Review

Impacts of Climate Change on Crop Yield in Ethiopia, Review

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Keywords: Climate; livelihood; crop production; collective action; public good

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Impacts of climate change on crop yield in Ethiopia, Review

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Abstract: Climate change is a large and challenging collective action problem facing the world today. This seminar reviews the impacts of climate change on the yield of major cereal crops. Literature has indicated that climate change would likely have a positive impact on highland agro-ecology in the short run. However, in the long run, climate change will have a negative impact on all agro-ecology. Negative impacts will be high in low land agro-ecology. Failure to prepare for climate variability can seriously affect the livelihood of smallholder farmers. Ethiopia by enacting a Climate-Resilient Green Economy strategy and National Adaptation Plan aims to minimize the impacts of CC. Despite the existing adaptation and mitigation strategies negative impacts of climate change on agriculture especially on cereal crop production are continued. Thus, both private and public investment in adaptation strategies should be expanded more. Studies regarding the impacts of climate change on labor productivity, the labor market, it's distributional (which section of society is mostly by climate change?), and why the existing adaptation strategies are not successful? are not well studied, as most literature is focused on the impact of climate change on yield, adaptation, and mitigation strategies.

Keywords: Climate, livelihood, *crop production, collective action, public good*

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1. INTRODUCTION

1.1. Background

Climate change is a large and challenging collective action problem facing the world today. It is occurring at an accelerated rate. The causes and consequences of climate change are very diverse, and its impacts are most acute in Developing countries, such as Ethiopia who contribute less[1]. According to an IPCC synthesis report on climate change, burning fossil fuels for more than a century, along with unequal and unsustainable energy and land use, has caused global warming of 1.1℃ above 1850-1900 in 2011- 2020 above pre -industrial levels[2]. Global surface temperature over the period 2011–2020 has increased by 1.59 ℃ over the land and 0.88 ℃ over oceans in comparison with the period 1850–1900[3]. Extreme climatological events have become more frequent, demonstrating climate change's impact on water resources, agriculture, and food production[4,5]. Droughts, floods, storms and heat waves can result from the inability to rapidly reduce factors that contribute to global warming [6-8].

There are various mechanisms by which "global climate change" may affect the welfare of human beings. The most direct and indeed most considerable impact lies on the agricultural sector such as cereal crop production. In recent decades, lack of rain and frequent droughts have severely reduced agricultural production and exacerbated hunger[9,10]. As a result, poor households are increasingly exposed to severe shocks, which have long-term implications[11]. It results in wilting crops, livestock deaths, rivers drying up, and socioeconomic damages[12]. For instance current(2021 and 2022 year) climate induced drought in southern parts of the country, Borena pastoral and agro-pastoral communities, outbreaks of livestock and crop diseases and pests resulted in in livestock loss and crop failure[13].

Ethiopia agriculture is highly vulnerable to climate change, is a prominent example in Africa[14]. This is due to the country's dependence on climate-sensitive agricultural production[15]. Drought, warming, and flooding can prevent households from meeting their food needs and lead to food insecurity[16]. Droughts used to occur every 10 years, but due to current climate change, especially the decrease in rainfall, droughts now occur every two to five years[17]. Climate change affects agriculture through change in temperature, precipitation, and other climate variability changes (such as erratic rainfall, floods and droughts)(see Table 1) [18]. Climate change(Rise in temperature) can cause crop failure and income loss due to flooding and reduced market value in Ethiopia [19].

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Cereal crops have been the dominant human diets for thousands of years [20]. They are a crucial source of energy, fiber, and a variety of micronutrients, minerals, carbohydrates, vitamins, proteins, and micronutrients essential for proper functioning of the body [21,22]. However, cereal crops crop production in Ethiopia, remain vulnerable to climate change despite their nutritional and economic importance[23]. Climate change, especially increased ambient temperatures, will reduce yields of important cereal crops[24]. The uncertainty in environmental condition will cause a reduction of 7% in the global crop yield[25]. Moreover, droughts are estimated to reduce global wheat (Triticum aestivum L.) and maize yields[26]. Changes in precipitation patterns could have negative impacts on crop production and yield [27]. Rise in temperature and precipitation also affect crop farm revenues in Ethiopia [19]. Due to the complex interaction of these variables, it's hard to predict regional climate change impact[28]. Even with country's role in climate negotiations, factors like El Nino worsen the local climate, leaving the population vulnerable to global changes[29,30].

Failure to prepare for more frequent or prolonged droughts, higher temperatures and climate variability can seriously affect the livelihood of smallholder farmers[31] . Literatures have emphasized the need to pursue adaptation alongside with mitigation strategies [32-36]. To cope with the expected pressure on cereal crop production as well as other agricultural products, policymakers have so far focused largely on addressing climate variability through adaptation and mitigation of greenhouse gas emissions, and carbon sequestration[37]. Ethiopia aims to combat climate change and collaborate with stakeholders to reduce risks and increase adaptive capacity and resilience[38]. Despite insignificant historic green-house gas emissions the country has taken actions against climate change by enacting Climate-Resilient Green Economy strategy[39] . Ethiopia's in its growth and transformation plan (GTP) recognizes climate change as a threat and opportunity, aiming to build a resilient green economy by 2030. The country also launch National Adaptation Plan (NAP)[40] to cope with the risks of climate change. The most common adaptation strategies include mixed farming, mixed cropping, varying planting dates, drought-resistant crops, conservation techniques, non-farm income, and irrigation[41]. However, mitigating climate change is challenging task as it is a global public good (It can lead to a free-rider problem). Each country faces private costs to reduce greenhouse gas emissions, while the benefit of mitigation efforts is shared by all countries, regardless of their contributions[42]. Countries must collaborate and negotiate to create a global path for reducing economic dependence on greenhouse gas emissions. Thus, as compared to mitigation, adaptation strategy is best strategy to reduce the impacts of climate change especially for developing counties like Ethiopia. The aim of this seminar is to review the impacts of climate change

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(mainly, Temperature, Rainfall, precipitation and occurrence weather event (drought, flood) on major yield of major cereal crop.

2. METHODOLOGY

We have identified the relevant literature to be included based on the research hypothesis formulated before. To search the relevant literatures, library data base such as, WorldCat, Scopus, AgEcon, ISI web of knowledge and Google Scholar in conjunction with RACER, were used. Only English-language articles containing combinations of multiple keywords were used to searches the literatures. We have included 117 papers out of 370 downloaded papers using the following inclusion criteria (Figure 1). The first broad inclusion criterion was whether a given study's focus was on the impacts of climate change (especially economic impacts) on cereal crop yield. Then relevant studies was assessed by title, by abstract and finally by a full-text review.

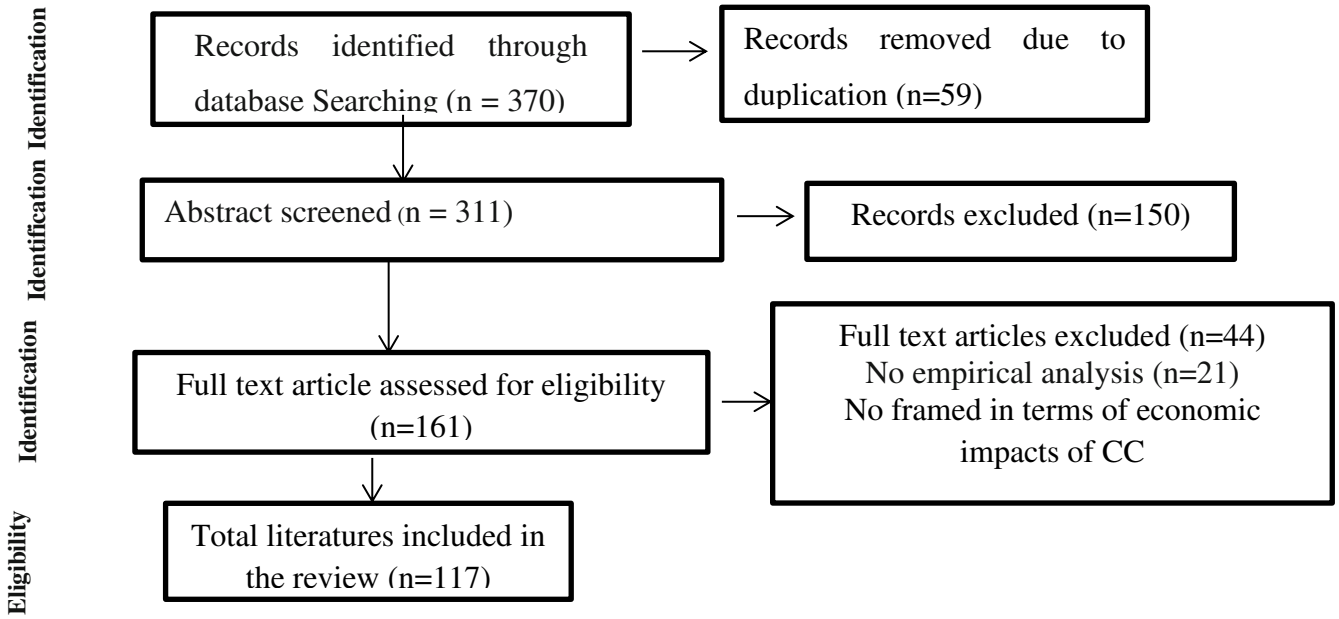

Figure 1 Systematic review process flow chart with study counts and exclusion reasons

3. LITERATURE REVIEW

3.1. Emission of Green-House Gases

The primary driver of climate change has been the steady increase in greenhouse gas emissions (GHGs) due to human activities[43]. The major greenhouse gases in the atmosphere are CO2 (76%), methane (16%), and to a limited extent, nitrous oxide (2%). GHG emissions are mostly caused by the use of fossil

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fuels (coal, oil, and natural gas) in automobiles and industries, which result in carbon emissions both during production and consumption [44,45]. The sources of these greenhouse gas emissions are more diffuse than any other environmental problem. Greenhouse gas emission resulting from human activities continues to increase. Emissions of GHG have increased rapidly over recent decades Figure 2. Global net anthropogenic GHG emissions include CO2 from fossil fuel combustion and industrial processes (CO2-FFI) (dark green); net CO2 from land use, land-use change and forestry (CO2- LULUCF) (green); CH4; N2O; and fluorinated gases (HFCs, PFCs, SF6, NF3) (light blue).

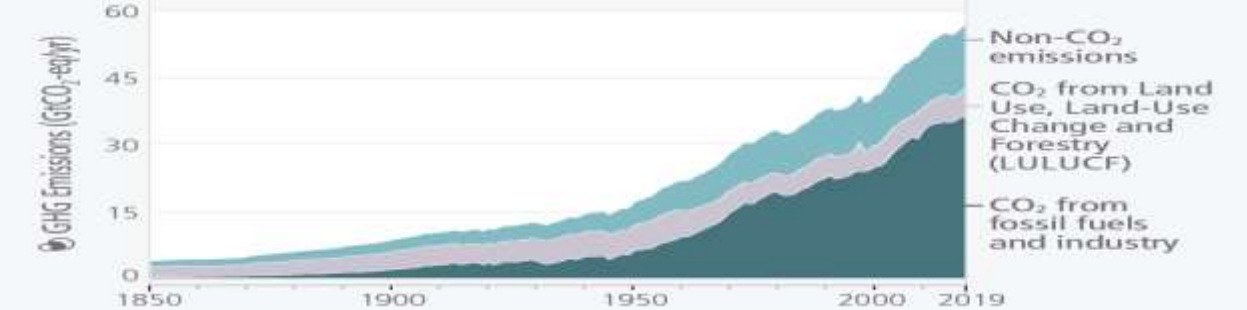

Figure 2 Emission greenhouse gas

Source [2]

These emissions have led to increases in the atmospheric concentrations of several GHGs including the three major well-mixed GHGs (CO_2, CH_4 and N_2O figure 2, annual values). The rising concentrations of theses greenhouse gases (GHGs) of anthropogenic origin in the atmosphere have increased, since the late 19th century[46]. The amount of CO_2 in the atmosphere before the industrial revolution used to be around 280 ppm and recently it has increased to 410 ppm (as of 2019), whereas the amount of Methane and Nitrioues oxide (N_2O) in the atmosphere has been increased from 980 ppb and 230 to 1866 ppb332ppb respectively (Figure 3).

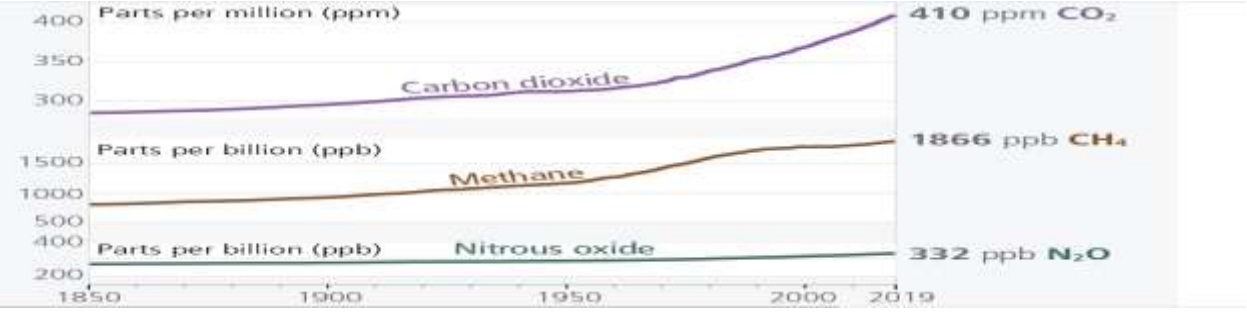

Figure 3 Concentrations greenhouse gas

Source [2]

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Because of the increase in concentration of greenhouse gases in the atmosphere, the global surface temperature has risen by 0.95°C–1.20°C globally. The global surface temperature has increased by around 1.1°C since 1850–1900 Figure 4. The vertical bar on the right shows the estimated temperature (very likely range) during the warmest multi-century period in at least the last 100,000 years, which occurred around 6500 years ago during the current interglacial period.

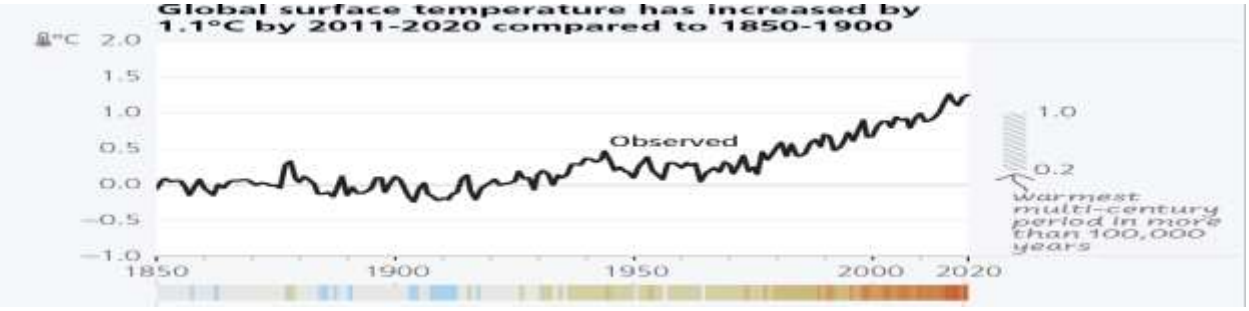


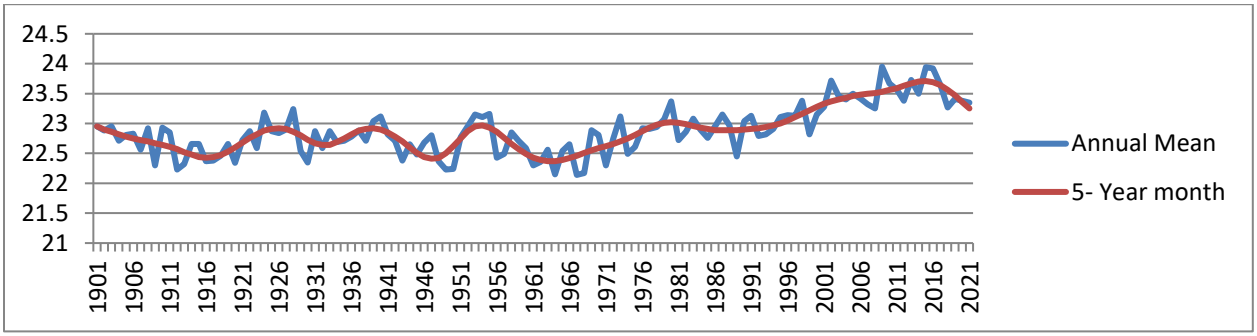
Figure 4 Global surface Temperature

Source [2]

3.2. Trend of climate change in Ethiopia

3.2.1. Trend of Mean daily temperature in Ethiopia

Mean daily temperatures in Ethiopia have showed an upward trend between 22°C and 24°C on a yearly moving average. Changes in temperature have been from 0.7 ℃ to 1.516℃ from 1901 to 2021 Ec (Figure 5).



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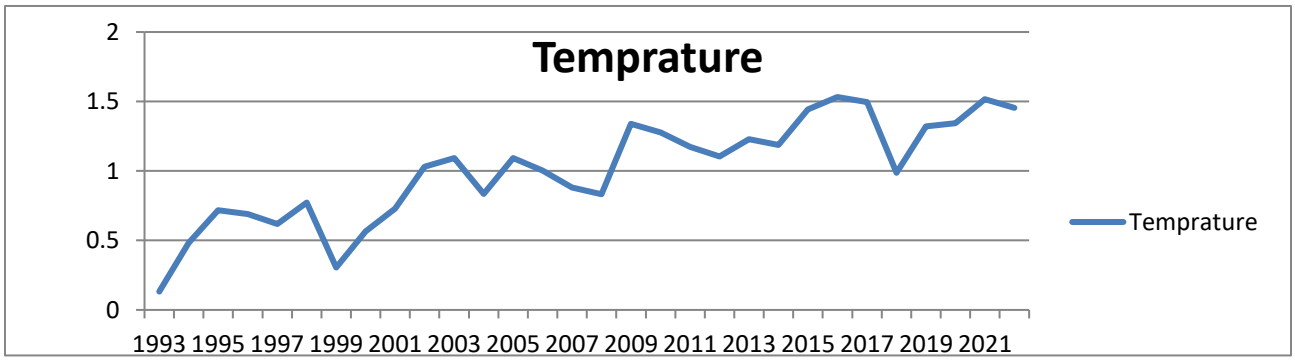
Panel (A)



Panel B

Figure 5 Observed Average Mean annual temperature of Ethiopia for 1901-2021 and temperature change of 1993-2021

Source (FAO, 2023)

3.2.2. Trend of rainfall in Ethiopia

Rainfall data shows variability, consistent with other studies [47-49]. The average monthly rainfall of Ethiopia was mostly below 1200mm. Understanding seasonal rainfall performance is therefore crucial for agriculture, water, energy, as well as other socioeconomic activities. During 1980 to 2016, the seasonal rainfall over Ethiopia was erratic both spatially and temporally (Figure 6).

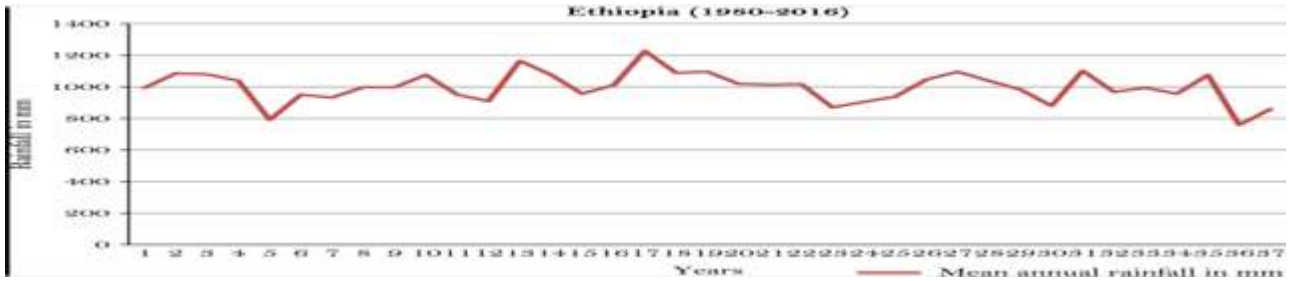


Figure 6 Mean Annual rainfall of Ethiopia

3.2.3. Trend of Extreme weather in Ethiopia

Drought and flood are extreme climate events that affect various socioeconomic activities[50]. Extreme weather events in Ethiopia include Drought, flood, thunderstorm, and strong winds, all of which have become increasingly frequent in recent decades. Ethiopia suffers more economic losses due to extreme droughts and floods[51]. The country has encountered more frequent and prolonged extreme weather event (drought and flood) thought history (Figure 7).Thus understanding their intensity and frequency is crucial.

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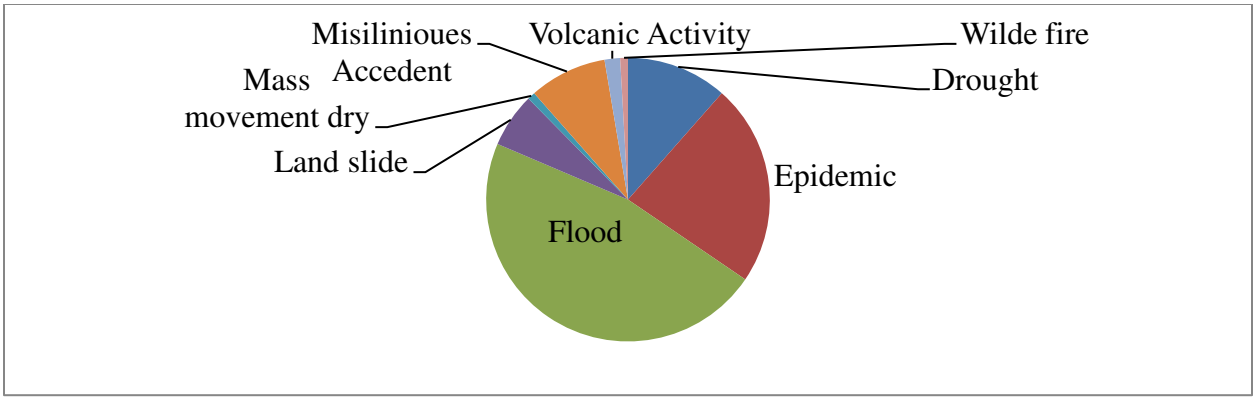

Figure 7 Extreme whether events over Ethiopia from 1920 to 2016

Source (https://climateknowledgeportal.worldbank.org/country/ethiopia/vulnerability)

Due to the variability, intensity, and frequency of precipitation extremes during the main rainy season, droughts and floods often occurred, primarily affecting agriculture and water resources[52]. Over Ethiopia, rainfall variability shows droughts and floods from the 1980s onward, and since 1990(Table 1), the country has experienced major floods that killed about 2,000 people and affected around 2.2 million people[53,54]. The north and northwest regions of Ethiopia experienced frequent and more severe drought conditions centered at the year 1983/1984[55,56], for the southern and southwestern regions, drought conditions have become more frequent and intense since 1997[56].

Table 1 Extreme Event in Ethiopia

Year	Extreme event
1920-22	Drought
1957-58	Drought
1962-63	Drought
1968	Flood
1971-75	Drought
1978-79	Drought
1982	Drought
1984-85	Drought
1987-88	Drought
1990-92	Both
1996	Drought
1996	Drought
2002	Drought
2005	Flood
2006	Flood

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2009	Drought
2015	Drought
2016	Drought
2021-22	Drought

Source [17,57,58]

3.2.4. Major contributor/driver of climate change in Ethiopia

As of 2014, African agricultural activities emitted 0.87 Gt CO2e, tenth of the sector's global GHG emissions, compared with 0.44 Gt in 1994 and 0.54 Gt in 2010. Among the major contributors to the total emissions, East and Southern Africa accounted for a third and 27% of the total emissions, respectively. Ethiopia was produced the largest amount of agricultural GHG emissions in Africa, next to Sudan[59]. The country's GHG emissions are on the rise with the waste leading the way (Figure 8).

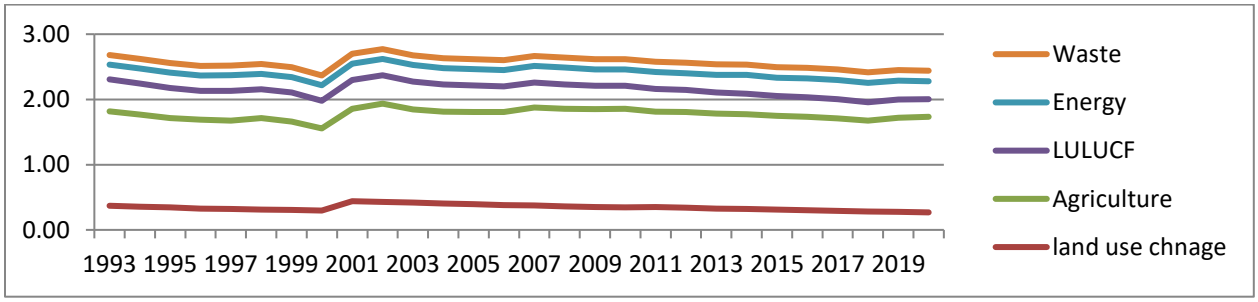

Figure 8 Driver of climate change in Ethiopia

Source (FAO, 2023)

3.3. Impacts of Climate Change on cereal crop yield in Ethiopia

The impacts of climate change and its variability on agriculture have attracted the attention of policy makers, scholars, and economist around the world. As a result large numbers of literatures have examined the correlation between climate change variable such as Temperature, Rainfall, precipitation and crop yield or profit using different methodologies. There are three approaches/models that are commonly used in the literature for investigating the impacts of climate change on crop yield [60].These are (1) Agronomic(crop model)[61] (2) Ricardian [19,62,63] and (3) Panel data analyses approaches [64,65]. Agronomic -crop simulation model are the most extensively used approach to evaluate the impacts of climate change on crop yield in the world. These models are based on biophysical representations of crop production simulating the relevant soil-plant-atmospheric components that determine plant growth and yield. Most of literature's in Ethiopia also examined the relationship between climate change and cereal crop yield using agronomic -crop simulation model[66,67]. However, this approach does not take into account economic considerations and human capital limitations both of

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which affect actual farm decisions[61]. On the other hand, Ricardian models are based on the idea that the long-term productivity of land is reflected in its asset value or farm net revenue, it implicitly incorporates adaptive behavior in its analysis (which include economic considerations) As a result, this approach has been effectively applied in various literature's the world [68-79] and Ethiopia [19,62,63]. However, climate change impact studies that are conducted in ethiopia are missd econmic informations like the impacts of climate change on welfare of diifrent section of the socity, labour productivity and labor market.

Climate change impacts cereal crop production by altering temperature, precipitation, rainfall, and extreme weather patterns[80,81]. There are contradictory findings on the impacts of climate change on cereal crop production. Climate change may have both negative and positive impacts depending on the agro-ecology and time period. Some studies show the negative impact of rise in temperature on crop yield in the long run[19,82-85], especially lower latitudes are expected to suffer adverse effects from higher temperatures, especially in areas where temperatures are near or at optimal levels for crop growth in the first place[86]. Rise in temperature, precipitation pattern alterations, extreme weather events, humidity shifts, and sunlight duration changes all result in lower overall crop productivity [87]. Extreme weather event like frequent drought and flood may disrupt cereal production, causing price hikes. High temperature lowers crop productivity[88] and may also result heat waves create favorable conditions for crop disease pathogens to thrive[89]. Rise in temperature reduces crop yields, worsens post-harvest losses, depletes soil moisture, and lowers farm labor efficiency in sub-Saharan Africa including Ethiopia[90,91]. Higher temperature can also lead to pest and weed problems while reducing crop protein and micronutrient content[92]. More importantly, rise in temperature (warming) and CO2 can harm herbicide success [93-95]. However, temperatures above the optimal(certain threshold, biophysical temperature limit) level may hinder photosynthesis and promote respiration, leading to slower grain filling [96]. Literature have putted this limit or turning point as 1.1℃ and standard deviation of 0.6 [97]. While other studies show that rise in temperature have positive impact on crop production [27], using FGLS and autocorrelation found that, high temperatures and humidity increased wheat production in high-land areas of the country. Similarly, Yang, Wang, Ahmed, Adugna, Eggen, Atsbeha, You, Koo and Anagnostou [84]find that higher temperatures would have a positive impact on cereal crop yield in highland parts of the country thus benefiting the areas(Table 2). It is also worth mentioning that rise in temperature (global warming), may increase cereal crop yield by boosting CO_2 fixation, resulting in positive effects such as better water use efficiency and higher photosynthesis rates[98-100]. Scholars on climate change and agriculture state that the projected 57% increase in CO_2 concentrations by 2050 should

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boost crop productivity, if climate change does not worsen [101] Meanwhile, there has been debate about overestimating the productivity gains due to CO2. [102] Argues the rise in global temperatures occurs with a long lag (after greenhouse gas concentrations have increased), whereas fertilization occur almost instantly. As a result of the increase in CO2 levels,[102] asserts that fertilization effects in crop yields should have already been observed.

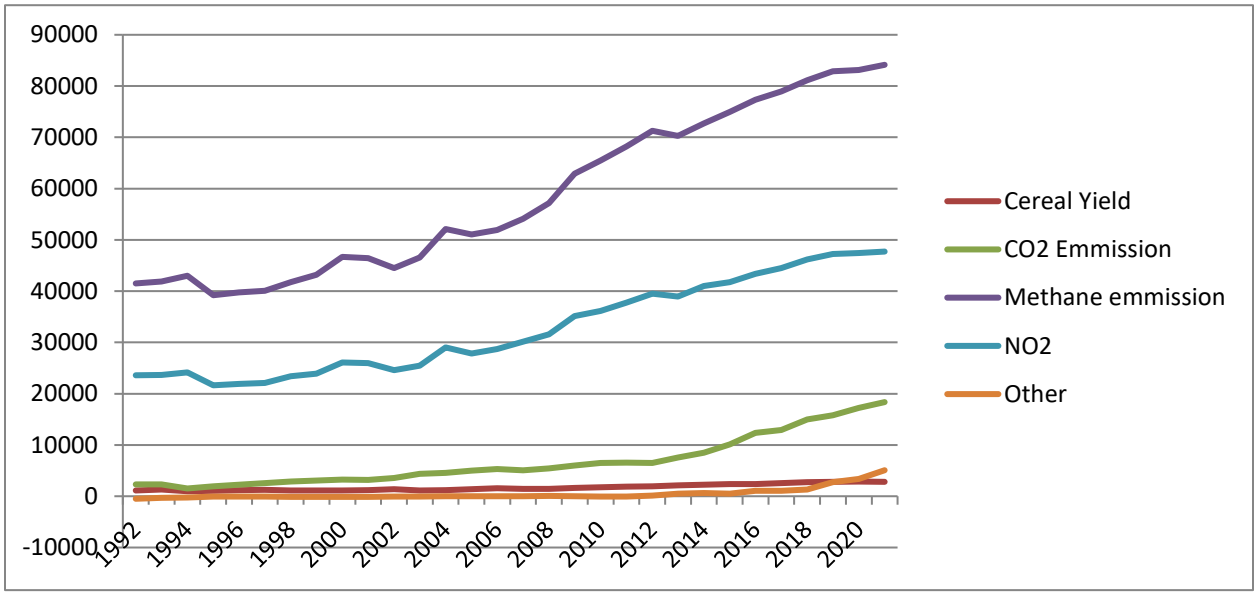

Figure 9 Emission Growth and trend of cereal yield since 1993

Source (FAO, 2023)

Despite climate change concerns, and ongoing negotiations, GHG emissions have increased more in the past decade than they did in the prior three decades[103]. Note that 80% of total emissions come from fossil fuels[104].

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S/No.	Author(s)	Time	Types of crop	Econometric model(s)	Results
1	Wakjira, *et al.* [105]	1981-2010	maize, teff, sorghum, wheat, barley, millet, oats and rice	Univariate linear regression model	Late-onset of rainy seasons=> - Cereals
2	Yang, Wang, Ahmed, Adugna, Eggen, Atsbeha, You, Koo and Anagnostou [84]	1979-2014	barley, maize, millet, sorghum, and wheat	DSSAT	Solar radiation and day time temperature => + Cereals Production *in western Ethiopia* Solar radiation and day time temperature =>- Cereals in eastern Ethiopia
3	Tofu and Wolka [17]			Multinomial Logit	extreme reduction in rainfall => - Cereals
4	Aberra [106]	1970-2010	Stable cereal crops		rainfall variability=> - Cereals Rainfall, Temperature => - Cereals Production CO2 => + Cereals Production
5	Kassaye, Shao, Wang, Shifaw and Wu [27]	1988 - 2018	teff, maize, wheat, and sorghum	FGLS	Rise in maximum Temperature =>+cereal Rise in minimum temperature => - Cereals
6	Asfew and Bedemo [107]	1990-2020	Teff, maize, wheat, and sorghum	ARDL	Precipitation=>+cereal both in SR and LR Temperature => - Cereals
7	Deressa and Hassan [19]	1977-2009		Ricardian approach	Temperature => - Cereals Precipitation =>+cereal
8	[108]			Ricardian approach	increasing temperature => - Cereals decreasing precipitation=> - Cereals

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9	Shumetie and Alemayehu Yismaw [109]				Insufficient rainfall=> - Cereals increase in summer temperature=> -Cereals
10	Tembo [110]		Teff	Ricardian model	Temperature =>-cereal Decrease in rainfall => - Cereals

Table 2 Summary of impacts of climate change on cereal crops

Note: =>, unidirectional relationship; +, positive effect; -, negative effect DSSAT, Decision support system for the agrotechnology transfer; FGLS, feasible generalized least square; ARDL, autoregressive distributed lag

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Table 3 Extreme weather and its effect crop production

Climate change event	Effect on crop production	Crop affected	Source
Flood	Pollution (carrying debris, pollutants, and nutrients) inundation of croplands and destruction of irrigation canals	Maize , wheat, rice, barley, Teff	[111] [111]
	crop losses, the upsurge of water-borne diseases	Maize , wheat, rice, barley, Teff	
Drought	Diminution of leaf water potential and a turgor loss. Leaf curling, partial, or complete stomatal closure, decrease in cell enlargement and growth, and a decrease of internal CO2 causing a decrease of photosynthetic activity complete crop failure, reduced yields, drying up of crops, increased pest damage[112]	Wheat	[113,114]
variability in the amount and duration of rainfall	brought a loss of crop in both kiremt and belg seasons	Maize , wheat, rice, barley, Teff	[115]
Extreme/intensive/ heavy rainfall	reduced yields, cut-off roads, soil erosion, reduced labo	Maize , wheat, rice, barley, Teff	[116]

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Storms (strong winds and/or hailstones)	destroyed leaves, broke shoots and flowers, broke house, reduce leaf quality	Maize , wheat, rice, barley, Teff	[117,118]

4. CONCLUSION

The impacts of climate change may be either positive or negative depending on the agro-ecological zones and time period. Even if climate change has benefit in the short run, it doesn't mean that greenhouse gas emission should be subsidized. Even though, total impacts of climate change are positive in the short run, incremental impacts are negative. Despite the existing adaptation and mitigation strategies the impacts of climate change on agriculture especially on cereal crop production is continued. This has the following policy implications –first climate change a Global public good-which has free-rider problem, makes mitigating strategy difficult especially for low-income countries. Thus, adaptation strategy (has both private cost and private benefit) is the feasible strategy to reduce the impacts of climate change on cereal crop yield. The economic impacts of climate change in Ethiopia are rarely studied, leaving there a lack of comprehensive information for a coordinated response. Studies regarding the distributional impacts of climate change on different section of the society (women, youth, small and micro-enterprise), labour productivity, labour market and change in total factor productivity are not well studied ,as most literature are focused on impact of climate change on yield, its adaptation and mitigation strategies.

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