual rainfall over the country. However, there is a tendency that the rainfall per day is increasing in the western part of the country while it remains unchanged in most parts of central Ethiopia [26]. On the other hand, there is a significant trend in mean annual surface air temperature; that it increased by 0.6 to 0.8°C during the 1975 - 2005 [39]. According to [73] the mean annual temperature rose by 1.3°C or by 0.28°C per decade during 1960-2006. The frequency of cold nights (linked to frost in dry season) has decreased much in all seasons but the frequencies of hot days and nights have shown an increasing trend during these years. While the average number of 'cold days' has decreased by 5.8% between1960-2003, the average number of cold's nights per year has decreased by 11.2% [6] According to the study by [41, 16] an approximate annual increase of 3˚C in Wenago Wereda over the past 100 years, an increase of about 0.6˚C every 20 years whereas rainfall has decreased by 6 mm annually since the turn of the century. Besides, evapotranspiration indicated a possible increase of about 4.3 mm/day.

According to [2], the trend in rainfall of the country indicated that declining trend from February to April of short rains from 1981-2000, and slight increases in June to August long rains, as well as in October and November over the same period. The projected temperature continues increasing, though the extent depends on emissions scenarios and varies between models. A review of 18 different models and emissions forecasts predicted warming of 1.2°C by the 2020s in all seasons in all parts of the country from 1961-2000 mean temperatures. It is also predicted that temperatures could increase by between 1.5°C and 5.1°C by 2090 (from 1970-1999 mean) but there is less confidence in rainfall projections and less convergence between models [79]. A slight increase in average annual rainfall is projected nationally, but with seasonal and regional differences. The models broadly agree that more rain will fall in 'heavy events' in increased volumes over shorter periods. A further complication in projecting climate impact in Ethiopia is due to exposure to drought and floods which is heavily influenced by the El Niño/La Niña and the impacts of climate change on these phenomena are not yet clear [2].

The [78] estimation showed that in the coming 100 years, the average temperature in Ethiopia has projected to increase from 23.08°C during 1961-1990 to 26.92°C in 2070-2099. The temperature variation magnitude varies across the country, where the Northcentral highlands of the country will be as cold as -0.5°C and the Southeast low lands will be as warms as 37°C. The strong inter-annual and inter-decadal variability in rainfall makes difficulty in detecting long-term trends in the country [65, 6, 5], temperature projections indicated that the mean annual temperature will rise in the range of 0.9 to 1.1°C by 2030; 1.7 to 2.1°C by 2050, and 2.7 to 3.4°C by 2080 as compared to 1961 to 1990 [2]. The increase in temperature in the country has been most rapid in July, August, and September at a rate of 0.32°C per decade. Besides, daily temperature observations have shown significant increasing trends in the frequency of hot days, and much larger increasing trends in the frequency of hot nights. The average number of 'hot' days per year in Ethiopia has increased by 73 and additionally 20% of days between 1960 and 2003. However, there is not a significant trend in mean rainfall between 1960 and 2006 [5].

The projections from different models are indicating increases in annual rainfall. These increases are largely a result of increasing rainfall in the 'short' rainfall season of October, November, and December (OND) in southern Ethiopia and this season is the ripening of crop and the increasing rain during the season might cause damage to the crops. The OND rainfall is projected to change by 10 to +70% as an average over Ethiopia. The Proportional increases in OND rainfall in the driest, easternmost parts of Ethiopia are large. The Projections of change in the rainy seasons April, May, June (AMJ), and July August and September (JAS) which affect the larger portions of Ethiopia are more mixed, but tend towards slight increases in the southwest and decreases in the northeast. The models indicated that there is a consistent increase in the proportion of total rainfall that falls in 'heavy' events that have devastation effect. The largest increases are seen in JAS and OND rainfall [5]. The extreme events increased the number of people looking for food aid by 30% and it will increase by 72% in the 2050s [28].

2. Impact of Climate Change

2.1. Impact on Public Health

Climate change is projected to increase threats to human health, particularly in lower-income populations, predominantly within tropical and subtropical countries. It can affect human health directly through death or injury by floods and storms and indirectly through changes in the ranges of disease vectors such as mosquitoes, water-borne pathogens, water quality, air quality, and food availability and quality [36]. As climate change progresses, it is expected that an increase in health related issues. Hence, it was predicted that certain effects of climate change contributed to about 250,000 deaths per year between 2030 and 2050 from conditions such as heat stress Malnutrition, diarrhea and malaria. The rising in temperature can cause or exacerbate a wide range of severe health problems such as heat stroke, heat exhaustion, muscle cramps, worsening of existing conditions, such as respiratory and heart conditions and death [74].

The substantial increment in an annual temperature is likely to change the ranges of vector-borne diseases [3]. For example, malaria is migrated to highland areas where it was previously not known. The increased in flood occurrence has facilitated the spread of waterborne diseases like diarrhea, cholera, and dysentery. Besides, it might also result in the aggravation of respiratory diseases caused by allergies and air pollution which intern is caused by climatic variability [67]. The study by [33] has confirmed that the increased in the frequency of

waterborne and food-borne infectious diseases in countries like Ethiopia was because of the inadequate supply of safe drinking water, low sanitation coverage and poor hygiene practices that might be caused due to water shortage induced by drought.

After the 2006 unusual flood in many areas has resulted in the outbreak of acute watery diarrhea in Gambela Region, West Arsi Zone, Addis Ababa, and Guji Zone [52]. Changes in climate are also likely to lengthen the transmission period of major vector-borne diseases and alter their geographic range [4]. It was projected that encroachment of malaria from lower altitudes in the Somalia and Afar regions to higher altitudes in the Tigray and the Amhara regions of the country [50]. According to [74], in Ethiopians, 68% of the population is living in areas at risk of malaria and the estimation also showed that 5-7% potential altitudinal increase in malaria distribution by the 2050s due to climate change [62]. This means that malaria-free highlands may experience modest changes to malarial conditions. Hence, if variability in climate continues, by 2080s malarial transmission in the highlands of the country will reach serious stage infestation [58].

In the Afar region, climate change has induced malaria that has resulted in the death of many people [4, 7]. Similarly, significant numbers of people were dead by Malaria in the southern region of South Omo. In both regions, the rate of flooding has increased and a large area has come under permanent flooding. This has triggered the infestation of bush and mosquitoes (malaria) [33]. Due to climate change, it Is observed that the spread of malaria to new localities in the country over the previous five years such as Libo and Fogera in Amhara, Tahtay Adiabo in Tigray, and Imey in Somali regional states were among the new localities covered in the spread of the disease [75]. Generally, pathogens that cause water-borne diseases are temperature-dependent. This means that rising water temperatures result in increased growth of bacteria in water leading to increased rates of diarrheal diseases [54].

Moreover, climate change-induced flood has resulted in the disruption of drinking water sources. This leads to pollution, which in turn, increases the risk of exposure to water-borne pathogens [55, 58] reported that the prevalence of diarrhea varies seasonally, an epidemic of cholera occurred following extreme floods in 2006, and led to widespread illness and loss of life [73]. Evidence indicated that the upper altitudinal limit for malaria transmission in Ethiopia was 2,000 meters above sea level, but in recent years malaria epidemics have occurred in areas with the highest altitudes ranges and respiratory ailments like asthma and bronchitis will increase as a result of climate change [80]. Based on the previous evidence [83] reported that climate change is expected to compound Ethiopia's health problems.

2.2. Impacts on Natural Resources

A decreased in annual rainfall results in lower soil moisture, which combined with high evapotranspiration, promotes desertification due to a reduction in vegetation cover. This leads to soil erosion and sediment discharge that may cause reservoir siltation. The main problem is that even if the total amount of precipitation for the year is sufficient, the distribution in many parts of Ethiopia may be uneven and unpredictable [15]. Extreme climatic conditions may also cause land degradation in the forms of soil erosion and the losses of organic matter and other nutrients, thereby reducing the carbon sequestration potential of the system [15]. A torrential rainfall as a result of climate change can cause soil erosion, crop damage, and waterlogging which makes the land difficult or impossible for agricultural purposes. Hence, it is estimated that Ethiopia loses more than 1.5 billion tons of top fertile soil each year through heavy rain and flooding due to variability in rainfall [83].

Biodiversity and biodiversity-based ecosystem services are intrinsically dependent on the climatic factors. During the twentieth century, climate change has posed major threats to biodiversity [22]. Globally, it is estimated that if the global average temperature increases by 1.5°C to 2.5°C, many species will not be able to survive in the warmer environment and prefer to migrate [37]. In Massachusetts, between 1970 and 2002, a 2°C increase in average temperatures was the main cause for 22 species extinctions [39]. Hence, at present rates of climate change about 20-30% of the world's plant and animal species will become extinct by the 2080s, and 25-40% of mammal species in sub-Saharan Africa will become endangered. [46] studied that the potential impact of climate change on plant diversity in the Cape Floristic Region in South Africa have shown that 11% of the species are at risk of extinction and a reduction of 42% of the species with the projected climate-change scenario. [68] revealed that climate change could result in the extinction of more than a million terrestrial species in the next 50 years.

In Ethiopia, the unique environments that support our already endangered species are becoming less hospitable because climate change is causing longer dry periods and shrinking of the available water resources [52] and it has posed potential major threats to biodiversity. Many forest tree species have shown hampered or poor regeneration due to human disturbances and climate change. For instance, dieback of *Juniperus procera* and *Olea europaea* subsp. cuspidata has occurred in Desa'a forest due to climate change [13]. Besides [85] reported that species with limited geographical ranges are, restricted to their habitat are more vulnerable to the impact of climate change, for example, Giant Lobelia, Walia Ibex, and Ethiopian Wolf are the best examples. Moreover, climate change has increased the spread and abundance of invasive alien species such as *Parthenium hysterophorus* and *Prosopis juliflora*, which are becoming threats to the biodiversity of the country [59, 15, 56, 82, 83] predicted that endangered and endemic species with restricted elevation ranges will suffer the risk of extinction due to extreme warming.

Climate change and a rise in the human population have put stress on almost all of our natural resources, making these resources increasingly scarce, and it commonly affected the global water resource and hydrological system [8]. The increased surface temperatures, melting of snow and glaciers, rise in sea level, and an increase in extreme weather events

such as droughts and floods significantly affected water resources [52]. Global warming has increased the evaporation of water into the atmosphere and changes the patterns of major airstreams and ocean currents such as El Niño and La Niña. This in turn alters the distribution of precipitation and some regions experience greater rainfall and flooding while others become more prone to droughts [52]. More frequent and longer periods of drought reduce the amount of run-off into rivers, streams, and lakes accordingly groundwater table gradually drops so that there is less groundwater to supply for springs and shallow wells. Hence, rural people in Ethiopia are complaining about the problem of obtaining water from shallow wells. Currently well have no water even at 100 m depth where previously found at 20 m. This created that women and children traveled for up to six hours to collect water from unprotected water sources such as ponds and, children are forced to drop out of school to collect water [52].

Gilgel Abay river and Lake Tana are important water bodies for various socio-economic and ecological services. However, due to climate change and variability, the water level from those sources fluctuates from year to year and unable to deliver the intended services [23]. Studies suggested that climate change has already created costs in Ethiopia and the recently exemplary is the drying up of water sources such as Lake Haramaya, decreasing the water volume of lakes, rivers, and dams which leads to serious seasonal electric power interruptions. This is mainly caused due to increased drought period and frequency, and some unprecedented heavy rains leading to over-flooding in the lower basins [2]. In addition, climate change has created favorable conditions for alien species such as water hyacinth (*Eichhornia crassipes*) which has affected water quality and volume and the aquatic ecosystems for example recently Lake Tana and Koka are extremely affected [40]. Climate change also alters the hydrology of streams, rivers, lakes, etc., thereby affecting the spatial and temporal availability as well as productivity of water resources.

In Ethiopia, almost all the electric energy is generated from hydropower, thus, the country's energy sector is highly vulnerable to the impacts of climate change [83]. Hence the influence on water availability will have direct implications to hydroelectric power generation as both droughts and floods. Furthermore, droughts can lead to water level decline in dams, while dangerous floods become considerable safety concerns for dams. The intense rainfall projected as a result of climate change can aggravate soil erosion from uplands and supply sediments into the dams, thus causing siltation. For instance, the siltation of Koka Dam has adversely affected the supply of energy in the country. Some reservoirs became fully-silted in less than 20 years, and their failure affected the local economy [25, 60]. The severe flood from the agricultural field increased the sedimentation of micro-dams and this resulted in the reduction of the lifetime of dams with 25% in the Tigray region [61]. Hence, as long as the current practices of deforestation and inappropriate land use continue, even the newly built grand renaissance hydropower dams and other dams in the country will suffer from a similar fate [60].

[45] Mentioned that the change in the amount of precipitation and temperature due to climate change has changed Gumara River flow volumes. The average annual total flow volume for the future showed an increasing trend as compared to the base period in which the flow volume increases from 13.04% (2001 to 2025) to 17.8% (2076 to 2099). However, the country has been facing degradation of numerous wetlands due to deleterious anthropogenic activities. Out of which climate change is the worst one [27]. Hence, many lakes such as Lake Tana, Ziway, Langano, Abijata, and Chamo are shrinking in water level. However, a few lakes have already dried up such Lake Haramaya which was once spread over an area of more than 10 miles and 30 feet deep is currently no any symptom of water body [42, 81, 82]. The highest evapotranspiration in Great Rift Valley caused by the increased temperature, threatened Lake Abjata and highly diminishing the water volume by 372 million cubic meters per annum, while the groundwater outflow is just only one million cubic meters [63].

2.3. Impact on Crop Production

As a result of extreme rainfall events and variability caused floods and droughts which affected agricultural production. It is anticipated that reduced precipitation and extremely high temperatures and evapotranspiration during droughts will negatively impact staple food production [48]. In Africa, overall agricultural productivity loss due to climate change is estimated to be between 17% and 28% as compared to 3% to 16% for the world, this indicated that climate change negatively affected the livelihood of Africans including Ethiopia. [15, 77] estimated that climate change reduced the yield of wheat by 33%.

Ethiopia's economy is based on agriculture mainly subsistence and rainfall dependent that makes it highly vulnerable to the impacts of climate change, particularly droughts, which occur due to increased temperature and unreliable rain. Consequently, Ethiopia forgoes more than 6% of each year's agricultural output if the current decline in average annual rainfall level continues in the medium term [67]. Climate change also causes more erratic rainfall both in amount and distribution that aggravated soil erosion and shifts in sowing and harvesting dates of crops due to the delayed onset and early ending of rainfall and changes in agricultural systems and increased incidence of pests and diseases that likely to affect crop yields negatively and consequently food security [48].

In 2015/16 due to the El Nino crisis, there was the failure of crop yield up to 100% especially in dryland parts of the country. [38] reported that climate change-induced drought in Menz Gera Midir District, devastated indigenous varieties of wheat and barley it also severely affected the livestock production as it causes a shortage of pastures and water. Crop and livestock pests and diseases are becoming more prevalent; they are spreading to areas that were once too cold for them to live in. For instance, cereal stem borers are expanding their niche to the higher elevation areas due to the variability in climatic conditions. Climate change has increased the

incidence and severity of plant pathogens and diseases such as coffee leaf rust, cereal rust, smut, Phytophthora cinnamon, P. infestans, Plasmopara viticola, Botrytis gladiolorum, chestnut blight disease, citrus canker, root-knot nematode, bacterial leaf blight of rice, Stewart's wilt, barley yellow dwarf, potato leafroll virus, Citrus tristeza virus, African cassava mosaic virus and bunchy top of banana, causing severe loss of crop yields [7]. Moreover, there are certain crops that unable to produce as of its potential productivity and few of them have changed its niche [34].

Reports indicated that in North-eastern Ethiopia, drought-induced losses in the crop and livestock from 1998–2000 were estimated at USD266 per household which is greater than the annual average cash income for more than 75% of households hence, climate change resulted in the significant declining of agricultural production [18]. Consequently, recurrent droughts have had profound impacts on the livelihoods of agriculture and biodiversity dependent household by causing millions to rely on food aids [72]. Therefore, climate variability and change severely affect agricultural production and productivity, and thereby the livelihoods of local people and the GDP. It was estimated that climate change will reduce Ethiopia's GDP by 2045 primarily by reducing agricultural productivity [32, 66]. Furthermore, the impacts of climate change could reduce the national income from the export of agricultural products such as coffee, pulses, and flowers. Particularly, Coffee arabica, which is the export commodity, is impossible to produce at the end of this century if the climate change continues at the current rate due to its sensitivity to climate variability [52].

The impact of climatic variability and change in the country has caused yield reduction to the extreme total yield loss. For instance, the 2006 flood in the Gambela region damaged about 1650 hectares of maize and reduced crop productivity by 20% as a result of waterlogging of farmland. This resulted in the loss of income of the country and exacerbated food shortages and malnutrition problems in the region [52]. Evidence suggested that recurrent droughts and the associated food insecurity and famine in Ethiopia are mainly caused by climate change, particularly rainfall variability [57, 69]. However, the change is varying within the country with places and season, hence the area that was experiencing higher variability is characterized by a higher probability of crop failures. In areas where previously Belg season rain is common, currently, there is greater rainfall variability that has been resulted in to yield reduction to total production shift [39].

2.4. Impact on Livestock Production

Ethiopia is known by its largest livestock population in Africa and the world's tenth-largest producer of livestock, which make up about 10% of the country’s foreign currency earnings [43]. However, livestock production has been influenced by climate change because climatological characteristics such as ambient temperature and rainfall patterns have a great influence on pasture and feed resource availability. [71]. Hence, during the rainy season pastures are available in higher quantities and show good nutritional quality whereas during dry season’s pastures have poor nutritional quality with high fiber and low protein contents, which often results in declining the animal production and productivity and starvation [1]. Besides, the rain pattern during the year also strongly influences animal disease and parasites outbreaks, that influencing animal production system [71].

The occurrences of frequent and extensive droughts in Ethiopia have a substantial effect on the country's livestock production due to decreased rainfall and shrinkage of available water resources and which enhances the reduction of the productivity of grassland. Moreover, increased temperatures can affect the behavior and metabolism of livestock, such as a reduced intake of food and further resulted in declining productivity [70]. Variability in rainfall and increased temperature also increase the geographical distribution and survival of vectors like flies that transmit infectious diseases to livestock [70]. The effect was felt in the past two decades in the Borana zone of Oromia region and in different districts of Afar region. This has resulted in the declining number of livestock per household due to climatic variability. Therefore, the pastoralists in those areas were forced to decrease their livestock population. For instance the numbers of oxen were reduced from ten to three, cows from thirty-five to seven and goats from thirty-three to six, and in certain serious cases it is common to find pastoralists without livestock [43].

Like drought, floods has also a significant impact on livestock resources. They can be drowned or washed away by floods. For instance, more than 15,600 livestock were lost due to flooding in 2006 from the southern region of Ethiopia [21]. Flood also covers large areas of grazing land with water and sediments making it impossible for the animals to find feed [52]. Hence, [43] have concluded climate change has affected the availability of water and feed which are the main causes of deaths of livestock in the country. According to [53, 71] climate change is expected to result in declining in livestock productivity. The future projection indicated that livestock productivity will be lower by 50% in the 2050s compared to without climate change scenario. Besides, agricultural GDP will be lowered by 3% to 30% in 2050. Furthermore, it reduces the country’s GDP by 2 - 6% by 2015, and up to 10% by 2045 [79].

[76] Mentiaoned that livestock disease incidence is increased during the long dry season when animals are in poor condition due to inadequate forage and water supply and increased heat stress as a result of the increased temperature. Pastoralists in Borena area confirmed that the emergence of new diseases is the major problem associated with climate variability. They believe that diseases to which they were not familiar are occurring in the area and claiming the lives of their livestock. This is associated to increased susceptibility of livestock to diseases aggravated by a shortage of feed that has been occurred due to change in climatic factors influence the environment and make it suitable for new pests and diseases [84]. Furthermore, [67] indicated that climate variability has brought the loss of livelihoods and forced migration due to

crop failure and livestock mortality that has decreased incomes of farmers and pastoralists by 19 - 30%.

3. Remedies for Climate Change Impacts

3.1. Policies and Programs

The government of Ethiopia has set policies for adapting climate change in terms of agricultural intensification, generation of power from hydroelectric and wind as additional mechanisms for adaptation and mitigation of climate change [31]. The country has put in place policies, strategies, and programs that enhance the adaptive capacity and reduce the vulnerability of the country to climate variability. Hence, in 2012 the Climate Resilient Green Economy (CRGE) initiative was launched to protect the country from the adverse effects of climate change and to build a green economy that will help realize its ambition of reaching middle-income country status before 2025 [16, 31]. The CRGE is based on reducing vulnerability to climate change risks and shocks as well as increasing adaptive capacity as a key for Ethiopia as climate-related disasters increased [24]. The government has also signed and ratified all the Rio Conventions, namely the United Nations Framework Convention on Climate Change and its Protocol, the Bio-diversity Convention and the Conventions to Combat Desertification.

Furthermore, the country has launched a fifteen-year National Adaptation Plan that costs about USD 6 billion annually to address climate change impacts. The plans aimed to bring about transformational change in the country's capacity to address the adverse consequence of climate change. The focus areas were agriculture, forestry, health, transport, power, industry, water, and urban sectors that are identified as most vulnerable. The country is also a signatory to relevant international environmental conventions and protocols, such as the United Nations Convention on Biological Diversity (CBD), United Nations Framework Convention on Climate Change (UNFCCC), UNCCD, Kyoto Protocol to the UNFCCC and the Paris Agreement. Besides, the country was an active participant in international climate negotiations and initiated and implemented several climate-related national strategies and programs [51, 83]. Additionally, the country established the National Secretariat of $REDD^{+}$ in 2013 under the Ministry of Environment, Forest and Climate Change. In line with this, Ethiopia prepared its Forest Reference Level and submitted to the UNFCCC in 2016, which is intended for accessing the results-based payments under the global REDD+ mechanism. The design of the national REDD+ strategy is now being implemented in selected districts of the country under environment, forest, and climate change commission and its structures at zone and district levels [83].

3.2. Adaptation Measures

Adaptation is central to many proposed strategies for reducing the negative impacts of climate change [17]. To boost socio-economic development and combat climate change, Ethiopia developed a CRGE strategy in 2011 [9]. Which is based on improving the crop and livestock production for higher food security and farmer income while reducing GHG emissions; protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks; expanding electricity generation from renewable sources of energy for domestic and regional markets and leapfrogging to modern and energy-efficient technologies in transport, industry and buildings. Currently, different adaptation strategies are being developed and implemented to interfere with the impacts of climate change [83]. The government has implemented adaptation measures in the selected sectors such as agriculture, roads, and hydropower through an increased area of irrigation, increase research activities and development in agriculture, modify plans for expansion of hydroelectric power and build climate-resistant road infrastructure (e.g. increase the capacity of roads and bridges to withstand greater heat and precipitation) [24].

The different levels of structures in the country have employed adaptation measures in their respective organizational setup. Hence, in agricultural sectors, soil and water conservation was the most dominant intervention which has been practiced through mass mobilization that helped in maintaining the existing climate as well as to create favorable climate to the country through anticipating on minimizing the negative impacts of climate change [29]. There were also coping strategies in agricultural; agro-pastoral and pastoral areas of the Oromia and Somali regions through pastoral migration, asset diversification, food aid, and supply side and demand side interventions concerning water [31]. The Borana pastoralists have designed adaptation mechanisms such as an adjustment in pastoral practices which includes shifting to non-pastoral livelihoods and practicing semi-pastoral lifestyle.

The adjustment responses were increased mobility, more adoption of drought-tolerant livestock species, increasing resort to purchased hay, competitive individual household land grabs for strategic private range enclosures for the double purpose of cereal cultivation and fodder production. Moreover, several forage banks have been established in many droughts prone areas of the country to cope with droughts. While the most non-pastoral adaptation strategy embraced is cereal cultivation which matures in a short period. Farmers in West-Arsi also follow a similar trend of coping mechanisms that are used to reduce the impacts of climate change are saving, crop diversification, wood sell, mobility, social interconnectedness, and credits. There are institutional coping strategies such as emergency aid, credit services, safety net, awareness rising on saving, and use of technology [31].

Crop variety development plays an important role in climate adaptation; researchers are working on generating new crops and forage varieties under different breeding programs. Many varieties were released based on their potential for broad adaptation. One proposed solution is to increase variety supply by accelerating crop breeding, removing older varieties from the seed supply chain, and assiduously promoting new varieties for farmers [12].

Melkassa Agricultural Research Center alone has released a substantial number of crop varieties for drought areas. For instance, 50 Common beans, 9 Cowpea, 3 Mung bean, 1 Pigeon pea, 1 Adzuki bean, and a totally 64 crop varieties were released.

3.3. Mitigation Measures

Mitigation mainly relies on tackling the emissions of GHG from the land-use sector. Hence, agricultural and forested lands are believed to be a major potential sink and could absorb large quantities of carbon if trees are maintained or reintroduced to these systems [15]. In Ethiopia, afforestation and conservation programs have been made in the last three decades and several huge areal closure activities in the northern parts of the country to rehabilitate degraded lands to increase above ground and below ground carbon stock [14]. There are several large projects for afforestation, reforestation, and forest management such as Participatory Forest Management (PFM). It is assumed that two million hectares of pasturelands will be afforested and one million hectares of previously degraded forest lands will be reforested up to 2030 to mitigate the impact of climate change [9].

The Oromia and Amhara regional states have established Forest and wildlife conservation enterprise to conserve the existing natural forest and re-afforest the degraded area so that to generate income from the forestry sector and to mitigate climate change that the country is facing. The Oromia forest and wildlife conservation enterprise have its branch from zone and district level such as Bale, Arsi, Borena Guji, Hararge, Finfine, Ilu Aba Bora, Jima, and Wollegga zones branches. The enterprise has been administering a huge forest area; for instance, the Wollega branch alone administering about 1,323,890 hectares of natural forest and 6,571 hectares of plantation forest and managed by group members of 68,194 male, and 15212 female heeded organized under PFM groups. PFM has been established at the zonal level by which natural forests are managed technically and degraded hillsides were afforested artificially to mitigate the ongoing climate change and enhance the economic benefit from the forest and non-timber forest products [83].

There is a need to enhance the conservation, development, and management of forests since they play a vital role in climate change mitigation and adaptation, among others [83]. Currently, Ethiopia is giving special attention to forestry and Agroforestry based development by considering the ongoing environmental hazards and international agreements. Hence, Ethiopia initiated the national tree-planting program “Green Legacy” to improve forest coverage, mitigate climate change, improve agricultural production and to maintain ecological balance by planting four about billion seedlings in the year 2019 and two hundred million seedling were planned to plant per day (in July, 28/2019). Hence, the country succeeded the world record of the number of seedlings planted per day, and its name was registered in the Guinness book of the world records by planting more than three hundred fifty million seedlings per day. Besides, in 2020 planting season, it is planned to plant about five billion seedlings of different trees, coffee and fruits species.

Agroforestry is the most important land-use system for climate change mitigation measures. The carbon sequestered within agroforestry systems may have a positive impact on the global GHG balance [35]. Most tree species in the over-story in southern Ethiopia from Gedeo home gardens are slow-growing and long-lived and can form a large canopy volume with a high total carbon accumulation. For instance, *Ficus vasta* is one of the most prominent canopy species, which is a slow-growing tree that can attain a large size, hence store higher carbon density, and can be credited with sequestering a maximum total carbon [15]. Traditionally farmers in many parts of Ethiopia have been experiencing the habit of leaving certain very old trees on their farmland which can play a critical role in climate change mitigation [35].

There are also mechanisms for reducing the emission of GHGs by using lower-emitting energy sources. A pilot project to distribute energy-efficient cooking stoves was identified as a voluntary offset project that would reduce GHG emissions. Energy-saving stoves were introduced in different parts of the country a decade ago [31]. Besides, the country is currently targeting carbon trading as a strategy in mitigating climate change through afforestation and reforestation practice [31]. Humbo natural regeneration (reforestation) is an exemplary project that was proposed by World Vision for the payment of ecosystem services has already been endorsed by the Ethiopian government is one example for carbon trading in the country. The ministry of environment, forest and climate change is working to implement a similar trend in different conservation sites of the country [31].

4. Conclusion

The Earth's climate is rapidly changing as a result of increasing in the concentrations of GHGs in the atmosphere caused by human activities, particularly the burning of fossil fuels, agriculture and deforestation. Currently, climate change is a global agenda, especially in developing countries due to their dependency on agriculture that managed by smallholder farmers who are fully dependent on rain which is influenced by climate change. However, their contribution to the emission of GHGs is insignificant as compared to the developed nations. In Ethiopia, agriculture and forestry are the dominant sectors the emitted the majority of GHGs and contribute to climate change. Conversely, agriculture is the prime sector affected by climate change impacts. Studies indicated that the trend in annual temperature has been significantly increasing nevertheless the rainfall has no clear trend in the previous and future projected analysis. The rainfall pattern varies in space and time, in some seasons there is a complete termination for example the Belg rain was terminated in many areas. Other places and seasons rainfall is occurred in a torrential form that causes damage to the environment and human. The impact has been seen as new diseases has been happening, crop failures in some areas range up to a loss of 100%, death of livestock due to drought and taken by flood, shortage of forage natural resource

degradation is also a common phenomenon for instance extinction of wild animals and plants, soil erosion and sedimentation of hydropower dams. To overcome the impacts induced by climate change the country implemented adaptation and mitigation measures. For instance establishing early warning systems, food, and fodder supply, de-stocking of livestock, establishing fodder banks, land rehabilitation, growing early maturing crops, and adopting agroforestry practices. The implementation of MDG, SDG, REDD^{+}, CDM projects are some of the projects to fight the impacts of climate change.

5. Recommendations

Though different measures were implanted, still there is a wide gap that should be filled and the following issues have to be considered:

Establishing precise weather forecasting and early warning system with strong coordination with relevant sectors.

Strategically integrating local and scientific knowledge in climate change adaptation and mitigation measures.

Researches should focus on generation of technologies and information that can be a remedy for the impacts of climate change.

Improve the capacity of experts, institutions, and systems with current knowledge, technologies, and infrastructures.

Developing policies and strategies based on local circumstances than adopting from others and distribute for the users.

Community-level awareness creation with tangible evidence.

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