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Research Article

The Effect of Climate Change on Agricultural Output in Ethiopia

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Abstract

Globally, the most pressing environmental issue at the moment is thought to be climate change. The resulting effect is a clear deterioration in both overall economic growth and agricultural output. The objective of the study was to look at how climate change might affect Ethiopian agricultural productivity in the short- and long-run between 1990 and 2023. An analysis of the short- and long-run effect of climate change on agricultural output was conducted using the ARDL cointegration approach. For the unit root test, the ADF test was employed. The results of the bound test exhibit that the real agricultural GDP, labour force, average annual rainfall, carbon dioxide emissions, average annual temperature, agricultural land and imports of fertilizer inputs have a stable long-run relationship. The estimated long-run model shows that the country's main component of GDP, agricultural output, is significantly impacted by climate change. The error correction term's coefficient is -0.783, indicating an annual adjustment of nearly 78.3% percent towards long-run equilibrium. The estimated coefficients of the short-run show that mean annual rainfall have a significant effect whereas the average temperature is an insignificant effect on output. Average temperature has a negative effect on agricultural output over the long run, whereas mean annual rainfall has positive effect. These are the two key variables of significance. According to the study, in order to lessen the effects of climate change, the government and other stakeholders should develop specific policies. They should also concentrate on technological innovation that prevents temperature increases from increasing output and the adoption of technology at both the macro and micro levels.

Keywords

Ethiopia, ARDL Method of Co-integration, Agricultural Output, Climate Variable

1. Introduction

Worldwide climate change frequently causes a series of natural, social, environmental and economic issues that are threatening human advancement and survival. Human society has experienced a several adverse consequences caused by climatic changes such as glacier melting, sea level rise and the increase of natural calamities (such as severe tropical storms, heat waves and irregular precipitations).

The concentration of energy of the climate system is impacted by extensive changes in land cover, solar radiation, and the environmental levels of greenhouse gases (GHGs) and aerosols. Greenhouse gases emissions are increment over time due to human activities. Economic and population growth are most drivers of the increase in Carbon dioxide [1]. More than 75% of all Co2 emission comes from developed countries. Recently there is accelerating emission GHGs in developing countries, especially in emerging economies like

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Brazil, China, and India had a serious concern. Moreover, the effect is not evenly distributed. Since they are more susceptible to the negative effects of rising sea levels and the impact on water resources, ecosystems, crop production, fisheries, and human health, the poorest countries and people will suffer the most from climate change [2].

Ethiopia is one of the least developing countries in the world, but recently Ethiopia has achieved better growth and poverty reduction in recent years, with GDP growth averaging 10.1 percent in 2010/11 to 2014/25, about 8 percent GDP per capita growth and in 2015/16 to 2020/21 Ethiopia GDP growth average 7.9 percent, about 6.7 percent GDP per capita growth. With a 30 percent Gini index, poverty has significantly decreased and inequality is low by both international and Sub-Saharan African (SSA) standards [3]. Ethiopia, however, depends mostly on rain-fed agriculture. Due to its topography, geographic location, and limited capacity for adaptation, the nation is very vulnerable to the negative effects of climate change. As a result, droughts occur periodically, which has a direct impact on agricultural productivity [4]. As a result, the nation experiences varying drought-related issues at different times, which might result in protracted chronic food shortage and food insecurity [5]. For example, in several parts of Ethiopia in 2015/16, El Niño driven climate change created one of the worst droughts. This had a direct impact on the performance of the agricultural sector, which in turn affected other economic sectors [6].

The rural population in Ethiopia that relies on the production of agricultural products for their livelihoods and income is directly impacted by the agriculture sector's vulnerability to climate change. In addition, the increasing cost of agricultural products has an indirect impact on the urban population and other sectors such as the industry sector, which uses agriculture's raw materials. Food security, the availability of electricity and water, the fight against poverty, and sustainable development initiatives would all be impacted, which would have an impact on the nation's economy [7]. Ethiopia is experiencing climate change, which has a direct impact on the nation's agricultural output, which is dependent on climatic input.

The economy would be impacted by modifications to the pattern of rainfall and temperature. Due to El Niño, Ethiopia saw its lowest annual rainfall in thirty years in 2015. This had an impact on the country's economy, as half of its GDP is derived from agriculture, and 99% of its electrical energy is produced by hydroelectric power, which is reliant on rainfall [8]. Through the year 2045, Ethiopia's GDP might drop by up to 10% due to climate change, primarily because of effects on agricultural production. These changes would also impede economic growth and exacerbate already-existing social and economic problems [9].

Along with of the agricultural industry's significance, any shock associated with climate change in the agriculture sector will affect the economy more broadly in both agriculture and other sectors. Previously research is conducted in this area, for instance, [10] studies the economic wide effect of climate change, [11] analyzed the impact of climate change on Ethiopian agriculture by Ricardian approach, [12] conducted economic impact of climate change and [13] analyzed the impact of climate change on economic growth. Most of those researches are used computable general equilibrium analysis which faces a limitation in that it doesn’t consider the temporal effect of climate change on agriculture, Ricardaian approach is based on survey data on climate change so it may face valuation problem by respondents and require knowledge and the other examined impact of climate change on economic growth, but climate change directly affect agricultural production. To the researcher's knowledge, there is no evidence about the paper that relates climate change to single aggregate agricultural output that used time series analysis and the aim is to fill the gap and supplement the existing literature, and researching in this area is useful for national policies. So the study focuses on the effect of climate change on agricultural output in Ethiopia by using time series data that span from 1990 to 2023.

2. Overview of Historical Development

Ethiopia is home to close to 120 million people, and it currently stands to be the second most populated country in Africa. Agricultural sector contributes about 40% of the Gross Domestic Product (GDP), 75% of employment, and 80% of export [14]. More than 85% of the rural population that depends on agricultural output is smallholder farmers. Ethiopia has liberalized its economy and developed poverty reduction strategies that support market-led methodologies for wide based agricultural development, poverty reduction and economic growth. Within the broader strategy, the focus given to support smallholder farming is believed to be the key rural household’s poverty reduction. Given the total sum of the population that directly and indirectly make their livelihoods from the sector; its improvement is seen as implies to move forward the living guidelines of smallholders and generate economic growth. However, the production is still characterized by low output, poor access to land, poor access to inputs, poor irrigation system, little access to know-how (risk management, technology, and skill), low level of market orientation, poor infrastructure and under developed institutions [15].

High levels of food poverty and persistent disputes over natural resources are caused by the nation's vulnerability to climate change, which is exacerbated by the aforementioned difficulties and the many development barriers. Even in years with adequate rainfall, 10% of the population has chronic food insecurity. A little over two thirds of people live on less than $2 a day, and there are few access points to essential services. Climate has a significant impact on the three rural livelihood systems of crop farming, pastoralism, and agro-pastoralism. Seasonal rainfall patterns are associated with patterns of food insecurity and rural household poverty; trends in hunger are shown to decline sharply following the wet seasons. Livelihoods are already badly impacted by climate variability, and this is probably going to get worse. In Ethiopia, drought is the most devastating natural hazard associated with climate change. By 2045, climate change is predicted to have a negative impact on Ethiopia's GDP of up to 10%, mostly through decreased agricultural production. Additionally, these modifications impede economic growth and exacerbate current social and economic issues [16]. Additionally Climate change challenges, including droughts, shifting seasons, floods and pest and disease outbreaks, pose a significant risk to agriculture, contributing to its fragility status. According to the 2020 Notre Dame Global Adaptation Initiative (ND-GAIN) Index, Ethiopia ranks 161st of 181 countries, and the World Risk Index indicates a risk of natural disasters between 5.88 and 12.88, with an exposure index of 0.511 and a vulnerability index of 0.56. Ethiopia's dependence on rain-fed agriculture, lack of adaptability, and climate-related risks make it vulnerable to climate change.

3. Literatures Review

3.1. Theoretical Review

Theories of climate change that are quite familiar are the anthropogenic or man-made global warming, or Anthropogenic or Man-Made Global Warming (AGW). According to the theory, man-made greenhouse gases like carbon dioxide, which were first produced 50 years ago, are the primary cause of global warming [17]. These gases cause a catastrophic rise in temperature which is commonly referred to as enhanced greenhouse effect or the theory of anthropogenic global warming. Energy from the sun travels and reaches the Earth’s surface through its transparent atmosphere to the surface of the earth where some of it is absorbed and some is reflected back as heat into the atmosphere.

The reflected heat is absorbed by the GHGs resulting in the Earth's atmosphere becoming warmer than it otherwise could have been. The proponents of this theory hold that over 0.7°C global warming for the past century and over 0.5°C for the last 30 years had been attributed to GHGs which are man-made and rejected the claim that it could be as a result of recovery from Ice Age. The computer models used in the theory to postulate future GHGs level predicted that doubling the level of carbon dioxide in the atmosphere would make the Earth’s temperature to rise further. The model also predicts that more warming would be experienced at the tropics due to warming of the troposphere than the level that has been observed by the satellites and radiosonde measurements. It is argued in the theory that man-made carbon dioxide is the main contributor of severe weather, oceanic coral bleaching, crop failures, species extinctions, floods, droughts, famines and spread of diseases while the study determine the effect of climate change on agricultural production.

The Bio-thermostat theory of climate change as put forward by [18], holds that negative feedbacks from biological and chemical processes wholesomely counteract positive feedbacks caused by rising CO2. The rise of CO2 in the atmosphere is due to increased carbon sequestration by plants and higher temperatures are also responsible for this increase. As carbon dioxide is a necessary raw material for photosynthesis in plants, the more carbon dioxide there is in the atmosphere, the more beneficial it is. The amount of carbon dioxide that can be offset by increased atmospheric concentrations depends on the size, rate of growth, and duration of carbon sinks.

In essence, the influence of climate change on agricultural output is a problem for both ecological growth and food security. In most developing nations, agricultural output is strongly linked to both the long-term needs of humankind for food and nutrition, as well as the livelihoods of farmers. Numerous researches are currently examining how climate change is affecting agricultural productivity. There is a wealth of research on how crop output is affected by climate change, but no single comprehensive study has been done on how agricultural productivity is affected by climate change [19].

Agriculture is impacted by climate in a number of ways. A number of factors, including temperature, radiation, rainfall, soil moisture, changes in the growing season, changes in pests and diseases, changes in atmospheric carbon dioxide, changes in the nutritional value of some foods, changes in sea level, and variations in the concentration of carbon dioxide (CO_2), are key factors of agricultural productivity, and their correlations are not merely linear [20].

3.2. Review of Empirical Studies

[21] Investigated how climate change was affecting Nigeria's economy using the OLS method and error correction model. In order to quantify climate change, time series data variables such as yearly rainfall, carbon emissions, and forest depletion are employed. Government spending, domestic private investment and exchange rates are used as control variables. They discovered that while forest loss has negative short-term effects, carbon emissions have negative long- and short-term effects on growth.

The study conducted by [22] examined the impact of climate change on Pakistan's economic growth. When the study's results are broken down, they reveal that temperature has a negative and significant association with GDP. The industrial, services, and agricultural sectors all have negative relationships with productivity. The agriculture industry is more negatively impacted than the manufacturing or service sectors.

Assesses how the effects of climate change on the agriculture sectors of African countries which are vital to these countries' economies are contributing to an increase in poverty throughout the continent. [23] It demonstrates that the poor are particularly exposed to the effects of climate change in Africa, as they are globally. The article also mentions how vulnerable African countries are to the effects of carbon dioxide despite their low carbon dioxide emissions. The author comes to the conclusion that rather than focussing on reducing carbon emissions, Africa's approach to climate change adaptation has been shaped by this paradox.

Talk on how Ethiopia's food security is being impacted by climate change, particularly in terms of agricultural productivity. [24] A sizable percentage of Ethiopians work in agriculture mainly, in home farming. The essay investigates the driving forces behind home farmers' adoption of climate change adaptation strategies. It assesses the effects of these modifications on Ethiopian farmers' crop production as well. Finally, the author offers some adaptation strategies that are most likely to stop crop output declines brought on by climate change.

The effects of climate change on Ethiopia's vulnerability in producing maize are evaluated by [25]. As it is described, maize is a staple crop of Ethiopian agricultural production and is essential to a large amount of the population's food security in addition to providing a sizable portion of income for farmers. According to the report, both biophysical and socioeconomic issues impede Ethiopian family farmers' ability to produce food. The author offers tailored ways to increase agricultural output in response.

Using a national CGE model, [26] examined the financial effects of climate change-related adaptations on Tanzania's economic performance. According to this study, the predicted impact of global climate change on agricultural productivity is initially somewhat small but gets worse with time. Nonetheless, the extended durations and low initial value of the economy offer sufficient time for element substitutability, enabling adaption strategies to substitute lower land productivity with higher labour and capital utilization. As a result, the authors concluded that the overall effect on Tanzania's economy might be fairly small over time.

4. Methodology and Data Sources

4.1. Data Description and Sources

Table 1. *Summary of the data source by variable.*

Type of variables	Unit of Measurements	Source of variables
Agricultural output	Real Agricultural GDP	NBE
Labor force	Total labor force(15-64) ages	CSS
Agricultural land	Percentage of total land	WDI
Mean annual temperature	Celsius per year	EMA
Mean annual rainfall	Millimeters per year	EMA
C02 Emission	Metric ton	EMA
Fertilizer input imports	Metric ton	NBE

Source: Computed by authors

Note: NBE-National Bank of Ethiopia, CSS-Central Statistics Service, WDI- World Development Indicators, EMA- Ethiopia Metrology Agency

4.2. Method of Data Analysis and Estimation Techniques

4.2.1. Unit Root Test

The reason for conducting a stationarity test is the use of non-stationary data can lead to spurious regressions. If the variables employed in a regression model are not stationary, then it can be proved that the standard assumption for asymptotic analysis will not be valid. In other words, the usual's-ratios' will not follow a t-distribution, and the F-statistic will not follow an F-distribution, and so on [27].

To test unit root there are several varying approaches have been developed. Among the methods of testing the presence of a unit root in a series the common ones include Dickey-Fuller (DF), and Augmented Dickey Fuller (ADF), Based on DF test, the series Y is stationary if the absolute value of 'δ' in the equation is less than unity. However, it is not stationary if the absolute value of 'δ' is greater than or equal to unity.

$$Y_t = \delta Y_{t-1} + \mu_t \quad (1)$$

$$\Delta Y_t = \alpha Y_{t-1} + \mu_t \quad (2)$$

Where, $\alpha = (1-\delta)$

Hence, the null that δ=1 is equivalent to H0: α=0. However, DF test assumes that the data generating process follows the Auto Regressive of order one which biases the test in the presence of serial correlation. In order to calculate the critical values of the τ (tau) statistic, Dickey-Fuller assumes that the error terms (μ_t) are not correlated [28]. But the error term in the Dickey-Fuller test usually has autocorrelation, which needs to be removed if the result is to be valid. In addition, the critical values of τ (tau) statistics do not follow the normal distribution function and in general, the critical value is considerably larger than its counterpart of t- distribution. Therefore, using such critical values can lead to the over-rejection of the null hypothesis when it is true. The ADF unit root test is used to overcome this limitation of DF test. ADF overcome these limitations by adding additional lag of the first difference of the dependent variable. Therefore, this study used ADF test for stationary test.

Procedure for ADF test

$$\Delta Y_t = \alpha + \delta t + \gamma Y_t - 1 + \sum \mu \Delta y_t - i + \varepsilon tpt \quad (3)$$

Where: δ is a time series variables under consideration in this model at time t,

t- Time trend variable

Δ - Denotes the first difference operator

εt - the error term; p is the optimal lag length of each variable chosen such that first- differenced terms make a white noise.

Thus, the ADF test is the null hypothesis of no unit root (stationary).

That is: $H0:\gamma = 0 : H1:\gamma \neq 0$ If the t value or t-statistic is more negative than the critical values, the null hypothesis (I.e. H0) is rejected and the conclusion is that the series is stationary. Conversely, if the t-statistic is less negative than the critical values, the null hypothesis is accepted and the conclusion is that the series is non-stationary.

4.2.2. Co Integration Test

The term of co-integration was first introduced by [29] after the work of [30] on spurious regression. It identifies a situation where two or more non-stationary time series are bound together in such a way that they cannot deviate from some equilibrium in the long term. In other words, there exist one or more linear combinations of those I(1) time series (that is stationary (or I(0)). Those stationary combinations are called cointegrating equations. There are three major methods of testing co-integration: the Engel-Granger two-step procedure (EG), the Johansen Maximum Likelihood procedure and ARDL bound test approach to co-integration. There are drawbacks to the Engle-Granger. These drawbacks are that the Johansen co-integration approach method requires a variable to be integrated order of same whether I(0) or I(1) but not mix of the two, and it is challenging to determine the number of equilibrium relationship if the variable is more than two since it allows for single co-integration. However, ARDL solves this issue.

4.2.3. ARDL Bound Test Approach to Co Integration

The Johansen co-integration technique has been applied in numerous previous researches to ascertain the long-term correlations between variables of interest. Actually, a lot of academics continue to use this method since they believe it to be the most accurate one to use when dealing with I(1) variables. The Autoregressive Distributed Lag (ARDL) bound test is an alternative co-integration technique that has been proposed recently, nevertheless, by a series of research by [31]. Comparing this method against Johansen co-integration methods reveals some benefits. To start, the more statistically significant method for figuring out the co-integration connection in small samples is the ARDL model. The ARDL model can be used to derive the error correction model, which integrates short-run adjustments with long-run equilibrium without sacrificing long-run information. The error correction term indicates the amount of disequilibrium being corrected, or how much of any disequilibrium from the prior period is adjusted for the current year.

4.2.4. Model Specification and Theoretical Framework

This study aims to examine how Ethiopian agriculture output is affected by climate change. The research begins with [32] on the neo-classical growth model. The production function that is neo-classical is defined in terms of conventional inputs such as capital and labour. The neoclassical production function that follows was employed. The benefit of this approach is that, as noted by [33], it explicitly accounts for other inputs. The drawback is that it ignores the entire spectrum of compensatory measures that farmers have taken in response to climatic changes [34].

$$Y_t = (L_t K_t) \quad (4)$$

Where Yt- is aggregate real output, Lt- is labor and kt- is capital inputs

The model is specified as the following

$$Y(t) = f(Temp, C02, LF, Fer, Rain, Agland) \quad (5)$$

Then converting to the Econometric model is:-

$$RagGDP = \beta_0 + \beta_1 Temp + \beta_2 C02 + \beta_3 LF + \beta_4 Fer + \beta_5 Rain + \beta_6 Agland + \varepsilon_t \quad (6)$$

Where, RagGDP=natural logarithm of Real agricultural growth domestic product

Temp= Mean Annual temperature

C02=Carbon dioxide Emission

LF= labor force

Fer= fertilizer input import

Rain= Mean Annual rainfall

Agland= Agricultural land

et=error term and β_0 are constant term while β1, β2, β3, β4, β5 and β6 are the parameter of independent variable to be estimated.

Table 2. Definition of variable and expected sign.

Variables	Description	Expected sign
Agricultural output	Total produce of the agricultural sector in the economy in a given year	positive
Labor force	Labor force (age from 15-64 years) a total number of labor force that are economically active.	negative
Average temperature	is annual temperature is averaged over 12 months of temperature that the country receive	positive
Mean Annual rainfall	rainfall that the country receives in 12 months taken as an average over those months throughout the years	positive
Agricultural land	The share of land area that is arable, under permanent crops, and under permanent pastures.	positive
Fertilizer input import	Fertilizer is the ingredient which increases the productivity of agricultural products	positive

Source: Computed by authors

5. Estimation and Discussion

The data gathered to assess the impact of climate change on the growth of agricultural production and its contribution to Ethiopia's GDP will be analyzed in this section. Variables in temperature, carbon dioxide, and long-term rainfall patterns are linked to climate change. In light of this, the study's data's times series characteristics were investigated. The effect of climatic change on the rise of agricultural output was then analyzed using an Autoregressive Distributed Lagged Model. The pre-estimation test was carried out before to the execution of the long- and short-run models. These tests are called bounds-cointegration and unit root tests. To ascertain whether each variable was stationary, the unit root test was used; to ascertain whether long-term relationships existed between the variables, the Bound-Cointegration test was employed.

5.1. Descriptive Statistics

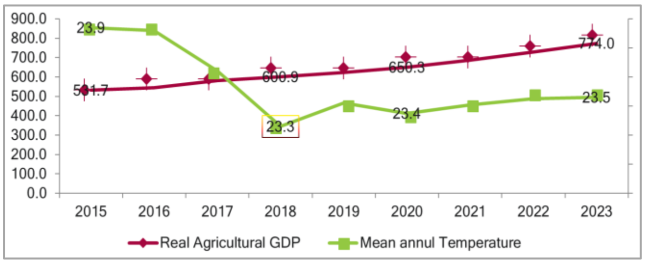

Figure 1. Real Agricultural Output and Mean annul Temperature.

In order to perceive the trend of Temperature in Ethiopia increased to 23.46 celsius in 2023 from 23.45 celsius in 2022. Temperature in Ethiopia averaged 23.4 celsius from 1990 until 2023, reaching an all-time high of 24.0 celsius in 2009 and a record low of 22.81 celsius in 1992. This showed that a continuous increases in temperature across the country. Average annual temperatures have been increasing to continue leading to climate change and caused to decline in GDP of agriculture. Therefore, the trend of climate change variable temperature showed that a negative effects on agricultural economic growth. The effect of climate change have seen that, the daily temperature is very hoot; the soil moisture and vegetation covers has been declined, water availability in the ground, lakes and rivers have been shriveled; changes the timing and distribution of agricultural pests and diseases have been increased.

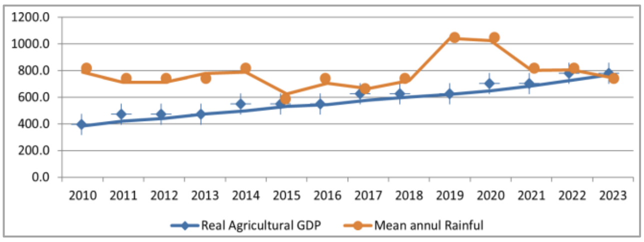

Figure 2. *Movement of Agricultural Output &Rainfall in mm.*

The average of rainfall trends was varying over the year. It found the lost in 2014/15, which was the disastrous droughts occurred in the country. Agricultural products may be impacted directly or indirectly by a shorter and more intense rainy season.

5.2. Empirical Results and Interpretation

5.2.1. Unit Root Test Result

A stationary part of the time series should be found before modeling or estimating. The ADF unit root test was used in the study to determine if the data series under investigation is stationary at levels or stationary at differences. In light of this, the Augmented Dickey Fuller (ADF) test was used to determine whether a unit-root existed in each time series. In ADF testing, the alternative hypothesis of the stationary process is opposed by the null hypothesis, which states that the data series are non-stationary (unit root). Table 3 displays the ADF result with and without trend. The variables are stationary in the level and initial differences. Therefore, the results Augmented Dickey Fuller unit-root tests indicate that mean annual rainfall variables and agricultural land are found to be stationary at level I (0), whereas the remaining variables are stationary at first difference, I(1). Note that the series is statistically significant and null hypothesis of non-stationary can be rejecting when ADF test statistics value is greater than the critical value.

Table 3. *Augmented Dickey Fuller Unit root test results at the level and First difference.*

Variable	With intercept and no trend				
	At levels	**Prob.***	**First difference**	**Prob.***	**Order of integration**
Ln (RagGDP)	1.635479	0.9993	-3.894671	0.0055**	I(1)
Ln (Temp)	-1.88001	0.3359	-5.269992	0.0012*	I(1)
C02	-1.791109	0.6846	-5.089744	0.0022*	I(1)
LF	-0.294192	0.9875	-4.740441	0.0032**	I(1)
Fer	-1.830313	0.0670	-5.652615	0.0003*	I(1)
Rain	-3.60583	0.0111**	-4.66457	0.0009*	I(0)
AgLand	-3.591493	0.0114**	-5.612171	0.0001*	I(0)

Source: Computed by authors using E-views 12 software
Notes: The rejection of the null hypothesis is based on [35] critical values Null hypothesis: series has unit root. *Rejection at 1% level and ** Rejection at 5 % level.

5.2.2. ARDL Bound Test to Co Integration Result

By using Automatic selection lag length criteria for the model bound test is applied so as to identify the presence of long-run relationship among the variables included in the model and test is as displayed here.

Table 4. Result of Bound Test.

Variable	F-statistics	Co integration
F(RagGDP, Temp, C02, LF, Fer, Rain, Agland)	9.686542	Co integration
Critical value	Lower bound	Upper bound
1%	3.41	4.68
5%	2.62	3.79
10%	2.26	3.35

Source: Computed by authors using E-views 12 software

At the 1% level of significance, the computed F statistics (9.6865) from Table 4 are greater than the upper bound critical values from [36] and [37]. This suggests that the alternative hypothesis that there is a long-run link based on the crucial values found in [36] and [37] at the 1% level of significance is to be accepted rather than the null hypothesis, which states that there is no long-run association. As a result, over time, there is a co-integration relationship between the variables.

5.2.3. Estimation of Long-Run Model Result

Table 5. Estimation of long run model ARDL result Dependent variable is ln(RagGDP).

Model selection method: Akaike info criterion (AIC), Selected Model: ARDL(3, 2, 3, 2, 2, 2, 2)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
LnRagGDP(-3)	0.574428	0.224522	2.5584	0.0337*
LnTemp(-2)	-5.287433	1.832495	-2.8853	0.0203*
C02(-3)	-11.20154	3.450794	-3.2460	0.0118*
Lf(-2)	0.257335	0.067661	3.8033	0.0052*
Fer(-2)	0.031800	0.012100	2.6380	0.0298*
Rain(-2)	0.069600	0.026300	2.6463	0.0296*
Agland(-2)	0.016423	0.005260	3.1221	0.0142*
C	-16.84498	8.527279	-1.9754	0.0836

R-squared: 0.998430 Adjusted R-squared: 0.994113

F-statistic: 231.2626 Durbin-Watson stat: 2.961938 Prob(F-statistic): 0.000000

*Ln- is refers to natural logarithm *, and ** indicate significance at the 5 and 1 percent levels.*

Source: Computed by authors using E-views 12 software

Effect of Average Annual Rainfall on Production in Agriculture: Table 5 shows that the average yearly rainfall has a substantial and favorable effect on the amount of agricultural output as determined by real agricultural GDP. According to the results, a 1% increase in the mean annual rainfall boosts agricultural output by 0.07 percent, and a 1 mm increase or change in rainfall causes a 0.07% long-run rise in real agricultural GDP. This result suggests that rainfall is the most important in determining agricultural output which is the major contributor to economic growth and it is consistent with the result by [38] in Sub Saharan Africa they found that if rainfall is declining it would reduce agricultural output and if rainfall increase agricultural output would be an increase in SSA. This shows rainfall is a major factor that determines agricultural output in SSA. Rainfall in Ethiopia is a major input in determining output due to this the country is named as rain-fed economy, where rainfall plays an important role. In addition, this result is going in line with [39] where they found that rainfall affect positively and significant relationship with agricultural productivity in the long run.

Effect of Temperature on Agricultural productivity: The findings show that average temperature adversely affects and considerably lowers agricultural productivity. Over time, a one percent increase in the average temperature would result in a 5.28% decrease in agricultural output. Agricultural output is most sensitive to an increase in average temperature, as indicated by its long-run elasticity of -5.28 with respect to temperature. Over time, this increase in temperature change is likely to lead to a decline in agricultural productivity. This could be due to the fact that high temperatures deplete soil nutrients, which negatively impacts cattle and overall agricultural productivity. Over time, rising temperatures cause the soil to become less moist, which has a detrimental effect on crop yield and lowers agricultural productivity. Temperature increases might increase output from crops and other sources in the short run, but they have negative long-run effects such as heat stress, decreased water availability, decreased livestock feed, and agricultural production failure, which lowers agricultural output and negatively impacts the nation's economy overall as well as the rural and urban populations in particular by driving up the cost of agricultural products for the latter.

The carbon dioxide emission also has negative relationship with agricultural economic growth and it is strongly significant at 5% level in the long-run. As 1% increase in carbon dioxide damage that causes agricultural economic growth decline by 11.2% in the lung-run. It implies carbon oxide emission showed that an increasing for the last three decades in Ethiopia. This indicates that to increase the concentration of CO_2 emissions in atmosphere. The concentration of C02 results from farming activities, such as usage of fertilizer and the conversion of forested areas agricultural land.

The Effect of Labor Force on Agricultural Production; the agricultural industry employs a significant portion of the labour force, accounting for approximately 0.25% of all jobs in the economy. The labour force has a long-run, beneficial, and large impact on agricultural productivity at all levels. Over time, the labour force would shift from traditional to educated labour, which would increase output in the agricultural sector. This would result in the labour force having a favourable impact on agricultural output. Additionally, the output of agriculture follows the same path. There would be a 0.25% rise in agricultural output and its significance at all levels for every 1% increase in the labour force.

The Effect of Fertilizer Input Import on Agricultural Output; Fertilizer is the primary input in the agriculture sector, particularly for crop production that would improve agricultural output. This has an effect on the import of fertilizer input. It has a considerable and favorable effect on agricultural output, as the table illustrates. It also boosts agricultural output. Agricultural output would rise by 0.03% for every 1% increase in fertilizer input imports. Over time, a rise in fertilizer imports raises output. A rise in fertilizer input imports translates into an increase in fertilizer consumption, which raises agricultural output overall and in crop productivity specifically. An increase in agricultural output leads to an increase of overall GDP and improve the living standard of the rural population whose livelihoods are dependent on agriculture. If there is an increase in the agricultural output it increases the export of the country which leads to the gain of foreign exchange to the country. This result is similar to [40] who used fertilizer input import as a control variable and he found a positive and significant effect on agricultural export through an effect on agricultural output.

The Effect of Agricultural Land on Agricultural output; The long-run result indicates that 1% increase in agricultural land leads to 0.016% increase in agricultural output since agricultural land plays an important role in determining agricultural output where there is an increase in agricultural land there would be an increase in output and it has a significant effect on agricultural output that increases the gross domestic product in general.

5.2.4. Error Correction Model of ARDL Result

Table 6. Error Correction Result Dependent variable is LnD (RagGDP).

ECM Regression				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(LnRagGDP(-1))	0.442489	0.096004	4.609065	0.0017**
D(LnTemp)	-4.508912	0.750531	-6.007628	0.0003*
D(C02)	1.695085	1.019905	1.662002	0.1351
D(Lf)	0.406011	0.050659	8.014565	0.0000**
D(Fer)	0.000170	4.29E-05	3.968088	0.0041*
D(Rain(-1))	0.046912	0.013601	3.449411	0.0001**

ECM Regression				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(Agland(-1))	0.026234	0.013041	2.011809	0.0051**
CointEq(-1)*	-0.782910	0.085385	-9.169181	0.0000**

Ln- is refers to natural logarithm D- differenced, *, and ** indicate significance at the 5 and 1 percent levels.

Source: Computed by authors using E-views 12 software

The short-run result shows that last year's mean annual rainfall has a positive and significant impact on agricultural output while last year's temperature has negatively affected agricultural output but it has a significant effect on agricultural output, whereas other variables have a positive impact on agricultural output. As reported in table 6, the error correction coefficient (CointEq(-1)) is negative sign and statistically significant at 1% significant level. The coefficient of error correction show that how rapidly a variable adjustment to equilibrium and it should be negative and significant. A highly significant error correction term is an additional confirmation of the existence of a stable long-run association. The error correction coefficient suggests that the speed of adjustment of any short-run disequilibrium towards the long-run equilibrium is 78.3 % each year.

5.2.5. Diagnostic Test Result

Table 7. Diagnostic Test Result.

Test	Null hypothesis	Prob>X^2	Decision
Breusch-Pagan-Godfrey	Homoscedasticity	0.7143	Homoscedasticity
Breusch-Godfrey LM Test	No serial correlation	0.1015	No serial correlation
Heteroskedasticity Test: ARCH	ARCH test	0.2592	No ARCH Problem
Jarque-Bera normality test	Normality	0.1874	Normally Distributed

Source: Computed by authors using E-views 12 software

As shown from the above, the diagnostic test recommends good fit of the model. The absence of issues with serially correlated errors, heteroskedasticity, ARCH effect, non-normality of the errors, and functional form misspecification further confirms that the estimation is BLUE. As a result, every diagnostic test for residuals and all observed tests pass the necessary model.

5.2.6. Model Stability

In addition from the diagnostic tests mentioned above, the stability of long-run estimates has been tested by applying the cumulative sum of squares of recursive residuals (CUSUMSQ) test. Since the test statistics of these stability tests can be graphed, we can identify not only their significance but also at what point of time a possible instability (structural break) occurred. If the plot of CUSUMSQ statistic moves between the critical bounds (at 5% significance level), then the estimated coefficients are said to be stable.

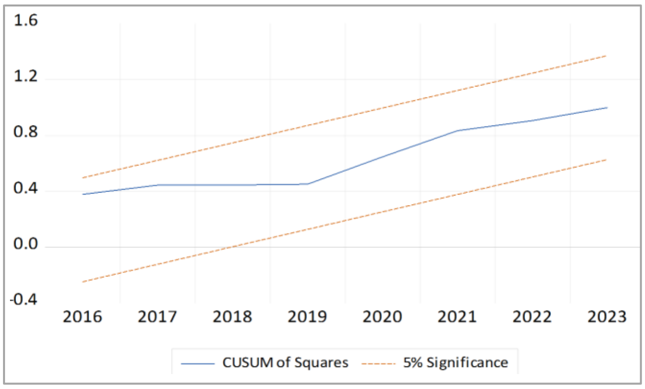

Figure 3. Plot of cumulative sum of recursive residuals.

Note: The straight lines represent critical bounds at 5% significance level)

The CUSUMSQ test results demonstrate that the graphs do not exceed the crucial limitations on the lower and upper ends. So, can conclude that long and short runs estimates are stable and there is no any structural break. Hence the results of the estimated model are reliable and efficient.

6. Conclusion and Recommendations

The main objective of the study was to analyze the effect of climate change on agricultural output in Ethiopia. The ARDL model method to co-integration was employed in the study. This study's the main conclusion is that, over the long run, agricultural productivity is impacted by climate change, as measured by average annual rainfall and temperature. Average annual rainfall has a positive and significant effect on agricultural output in the long run, while average temperatures have a significant and negative effect. In other words, holding other things remaining constant one percent increase in mean annual rainfall has resulted in 0.07% real agricultural GDP in the long run, however, one percent increase in temperature has resulted from 5.28% reduction of real agricultural GDP. In the short run coefficient of error correction -0.783 suggesting about 78.3% annual adjustment towards long-run equilibrium. This shows that the variables have a consistent, long-term relationship. In contrast to average temperatures, which have a negative impact on agricultural output but, unlike their long-run major influence, have no significant short-run effect on agricultural output, rainfall is found to have a positive effect on agricultural output in the predicted short run.

In order to reduce effect of climate change in the long run and short run mitigation and adaptation strategies should be in place. Adaptation techniques may focus on the option of producing or water harvesting as it rains instead of waiting for the traditional seasons of agricultural activities. The Moderation will be essential in the short run; adaptation is more significant in the long run. In addition, the government and other relevant parties should use alternative technologies to strengthen the agriculture sector's resilience to climate change and give farmers access to adequate and timely information on macro and microclimate forecasts. Additionally, diversifying the economy to include climate-resistant sectors will lessen reliance on the rainfall economy.

Abbreviations

ADF	Augmented Dickey Fuller
AGW	Anthropogenic Global Warming
ARCH	Autoregressive Conditional Heteroskedasticity
ARDL	Autoregressive Distributed Lagged Model
BLUE	Best Linear Unbiased Estimation
CGE	Computable General Equilibrium
CSS	Central Statistics Service
CUSUMSQ	Cumulative Sum of Squares of Recursive Residuals
DF	Dickey-Fuller
ECM	Error Correction Model
EMA	Ethiopia Metrology Agency
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IMF	International Montary Fund
IPCC	Intergovernmental Panel on Climate Change
NBE	National Bank of Ethiopia
NMA	National Metrology Agency
USAID	United States Agency for International Development
WB	World Bank
WDI	World Development Indicators

Author Contributions

Antehun Eshetu is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

Appendix

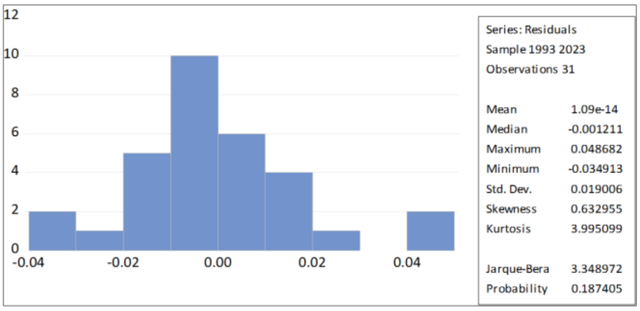

Figure 4. *Normality Test.*

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