International Journal of Energy and Environmental Science
2024, Vol. 9, No. 5, pp. 98-106
https://doi.org/10.11648/j.ijees.20240905.12

Review Article

Climate and Coffee Production in Ethiopia: A Review

Zinash Nigussie*

Department of Climate and Computational Science, Jimma Agricultural Research Center, Jimma, Ethiopia

Abstract

Climate is a complex system involving the atmosphere, land surface, snow and ice, oceans, and other water bodies. It is measured by variations in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particles, and other meteorological variables over a 30-year period. Climate change has gained momentum due to anthropogenic disturbances, which may negatively impact human health and the biosphere. The complex relationships between humans, microbes, and the biosphere are causing an increase in greenhouse gases (GHGs), causing global warming and other cascade effects. Climate change is a key environmental concern, posing challenges to ecosystems, food security, water resources, and economic stability. Historical climate records and projected patterns across global regions have confirmed this, with Ethiopia experiencing significant increases in annual mean temperature, hot days, and nights. Climate variability refers to the Spatio-temporal fluctuation of climatic conditions, focusing on the variability dimensions. The Intergovernmental Panel on Climate Change (IPCC) has declared climate change a key environmental concern. Climate in Ethiopia is characterized by significant geographic variance in rainfall and temperature data. The country has three seasons: bega (dry season) from October to January, belg (short rain season) from February to May, and kiremt (long rainy season) from June to September. The country's climate is influenced by the seasonal migration of the Intertropical Convergence Zone and its varied geography, affecting landforms, natural landscapes, and local people's living situations. Coffee is susceptible to drought, over-wetting, and wind damage because its production and quality are largely dependent on temperature and rainfall levels. In key coffee-growing regions around the world, the yield of coffee is at risk due to climate change and unpredictability. The production of coffee is expected to be severely impacted by high temperatures and unpredictable rainfall patterns in terms of yield, quality, pests, and illnesses.

Keywords

Climate Change, Climate Variability, Coffee

1. Introduction

Climate is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans, and other bodies of water and living things which are determined by the balance between the solar energy that the earth has absorbed and the energy that the earth is reradiating. Climate is the weather condition prevailing in a place over 30 years. It is measured by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particles, and other meteorological variables in a given region over an extended period. During the preindustrial period, there might be modest climate change, but it changed dramatically after the industrial revolution because climate dynamics now have a new element in the form of anthropogenic inputs [47].

*Corresponding author: Zinnash2015@gmail.com (Zinash Nigussie)

Received: 1 October 2024; **Accepted:** 29 October 2024; **Published:** 20 November 2024

Climate is changing naturally at its own place, since the beginning of the evolution of the earth, 4–5 billion years ago, but presently, it has gained momentum due to inadvertent anthropogenic disturbances. These changes may culminate in an adverse impact on human health and the biosphere on which we depend. The complex relationships between humans, microbes, and the rest of the biosphere are beginning to show signs of an increase in the concentration of GHGs, such as CO_2, CH_4, and N_2O. These GHGs are causing global warming, along with other cascade effects like altered rainfall patterns, ice melting, sea level rise, etc. The aforementioned complex relationships between atmospheric composition, climate change, and the health of people, plants, and animals need to be carefully examined, and potential remedies for the unfavorable changes could be looked for [39].

Climate change is defined as a change in the statistical characteristics of the climate system that can be detected by changes in the mean and/or variability of those properties over time, usually decades or more [15]. Climate change is a key environmental concern in today's globe, posing serious challenges to ecosystems, food security, water resources, and general economic stability, resulting in regionally dependent increases or decreases in rainfall, increased cloud cover, and rising sea levels. Extreme events like as greater maximum temperatures, more intense precipitation events, increased drought risk and duration, and enhanced peak wind intensities of cyclones will all rise in severity and frequency [34].

According to the decision of IPCC climate change is already happening with multifaceted effects on humans and the environment [14]. Analysis of historical climate records and projected patterns across several global regions has verified this. For instance, an examination of historical climate data for Ethiopia revealed that the country's annual mean temperature increased by 1.3 ℃ between 1960 and 2006, and its annual lowest temperature increased by 0.37 ℃ per ten years since 1951 [26]. Moreover, the average number of hot days and hot nights per year had increased by 20 and 37.5 % between 1960 and 2006, respectively, while the average number of cold days and nights declined by 5.8 and 11.2 %, respectively [11].

Climate variability refers to the Spatio-temporal fluctuation of climatic conditions [7]. Climate variability is also defined by [13] as fluctuations in the mean state and other statistical descriptions of severe climatic conditions on all temporal and geographical scales beyond individual weather occurrences. Climate variability, according to [13], is defined as a climatic parameter of an area that deviates from its long-term mean. The importance of Spatio-temporal scales of meteorological occurrences is also emphasized once more. The [14] definition of climatic variability is similar to that of [13], with a focus on the variability dimensions.

2. Climate of Ethiopia

The statistical interpretation of rainfall and temperature data accumulated over a lengthy period for a certain region or place is frequently used to characterize climate. As a result, the mean annual rainfall distribution across the nation exhibits significant geographic variance, ranging from nearly 2000 mm in certain pocket regions in the Southwest to less than 250 mm in the Afar and Ogaden lowlands [27]. Rainfall happens at several seasons throughout the year. In contrast to much of the tropics, where two seasons are prevalent (one wet season and one dry season), Ethiopia has three seasons: *bega* (dry season) from October to January, *belg* (short rain season) from February to May, and *kiremt* (long rainy season) from June to September [38]. The country's diverse altitude also has a significant impact on temperatures. Because of its geography, the nation has mild temperatures for its tropical latitude. The average annual temperature in the nation ranges from around 10^0C in the northwest, central, and southeast highlands to about 35^0C in the north-eastern lowlands.

Ethiopia is one of Africa's biggest countries, with a diverse range of landscapes, strong topographical differences, and elevations ranging from about 155 meters below sea level at Assale Lake in the Danakil valley to roughly 4,533 meters above sea level at Mount Ras Dashin. Because of these factors, as well as its physical location near the equator and the Indian Ocean, the country experiences significant temperature and precipitation changes across the country. Ethiopia's climate is largely influenced by the seasonal migration of the ITCZ and related atmospheric circulations, as well as the country's varied geography [17]. Landscapes with varying physiography and elevation, such as the highlands and lowlands, experience a range of climates, ranging from desert climates to tropical mountain climates. In a country whose economy is primarily dependent on rain-fed agriculture, climate has many evident repercussions on landforms and its dynamic evolution of natural landscapes, as well as on the living situations of local people. [11].

Rainfall

Because water is such an important component of agricultural production, changes in water availability may have an influence on agricultural productivity and income. According to climate research, most of these oscillations are now caused by intra-year, rather than inter-annual, alterations in rainfall timing and intensity [18]. Because all plants require at least some water to thrive, agriculture relies heavily on rain (which is the most efficient method of watering). While a consistent rain pattern is beneficial to plants, too much or too little rain can be detrimental to crops. Aside from illness, rainfall may influence how quickly a crop grows from seed, as well as when it is ready to harvest. A good combination of rain and irrigation can result in faster-growing plants, reducing germination time and the period between sowing and harvest [44].

Temperature

The balance of the planet's system's incoming and outgoing energy influences the earth's temperature. Large swings in climate and weather can be caused by little changes in the

Earth's average temperature. As a result, agriculture, as a highly climate-sensitive industry, is especially vulnerable to temperature variations. Warmer temperatures speed up the growth of some crops, whereas quicker growth shortens the time it takes for seeds to grow and mature, reducing harvests. Increased weeds, pests, and fungus, which flourish in warmer temperatures, as well as a rise in extreme weather events like floods and drought, can have an impact on crops and diminish yields [4]. Increased plant temperature accelerates growth by reducing the window of opportunity for photosynthesis because the life cycle is shortened, whereas heat and drought stress may also restrict growth directly at the metabolic level.

2.1. Climate Variability and Trend in Ethiopia

Global trends of temperature and rainfall point to the fact the climate is changing. Mean annual temperatures have been increasing and places in Sub-Saharan Africa and Asia continue to experience weather extremes like flood and drought respectively. With global warming, not a hiding secret whether caused by natural variability or anthropogenically induced [14], it is important to be informed and regularly updated on observed regional temperature and precipitation trends at both regional and local levels. The [15] has projected that, if measures are not taken to reduce the generation of GHG emissions, the future temperature will continue to increase as well as extreme weather conditions such as drought in most parts of the world especially, countries in Sub-Saharan Africa.

Climate variability is short-term fluctuations in average weather patterns which has an impact on agriculture. Climate variability, on the one hand, has an impact on agroecological, agricultural, and livestock growth conditions. A delicate balance between agricultural output and food security is created by high climate variability (e.g., low and irregular rainfall distribution). According to studies, changes in agriculturally important climatic factors (e.g., rising temperatures and diminishing rainfall amounts and distribution) are anticipated to affect maize, rice, wheat, and other food crop yields in semi-arid parts of the world [19]. Many additional characteristics of agricultural productivity among smallholder farmers in Sub-Saharan Africa (SSA) are influenced by rainfall, including farm sizes, crop enterprises, cropping calendars, and the occurrence and growth of weeds, crop pests, and illnesses [51].

2.1.1. Rainfall Variability and Trend in Ethiopia

Ethiopia has one of the most unpredictable rainfall patterns, which is a natural aspect of agriculture. The country is sensitive to rainfall unpredictability due to its geographic position and terrain. Long-term trends in the nation are difficult to identify due to the high inter-annual and inter-decadal variability in rainfall. Between 1960 and 2006, there was no statistically significant trend in recorded mean rainfall in any season. Significant interannual variations between 2.2 and 3.8-year periodicity were found in reconstructed rainfall since 1811, with significant decadal and multidecadal variations during 1855–1900 and 1960–1990; the duration of negative and Positive rainfall anomalies ranged from one to eight years [24].

For farmers who rely on agricultural production, rainfall fluctuation is the most significant source of risk. In Ethiopia, there are two major rain seasons: '*kiremt*' and '*belge*.' The *kiremt* rains start in the south west in March and May and move northwards from July to September, impacting the majority of the nation. The *kiremt* rain accounts for over 90% of the agricultural produce gathered between October and December [5]. Droughts and floods wreaked havoc over the land, resulting in catastrophic famines and floods [49].

Intra-seasonal rainfall variability in terms of start of the season, end of the season, length of the growing season, number of rainy days, length of the dry spell within the growing period, and trend is more important for agricultural purposes in dry land areas than annual and seasonal totals, according to a study of the past and future [11]. The first occurrence of at least a specified mm of rainfall totaled over certain consecutive days is considered the commencement of the rainy season. [38] defined onset date as any date when 20 mm of rain is accumulated over three consecutive days and there are not more than eight dry (0.1 mm) days in the next 30 days. [43] utilized 20mm rainfall over three days and no dry periods longer than seven days in the next 30 days to define onset. On the other hand, [23] defined onset date as the time when precipitation equals half of the reference evapotranspiration at the start of the growing season.

The [38] also define the end of the rainy season as the first day following the commencement of a dry spell (0.1mm rainfall per day) lasting at least 20 days, while [43] define the end date as the day when the soil water level reaches zero after September 1. The Length of Growing Period is the difference between the onset date and the termination date (cessation), which is a critical component in determining the maturity of cultivars to be cultivated in different rainfall regimes [10]. When a certain amount of precipitation is recorded the day is the rainy day which means when more than 0.85mm precipitation is accumulated and a dry day is a day with less than 0.85mm precipitation or no precipitation is recorded [19].

2.1.2. Temperature Variability and Trend in Ethiopia

Global average surface temperatures have been increasing since the mid-nineteenth century, according to climate trends and climatic extreme indices developed from empirical, observed data, with the largest pace of change documented since the mid-1970s [16]. This is due to the ongoing production of greenhouse gases as a result of human activity. Anthropogenic forces remain a key contributor of recent global warming, according to the IPCC's latest assessment. Because of the increased concentration of greenhouse gases in the atmosphere, the temperature continues to rise due to the greenhouse effect, which may have led to changes in rainfall

patterns throughout the world. According to recent climatological studies, worldwide surface air temperature increased by 0.76 ℃ from 1850 to 2005 [2]. Ethiopia's climate is inherently both diverse and unpredictable, and the country has seen both climatic fluctuation and change.

But the climate has changed significantly in recent years [24]. The temperature (maximum, minimum, and mean) is rising, but the rainfall has no discernible pattern–it is highly variable [27, 22, 24]. According to studies, there has been a significant temperature variance and trend shift throughout time. The annual lowest temperature, represented as temperature deviations from the mean and averaged across 40 sites from 1951 to 2005, exhibited a significant degree of fluctuation [26]. Over those 55 years, the country saw both warm and chilly years, with recent years being the warmest compared to earlier decades. Furthermore, between 1951 and 2005, there was a rising tendency in the annual lowest temperature. Every ten years, it has risen by roughly 0.370 ℃ [26].

2.2. Impacts of Climate Change and Variability on Agriculture

Climate change, according to the [15], impairs agricultural productivity, posing a significant danger of global food insecurity. Africa is one of the world's most susceptible areas to climate change. Due to factors such as widespread poverty, repeated droughts, inequitable land distribution, and over reliance on rain-fed agriculture, previous assessments by [20] concluded that Africa is particularly vulnerable to the impacts of climate change due to temperature and rainfall changes and extreme events. Climate change and unpredictability, according to [35], restrict agricultural growth and influence crop species and cultivar selection, as well as farm management decisions. Climate change's impact on agricultural systems raises significant doubts regarding crop yield and appropriateness in the future, particularly in locations prone to extreme environmental change [32]. Agriculture is vulnerable to short-term weather fluctuations as well as seasonal, yearly, and longer-term climatic variations. Agriculture can sustain minor deviations in the climatic mean for long-term changes. Variations in meteorological factors are more transient, yet they have a significant impact on agricultural systems. Crop production and animal agriculture will be affected by changes in temperature, solar radiation, and precipitation. Climate change will have an economic influence on agriculture, affecting farm profitability, pricing, supply and demand, trade, and regional comparative advantages, among other things. The size and distribution of such climate-induced changes may have an impact on our capacity to grow food production [39].

The agricultural industry contributes significantly to greenhouse gas emissions, and climate change has the potential to irreparably harm the natural resource base upon which agriculture relies, as well as negatively impact agricultural output in general. In the mid-to-high latitudes, mild temperature rises can have a slight beneficial influence on crop yields; but, in the low latitudes, even moderate temperature increases are likely to have a detrimental effect on yields. Water scarcity and availability will become increasingly constrained, necessitating a rethinking of water storage to deal with more intense precipitation events, higher intra- and inter-seasonal variability (floods and droughts), and higher evapotranspiration. Invasive species, pests, and disease vectors are already harming agricultural output and are predicted to worsen as a result of climate change [34].

2.2.1. Climate Variability and Crop Production

Worldwide climate changes have raised worries about prospective changes to food yields and crop production systems, according to the [14] report. Increased atmospheric concentrations of greenhouse gases might lead to regional and worldwide changes in temperature and precipitation, according to studies undertaken to examine the impact of climate change on agriculture. These changes are expected to have an influence on agricultural production systems, according to new [14] estimates. Global warming, according to [40], has increased the intensity of heat and decreased the dependability of rainfall in East Africa, resulting in droughts and floods that have been observed to cause crop loss and damage. [36] found the same thing in his research. Similarly, according to [36], changes in rainfall patterns and levels have resulted in agricultural losses in several regions of Africa. In general, variations in rainfall and temperature are expected to lower agricultural production. Changes in rainfall patterns may raise the chances of crop failure in the short term while decreasing productivity in the long term.

Despite significant advances in specific crops in some parts of the world, climate change is anticipated to have a negative overall influence on food productivity [36]. Increases in average temperature can prolong the growing season in areas where the spring and autumn are generally mild, while also harming crops in areas where July heat already limits yield [19]. Furthermore, rising temperatures result in increased respiration rates, shorter seed development times, and, as a result, poorer biomass output [3]. Additionally, warmer temperatures cause a shorter grain filling time, smaller and lighter grains, and so poorer crop yields and perhaps inferior grain quality [50]. For some plants, a temperature increases of less than 1 ℃ can increase transpiration rate by up to 30% [16]. Temperature rises may also influence water supply by changing runoff and groundwater recharge rates, as well as capital and technology needs such as surface water storage and irrigation systems [29]. Climate change will most likely result in a major spatial shift and extension of croplands, according to [30], because it will create a favorable or restricted environment for crop growth across different regions, and because climate is a primary determinant of agricultural productivity, any significant changes in climate now and in the future will influence crop productivity.

2.2.2. Climate Variability & Coffee Production

Coffee productivity and quality, according to [12], is highly reliant on temperature and rainfall conditions, and is particularly vulnerable to drought, excessive wetness, and wind damage. [40] found that the blooming and fructification of Arabica coffee, in particular, need a precise pattern of dry and rainy seasonal alternation. Steps in coffee production and possible implications from severe effects of climate change and variability according [12]. Increasing temperatures and erratic rainfall patterns are projected to have severe repercussions for coffee production in terms of quality, yield, and pests and illnesses, even if future climatic variations between areas remain unclear. Climate change and unpredictability are posing a danger to coffee output in every major coffee-growing location on the planet.

Climate change has resulted in higher temperatures, longer droughts interrupted by severe rains, and more resilient pests and plant diseases, all of which have impacted coffee output in the majority of cases. Temperature and rainfall are thought to be crucial elements in deciding whether or not coffee can be grown. According to research done by [21], mean temperatures above 23 ℃ inhibit coffee growth, and persistent exposure to daily temperatures as high as 30 ℃ might result in lower yield. Nonetheless, as scientific studies and participatory evaluations have shown, many of today's coffee-growing locations are already experiencing climate change and unpredictability, and are extremely likely to be influenced in the near and long term. According to [41], a quality issue may occur as a result of the rapid plant growth, which will result in inferior coffee fruit quality.

Furthermore, during the summer months, high maximum temperatures may produce excessive fruit ripening, which is detrimental to fruit quality. Although coffee trees are resistant to high temperatures and drought, the occurrence of more extreme circumstances can lead to physiological stress, such as a decrease in photosynthetic efficiency. Flowering and maturation in connection to the anticipation of bud potential break are the recognized crucial stages that may be impacted, according to [25]. Furthermore, during the reproductive period, high temperatures and dry conditions might be crucial for optimal coffee yield and quality. The establishment of appropriate air temperature restrictions for coffee is critical for its distribution and commercial utilization. Coffee output will be negatively affected when temperatures climb in the highlands.

2.2.3. Climate Change and Crop Production in Ethiopia

In many parts of the world, climate change is one of the biggest risk factors impacting the agricultural system's performance and management. Many people who are already vulnerable face worse living situations as a result of climate change, especially in developing nations where there is a dearth of assets and sufficient insurance coverage. According to [28], climate change is expected to result in a general drop in cereal crop yields in Africa by shortening the growing season, intensifying water stress, and raising the frequency of disease, insect, and weed outbreaks. Among the various environmental changes brought by climate change that limits crop yields, heat and water stresses are considered the most important [33]. The major impacts of climate change are predicted to be harsh in sub-Sahara Africa because of the region's characteristic of high heat stress and low precipitation [49, 46]. Africa is most vulnerable to climate change and climate variability and the situation is aggravated by the interaction of multiple stresses occurring at various levels and low adaptive capacity. Agricultural production and food security (including access to food) in many African countries and regions are likely to be severely compromised by climate change and climate variability [15]. Climate change is expected to shorten the growing season and drive out vast areas of marginal agriculture, in addition to the semi-arid conditions that already provide challenges for agriculture in some African countries.

Agriculture, which is the mainstay of the Ethiopian economy, is highly exposed to the impacts of climate change which threatens sustained economic growth that will lead to extended poverty. However, like the rest of Sub-Saharan Africa, Ethiopia's agriculture is mainly rain-fed and therefore highly vulnerable to climate change. Rain-fed crop production is the basis of all subsistence farming in most parts of Ethiopia and accounts for more than 95% of the land area cultivated annually. In semi-arid regions, a typical agricultural household owns a tiny plot of land (usually less than one hectare) that is used to grow crops and partially sustains varying numbers of sheep, goats, cattle, and donkeys [9]. According to [9] climate change, especially increasing temperature has a damaging impact on Ethiopian agriculture. In Ethiopia, models indicate that the average daily rainfall amount will decline to around 1.97 mm from 2070 to 2099. The decrease in rainfall amount will be aggravated by increased evapotranspiration rates caused by likely mounting temperatures and aridity. The mean annual temperature will rise to 26.9^{o}C during 2070-2099 [8]. On the other hand, the [27] revealed that in Ethiopia climate variability and change in the country are mainly manifested through the variability and a decreasing trend in rainfall and increasing trend in temperature. Besides, rainfall and temperature patterns show large regional differences [26].

2.2.4. Coffee Production and Its Importance in Ethiopia

Coffee is growing in more than 60 tropical countries among which Ethiopia is one, and its production is a significant contributor to agricultural GDP. Coffee (Coffee *arabica L.*) is an economically important crop, which is contributing the highest of all export revenues in Ethiopia accounting for about 27-34 % of the value of all exports. It is a cornerstone in the export economy of the country and it supports directly or

indirectly for about 25 mill livelihoods of people. As is widely known, Ethiopia is the only Arabica coffee origin and diversification center [48]; in the country's western, southern, and southwest regions, coffee is produced using four different production systems: forest, semi-forest, garden, and plantation coffee [6]. Of the Southwestern parts of the country, Jimma Zone is one of the coffee-growing zones by small-scale farmers' holdings as well as state and private-owned plantations. The Garden coffee production system is predominantly implemented by small–scale farmers' holdings.

2.3. Adaptation to Climate Variability

Stafford defines adaptation as "the entire adjustment made or self-made within natural and human systems as a therapeutic or preventative reaction to present or future climatic stimuli or their consequences in order to limit harm or take benefit of it at the appropriate moment [37]." [42] define adaptation as a shift in ecological, social, and economic systems in reaction to climate stimuli—actual or predicted—and its ramifications. Consequently, these are modifications to procedures, customs, and frameworks to lessen possible harm or seize chances brought about by climate change. It is defined as a change in procedures, practices, and structures aimed at limiting or eliminating potential damages or taking advantage of opportunities created by variability and climate change.

Adaptation to Climate Variability and Change

Making decisions about how to adapt to the consequences of climate change coffee yield. The impact of numerous climate variables on agricultural yields needs to be isolated and measured in order to execute such techniques. A different adaptation approach, for example, will be needed in response to a change in temperature than a change in rainfall [1]. In order to study adaptation strategies that can be utilized to increase food productivity under climate change in Cameroon, [45] combined climate and crop models. The study's findings suggest that using new crop cultivars—late-maturing and heat-tolerant cultivars—can significantly lessen the negative effects of climate change on food supply in Cameroon.

There are two different types of production system adjustments involved in agricultural adaptation. The first is more diversification, which entails engaging in production activities that can withstand temperature stressors and/or droughts as well as activities that effectively utilize and fully exploit the current water and temperature circumstances, among other considerations. Given that different crops are impacted by climate events differently, crop diversification can act as insurance against rainfall variability [31].

The second technique focuses on crop management procedures designed to prevent crucial crop growth stages from coinciding with extremely unfavorable weather circumstances, such as dry periods in the middle of the growing season. Changes in planting and harvesting dates, as well as lengthening the growing season, are all possible crop management techniques. Testing possibilities for adaptation in-depth seemed to be hindered by a number of factors. Prioritizing among crop management modifications that could be adaptive is the main challenge, particularly for interacting practices like planting dates, fertilizer levels, cultivar selection, and irrigation management [31].

3. Conclusion

Ethiopia's climate is distinguished by notable regional variations in temperature and precipitation data. The three seasons in the nation are kiremt (long rainy season) from June to September, belg (short rain season) from February to May, and bega (dry season) from October to January. The average annual temperature of the nation varies from approximately 10^0C in the northwest, central, and southeast highlands to approximately 35^0C in the northeastern lowlands, reflecting the country's diverse topography. Ethiopia's diverse terrain, together with the yearly movement of the ITCZ and associated atmospheric circulations, have a significant impact on the country's climate. Climate has a major impact on local people's living conditions, natural landscapes, and landforms. Water availability fluctuations can impact agricultural revenue and productivity; the majority of these fluctuations are brought about by variations in the timing and intensity of rainfall within a given year [14, 15].

A tight balance between agricultural output and food security is created by climate variability, which affects agroecological, agricultural, and cattle growth conditions. In semi-arid regions of the world, high climate variability—such as low and uneven rainfall distribution—is predicted to have an impact on the yields of food crops, including wheat, rice, and maize. Rainfall also affects crop enterprises, crop sizes, cropping schedules, and the prevalence and growth of diseases, weeds, and crop pests among Sub-Saharan African smallholder farmers. Ethiopia's geography and geographic location contribute to its irregular rainfall patterns, which present serious threats to farmers who depend on agricultural productivity. The two main rainy seasons in the nation are "belge" and "kiremt," with the former providing more than 90% of the agricultural output. Catastrophic floods and famines have been brought on by droughts [5].

Global food insecurity is a serious risk as a result of climate change's negative effects on agricultural productivity. Africa has a high rate of poverty, frequent droughts, unequal land distribution, and an excessive dependence on rain-fed agriculture, making it one of the most vulnerable regions in the world to climate change. Unpredictability and climate change limit agricultural expansion, impact cultivar and crop species selection, and influence farm management choices. The agricultural sector is a major contributor to greenhouse gas emissions, and climate change has the potential to seriously damage the natural resource base that supports agriculture as well as have a det-

rimental effect on agricultural productivity. Agronomic productivity is already being harmed by invasive species, pests, and disease vectors, and climate change is expected to make the situation worse [36]. According to the [14] report, food yields and crop production systems around the world are becoming more vulnerable to climate change. Raising greenhouse gas concentrations have the potential to impact agricultural production systems by causing global and regional variations in precipitation and temperature. Droughts and floods brought on by climate change have damaged and destroyed crops in East Africa. It is anticipated that variations in temperature and rainfall will reduce agricultural output, leading to a rise in crop failure in the short run and a decline in productivity over the long run. It is anticipated that climate change will have a detrimental overall impact on food productivity, even in the case of notable advancements in individual crops. Raising the average temperature can damage crops in areas with low yields while extending the growing season in milder climates. Additionally, shorter seed development durations, higher respiration rates, and lower biomass output are caused by rising temperatures.

Coffee is susceptible to drought, over-wetting, and wind damage because its production and quality are largely dependent on temperature and rainfall levels. In key coffee-growing regions around the world, the yield of coffee is at risk due to climate change and unpredictability. The production of coffee is expected to be severely impacted by high temperatures and unpredictable rainfall patterns in terms of yield, quality, pests, and illnesses. Coffee distribution and commercial use depend on the establishment of suitable air temperature limitations.

Global agricultural systems are highly vulnerable to the effects of climate change, especially in developing countries with inadequate insurance and resource availability. It is anticipated to shorten the growing season, exacerbate water stress, and increase outbreaks of weeds, insects, and disease while also lowering cereal crop yields in Africa. Sub-Saharan Africa, with its high levels of heat stress and limited precipitation, is especially vulnerable to climate variability and change. Climate variability and change are anticipated to have a significant negative impact on agricultural productivity and food security. Ethiopia's primarily rain-fed agriculture is extremely susceptible to the effects of climate change; projections indicate that daily average rainfall will decrease between 2070 and 2099 [8].

The term "climate variability" describes how biological, social, and economic systems alter in response to climatic cues. These adjustments seek to mitigate the effects of climate change or take advantage of its potential. Temperature and rainfall are two examples of climate variables that can affect coffee production adaptation options. Using novel crop cultivars, such as late-maturing and heat-tolerant cultivars, can lessen the detrimental effects of climate change on the availability of food, according to a Cameroonian study. Two types of adaptation techniques exist: crop management, which entails avoiding critical crop growth stages from coinciding with unfavorable weather circumstances, and diversification, which entails engaging in productive activities that can tolerate temperature stresses and droughts. However, issues like prioritizing adaptive techniques like planting dates, fertilizer levels, cultivar selection, and irrigation management make it difficult to explore adaptation potential in-depth [31].

Abbreviations

GDP	Growth Development Program
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
ITZ	Intertropical Convergence Zone
SSA	Sub-Saharan African

Author Contributions

Zinash Nigussie is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Ainsworth, E. A., Beier, C., Calfapietra, C., Ceulemans, R., DURAND‐TARDIF, M. Y. L. E. N. E., Farquhar, G. D., Godbold, D. L., Hendrey, G. R., Hickler, T., Kaduk, J. and Karnosky, D. F., 2008. Next generation of elevated [CO2] experiments with crops: a critical investment for feeding the future world. *Plant, cell & environment*, *31*(9), pp. 1317-1324. https://doi.org/10.1111/j.1365-3040.2008. 01841.x

[2] Bakri, H. H. and Abou-Shleel, S. M., 2013. Economic impacts of climatic changes on some vegetable crops in Egypt. *World Journal of Agricultural Sciences*, *9*(4), pp. 361-368. https://10.5829/idosi.wjas.2013.9.4.75193

[3] Battisti, D. S. and Naylor, R. L., 2009. Historical warnings of future food insecurity with unprecedented seasonal heat. *Science*, *323*(5911), pp. 240-244. https://doi.org/10.1126/science.1164363

[4] Bozzano, M., Öalonen, R., Thomas, E., Boshier, D. and Loo, Ö. 2014. Food and agriculture organization of the united nations Rome.

[5] Central Statistical Agency (CSA). 2008a. Agricultural Sample Survey, 2007/08 (2000 EC), Volume II: Report on Livestock and Livestock Characteristics (Private Peasant Holdings). Statistical Bulletin 417. Addis Ababa: CSA, Federal Democratic Republic of Ethiopia.

[6] CFC (Common Fund for Commodities). 2004. Improving coffee quality in east and Central Africa through enhanced Processing practices; A (CFC/ICO/22) Project for Rwanda and Ethiopia, Final Appraisal Report. The Netherlands, Amsterdam. pp. 10-11.

[7] Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R. K., Kwon, W. T., Laprise, R. and Magaña Rueda, V., 2007. Regional climate projections. Chapter 11.

[8] Cline, W. R., 2007. *Global warming and agriculture: End-of-century estimates by country*. Peterson Institute.

[9] Deressa, T., 2007. Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach. World Bank Policy Research Paper No. 4342. World Bank, Washington, DC.

[10] Getaneh, A., Tadesse, F. and Ayele, N., 2015. Agronomic Performance Evaluation of Ten Sugarcane Varieties under Wonji-Shoa Agro-Climatic Conditions. *Scholarly Journal of Agricultural Science*, *5*(1), pp. 16-21.

[11] Hadgu, G., Tesfaye, K. and Mamo, G., 2015. Analysis of climate change in Northern Ethiopia: implications for agricultural production. *Theoretical and applied climatology*, *121*, pp. 733-747. https://doi.org/10.1007/s00704-014-1261-5

[12] Haggar, J. and Schepp, K., 2012. Coffee and climate change. Impacts and options for adaption in Brazil, Guatemala, Tanzania and Vietnam. *Climate Change, Agriculture and Natural Resource*, (4).

[13] Houghton, J. T., Ding, Y. D. J. G., Griggs, D. J., Noguer, M., van der Linden, P. J., Dai, X., Maskell, K. and Johnson, C. A. eds., 2001. *Climate change 2001: the scientific basis: contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change*. Cambridge university press. https://doi.org/10.1002/qj.200212858119

[14] Intergovernmental Panel on Climate Change (IPCC). 2007. New Assessment Methods and the Characterization of Future Conditions: In Climate change 2007: Impacts, adaptation and vulnerability, pp: 976. Contribution of working group II to the fourth assessment report of the Intergovernmental panel on climate change. Cambridge university press, Cambridge, UK.

[15] Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability: Regional Aspects. Cambridge University Press.

[16] Kimball, B. A., 1983. Carbon dioxide and agricultural yield: An assemblage and analysis of 430 prior observations 1. *Agronomy journal*, *75*(5), pp. 779-788. https://doi.org/10.2134/agronj1983.00021962007500050014x

[17] Korecha, D. and Barnston, A. G., 2007. Predictability of june–september rainfall in Ethiopia. *Monthly weather review*, *135*(2), pp. 628-650. https://doi.org/10.1175/MWR3304.1

[18] Love, D., Uhlenbrook, S., Twomlow, S. and van der Zaag, P. 2008. Changing rainfall and discharge patterns in the northern Limpopo Basin, Zimbabwe. European Geophysical Union General Assembly, Viena, Austria, April 2008. http://www.worldwaterweek/stockholmwatersymposium/Abstract_volume_06/ workshop_9.htm

[19] Lobell, D. B., Cassman, K. G. and Field, C. B., 2009. Crop yield gaps: their importance, magnitudes, and causes. *Annual review of environment and resources*, *34*(1), pp. 179-204. https://doi.org/10.1146/annurev.environ.041008.093740

[20] Lema, M. A. and Majule, A. E., 2009. Impacts of climate change, variability and adaptation strategies on agriculture in semi-arid areas of Tanzania: The case of Manyoni District in Singida Region, Tanzania. *African Journal of Environmental Science and Technology*, *3*(8), pp. 206-218. https://10.5897/AJEST09.099

[21] Marengo, J. A. and Antonie, S., 2009. Assessment of Impacts and Vulnerability to Climate Change in Brazil and Strategies for Adaptation Option. *Crop Science Journal2009*, pp. 5-26.

[22] Mengistu, D., Bewket, W. and Lal, R., 2014. Recent spatio-temporal temperature and rainfall variability and trends over the Upper Blue Nile River Basin, Ethiopia. *International Journal of Climatology*, *34*(7). https://10.1002/joc.3837

[23] Meza-Pale, P. and Yunez-Naude, A., 2015. The effect of rainfall variation on agricultural households: Evidence from Mexico.

[24] Mokria, M., Gebrekirstos, A., Abiyu, A., Van Noordwijk, M. and Bräuning, A., 2017. Multi‐century tree‐ring precipitation record reveals increasing frequency of extreme dry events in the upper Blue Nile River catchment. *Global Change Biology*, *23*(12), pp. 5436-5454. https://doi.org/10.1111/gcb.13809

[25] Muya, M. (2008). Improving productivity of field crops and post-harvest management in northwest Tanzania. Ministry of Agriculture, Food and Cooperatives. pp. 148- 167.

[26] National Meteorology Agency (NMA). 2007. Final Report on Evaluation Criteria for Identifying High Priority Adaptation Activities prepared by B and M Development Consultants for NMA. Addis Ababa, Ethiopia.

[27] National Meteorological Services Agency (NMSA). 2001. Report submitted to initial national communication of Ethiopia to the United Nations Framework Convention on Climate Change, Addis Ababa, Ethiopia.

[28] Niang, I., O. C. Ruppel, M. A. Abdrabo, A. Essel, C. Lennard, J. Padgham, et al. 2014. Africa. Pp. 1199–1265 in V. R. Barros, C. B. Field, D. J. Dokken, M. D.

[29] Oki, T. and Kanae, S., 2006. Global hydrological cycles and world water resources. *science*, *313*(5790), pp. 1068-1072. https://doi.org/10.1126/science.1128845

[30] Olesen, J. E. and Bindi, M., 2002. Consequences of climate change for European agricultural productivity, land use and policy. *European journal of agronomy*, *16*(4), pp. 239-262. https://doi.org/10.1016/S1161-0301(02)00004-7

[31] Orindi, V. A. and Eriksen, S., 2005. Mainstreaming adaptation to climate change in the development process in Uganda.

[32] Orlandi, F., Rojo, J., Picornell, A., Oteros, J., Pérez-Badia, R. and Fornaciari, M., 2020. Impact of climate change on olive crop production in Italy. *Atmosphere*, *11*(6), p. 595. https://doi.org/10.3390/atmos11060595

[33] Prasad, P. V. V., Staggenborg, S. A. and Ristic, Z., 2008. Impacts of drought and/or heat stress on physiological, developmental, growth, and yield processes of crop plants. *Response of crops to limited water: Understanding and modeling water stress effects on plant growth processes*, *1*, pp. 301-355. https://doi.org/10.2134/advagricsystmodel1.c11

[34] Reynolds, M. P. ed., 2010. *Climate change and crop production*. Cabi.

[35] Rickards, L. and Howden, S. M., 2012. Transformational adaptation: agriculture and climate change. *Crop and Pasture Science*, *63*(3), pp. 240-250. https://doi.org/10.1071/CP11172

[36] Rosenzweig, C., Tubiello, F. N., Goldberg, R., Mills, E. and Bloomfield, J., 2002. Increased crop damage in the US from excess precipitation under climate change. *Global Environmental Change*, *12*(3), pp. 197-202. https://doi.org/10.1016/S0959-3780(02)00008-0

[37] Stafford, M.R., 2005. International services advertising (ISA): defining the domain and reviewing the literature. *Journal of Advertising*, *34*(1), pp. 65-86. https://doi.org/10.1080/00913367.2005.10639184

[38] Segele, Z. T. and Lamb, P. J., 2005. Characterization and variability of Kiremt rainy season over Ethiopia. *Meteorology and Atmospheric Physics*, *89*(1), pp. 153-180. https://doi.org/10.1007/s00703-005-0127-x

[39] Singh, S. N. ed., 2009. *Climate change and crops*. Springer Science & Business Media.

[40] Schreck III, C. J. and Semazzi, F. H., 2004. Variability of the recent climate of eastern Africa. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *24*(6), pp. 681-701.

[41] TACRI (Tanzania Co. ee Research Institute). 2008. TACRI annual report 2008. Lyamungu, Tanzania.

[42] Tarleton, M. and Ramsey, D., 2008. Farm-level adaptation to multiple risks: climate change and other concerns. *Journal of Rural and Community Development*, *3*(2).

[43] Tesfaye, K. and Walker, S., 2004. Matching of crop and environment for optimal water use: the case of Ethiopia. *Physics and Chemistry of the Earth, Parts a/b/c*, *29*(15-18), pp. 1061-1067. https://doi.org/10.1016/j.pce.2004.09.024

[44] Torres, M., Howitt, R. and Rodrigues, L., 2019. Analyzing rainfall effects on agricultural income: Why timing matters. *EconomiA*, *20*(1), pp. 1-14. https://doi.org/10.1016/j.econ.2019.03.006

[45] Tingem, M., Rivington, M. and Bellocchi, G. 2009. Adaptation assessments for crop production in response to climate change in Cameroon. *Agronomy for Sustainable Development* 29: 247-256.

[46] Thornton PK, Jones P, Alagarswamy G, Andresen J. 2009. Spatial variation of crop yield response to climate change in East Africa. Global Environmental Change 19: 54–65. https://doi.org/10.1016/j.gloenvcha.2008.08.005

[47] Uprety, D. C., Reddy, V. R. and Mura, J. D., 2019. Historical Analysis of Climate Change and Agriculture. In *Climate Change and Agriculture* (pp. 7-29). Springer, Singapore. https://doi.org/10.1007/978-981-13-2014-9_2

[48] Vavilov, N. I., 1951. *The origin, variation, immunity and breeding of cultivated plants* (Vol. 72, No. 6, p. 482). LWW.

[49] World Bank, 2006b, Managing Climate Risk: Integrating Adaptation into World Bank Group Operations, World Bank, Washington, DC.

[50] Waggoner, P. E., 1983. Agriculture and a climate changed by more carbon dioxide. *Changing Climate*, pp. 383-418.

[51] Yengoh, G. T., Tchuinte, A., Armah, F. A. and Odoi, J. O., 2010. Impact of prolonged rainy seasons on food crop production in Cameroon. *Mitigation and Adaptation Strategies for Global Change*, *15*, pp. 825-841. https://doi.org/10.1007/s11027-010-9241-2