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Research Article

Impact of Climate Change on Cereal Crops Production in Ethiopia

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Climate change adversely affected agricultural productivity in developing countries. This study aimed to explore the effects of this climate change, particularly on cereal crops production in Ethiopia. The study employed Autoregressive Distributed Lag (ARDL) model approach to the co-integration with an error correction term. ARDL technique was selected due to its stationarity assumption and unbiased estimates of its long-run coefficients. The estimated model justifies the existence of a long-run relationship between cereal crops production, climate change variables (temperature and precipitation), and other explanatory variables. Precipitation has a positive and significant effect on cereal crops production both in the long and short runs, while temperature change has a significant negative effect. In the long run, cereal crops production was positively and significantly affected by arable land, fertilizer consumption, and carbon dioxide emissions, while in the short run, labor force participation has a positive and significant effect on cereal crops production. The study results confirmed that there is a long-run relationship between cereal crops production and climate change variables. In agriculture, research and development should focus on varieties of cereal crops that can tolerate high temperatures. Climate Resilient Green Economy should have to strengthen in the country. All countries should have to work hand-in-hand to mitigate the effect of climate change.

1. Introduction

In recent years, studies have shown that climatic conditions are changing due to greenhouse gases such as carbon dioxide emissions (CO_2), and it brings adverse effects on agriculture, ecological systems, and the economy all over the world [1–3]. It raises upcoming temperatures, hypothetically resulting in reduced crop production and productivity [4], and it is a serious threat, especially in countries that are already food insecure [5]. Globally, Sub-Saharan African countries are highly vulnerable to future climate change, and Ethiopia is often cited as one of the most extreme examples [6]. The climate of Ethiopia is most likely allied with tropical monsoon-type behavior, experiencing significant June to September rainfall yet measurably cooler in its high plateau and Central Mountain range elevations [7]. Ethiopia's rain-fed agriculture-based economy, with cereals as the major food crop, is highly sensitive to the adversities of weather variability and climate change, and poor productivity [8].

In Ethiopia, when compared to other crops production, cereal production is a leading form of agricultural practice. Out of the total grain crops area, 81.19% of hectares of land were under cereals, with a production contribution of 88.36% of the total grain in the country, which is by far higher than the percentage shares of other crops such as pulses (12.9%) and oilseeds (5.9%) [9]. As a result of this and because of their large shares in the diets of the people, the cereal crops production subsector has received particular attention in the country. Specifically, the five major cereal crops (teff, maize, sorghum, wheat, and barley) are the staple of Ethiopia's agriculture and food sources, accounting for approximately 64% of the calories consumed [10]. Moreover, for the elimination of hunger and contribution to food security, sustainable agriculture, in particular enhancing cereal crops production, is considered the most important issue of the 2030 agenda of the country [11]. However, meeting this agenda is very challenging and complicated due to climate change effects, soil degradation, reduced fertilizer supply, and the occurrence of different diseases and pests that attack mainly cereal crops [12]. Climate changes not only affect productivity but also affect the protein content and quality and grain size of cereal crops.

Different literature tried to study the influence of climate change on agricultural production and productivity in different parts of the world. For instance, in Pakistan, the availability of water has been identified as the main factor influencing agricultural production. A similar study in India by Abbas Ali et al. [13] claims that agricultural production and productivity were determined by climate factors like temperature, carbon dioxide emissions (CO_2), the area under crop, and the labor force. On the other hand, rainfall, temperature, and area under cropland were found to be the key variables influencing agricultural production in Somalia [14]. However, most of the studies made in Ethiopia were not focused on the effect of this climate change on agricultural production in general and cereal crops in particular. Moreover, even though there are some studies [15, 16] on identifying the determinants of agricultural production and productivity in Ethiopia, less attention was given to examining the long-run effects of climate change (temperature and precipitation), particularly on cereal crops production. Thus, to have a policy that coincides with climate change and its effect on cereal crops production, it is essential to study the long-run effects of climate change on cereal production for better policy recommendations.

Moreover, this study emphasizes the issue of cereal production not only because it accounts for more than 87% of total crop production but also because the country is importing a large number of cereal crops, such as maize and wheat, to keep the demand and supply balances in the domestic market [17]. The study aimed to examine the effects of climate change on cereal crops production in Ethiopia. Compared to previous articles, this study correlated climate change proxy variables with cereal crops production and reported a significant effect of climate change on this crop's production. So, this can strengthen the negative effect of climate change on cereal crops production in particular.

This paper was organized into four main sections. Following the introduction in Section 1, Section 2 provides a review of the empirical literature, and Section 3 outlines the methodology of the study. Section 4 presents the major findings of the study and then makes discussions on them, and finally, a conclusion and policy implications are provided in the end.

2. Empirical Literature Review

Increasing the production and productivity of crops can be attained by promoting new technology and reducing the impact of climate change by adopting different strategies. The sustainable growth of the agricultural sector and its productivity may be hampered by different climatic and nonclimatic factors over the world. Different studies have been conducted by different scholars to identify the main determinants of agricultural production and productivity in different countries by applying different models. A brief review of related literature is provided below.

A study by Ketema [15] applied the ARDL approach to cointegration to investigate the long-run and short-run determinants of agricultural output. The result reported that rainfall, fertilizer input, trade openness, and inflation rate affected the output positively and significantly, while drought has negatively affected agricultural output in the long run. In the short run, fertilizer input import and labor force showed positive and significant effects, but drought affected agricultural output negatively and significantly. The coefficient of the error correction term was −0.738, signifying about 73.8% annual adjustment towards long-run equilibrium. Another study by Tirfi and Oyekale [18] examined the impact of climatic and other variables on the supply of maize in Ethiopia from 1981 to 2018. They employed Autoregressive Distributed Lag (ARDL) approach to analyze the data. The result reported the existence of a long-run relationship between maize output and variables included in the model. The result showed that in both the long and short runs, CO_2 and seasonal rainfall hampered maize output supply. Similarly, Kariuki et al. [19] studied the temperature and rainfall changes in maize output between 1970 to 2014 in Kenya. The study adopted an ARDL method, and the findings showed depending on the period, maize output has a mixed reaction to rainfall and temperature, while the change in temperature has a negative effect.

Chandio et al. [20] employed the ARDL approach to cointegration to investigate the short and long runs determinants of grain crops productivity in Pakistan over the period 1978 to 2016. Their study results showed that grain crops area, fertilizer, improved seed, and water accessibility have a positive and significant effect. Also, another study by Chandio et al. [21] confirmed the occurrence of a positive and significant effect of area and fertilizer on wheat production both in the short and long runs. Moreover, a study conducted by Abbas Ali et al. [13] showed that in the long-run, CO_2 emissions and rainfall positively affected both cereal production and yield, while temperature had an adverse effect. Their finding further revealed that the cereal cropped area and labor force positively and significantly impacted the long-run cereal production and yield.

A study by Chandio et al. [22] examined the effect of climate change factors on cereal yield in Turkey during 1968–2014 by employing ARDL cointegration model. The empirical results showed that there is a long-run relationship between climate change factors and cereal yield. CO_2 emissions and average temperature have diverse effects on cereal yield, whereas average rainfall has a positive effect on the yield in both the long-run and short-run periods. In addition, Dumrul and Kilicaslan [23] evaluated the effects of climate change on agricultural production in Turkey from the period of 1961–2013. In this study, the economic effects of climate change on agriculture were analyzed by applying the ARDL approach and reported that an increase in precipitation affected agricultural Gross Domestic Product (GDP) positively, while the increase in temperature showed a negative effect on agricultural GDP. A similar study by Ahsan et al. [24] examines climate change impacts on cereal crops production in Pakistan from the period 1971 to 2014. The study used the Johansen cointegration test and ARDL approach to estimate the long-run relationships. The outcomes of the Johansen cointegration test confirmed the existence of a long-term cointegrating relationship between the production of cereal crops and the exogenous variables used in the study. The results showed in the long-run CO_2 emissions, energy consumption, cultivated area, and labor force have a positive and significant impact on cereal crops production in Pakistan.

Maïga et al. [25] investigated maize production and climate change in Mali during the period 1990 to 2020. The ARDL approach to cointegration was applied to assess the association between the study variables. The results showed that precipitation and temperature in June and July have negative effects, but the area of land devoted to maize crops and GDP per capita showed a positive and significant effect on maize production. Similarly, the effect of climate change on crop production was studied by Warsame et al. [14] in Somalia using data from 1985 to 2016. The study employed the ARDL bounds testing to examine the long-run relationship among the variables involved. The result of the study found the existence of cointegration between the variables. They discovered that rainfall increases crop production in the long run, but it hinders in the short run. The temperature has an adverse effect on crop production both in the long and short runs. The study also reported a positive and significant impact of land under cereal cultivation on crop productivity in the long run.

Kumar et al. [26] examined the impact of climate change on cereal production in selected lower-middle-income countries with a balanced panel dataset spanning from 1971 to 2016. The study applied feasible generalized least square and fully modified ordinary least square models. The finding reported that a temperature rise reduces cereal production in lower-middle-income countries. In contrast, cereal crops production was positively affected by rainfall and CO_2 emissions. Ozdemir [27] used dynamic and asymmetric panel Autoregressive Distributed Lag estimators to investigate the effects of climate change on agricultural productivity in Asia over the period 1980–2016. The study also reported that there is a long-run relationship between agricultural productivity and climate change variables.

In general, as reviewed above, different studies used different techniques to examine challenges of agricultural production and the effect of different climate change elements on influencing agricultural output and productivity across the world. The findings on the determinants of crop production in different countries may imply that the policymakers and other development workers can design and implement an appropriate policy intervention of their own based on agroecology and the socioeconomics of the country. It was also indicated that several factors could affect the agricultural output, but those factors are not equally important and similar in all areas all over the world at all times. An influential factor in one country at a certain time may not necessarily be a significant factor in other countries or even in the same places after some time. Therefore, from the above empirical works, policy drawn may allow for designing country-specific policies to be compatible with its socioeconomic as well as agroecological conditions.

3. Research Methodology

3.1. Data Sources and Variable Descriptions. The study employed 31 years of time series data of Ethiopia spanning from 1990 to 2020. The data was obtained from world development indicators published and updated online by the World Bank database, FAOSTAT, and Central Statistical Authority (CSA). The details of the variables used in this study are shown in Table 1.

3.2. Econometric Method. This study used the ARDL bounds-testing approach to the cointegration developed by Narayan and Narayan [28] and Pesaran et al. [29] to investigate the existence of a long-run equilibrium between the proposed variables. The ARDL approach has a number of benefits as compared to other co-integration approaches like Engle and Granger [30] and the maximum likelihood-based approach by Johansen and Juselius [31]. It simplifies testing of the presence of long-run relationships without considering whether the series are integrated at level I (0) or at the first difference I (1) or in mixed order of integration. In addition, this approach is very much reliable in case of slight sample sizes, eludes the issues of endogeneity, and helps to explore the coefficients in the long -run. Moreover, this approach also estimates the Error Correction Model (ECM) that shows the speed of adjustment to the equilibrium point.

Next, the study uses the error correction term (ECT) technique which integrates the short-run dynamics with the long-run equilibrium. The coefficients of ECT integrate the short-run dynamics with the long-run equilibrium without losing long-run information and avoid problems, such as spurious relationships resulting from nonstationary time series data. The study estimates both long and short-run relationships using the linear empirical model specified in

$$\ln \mathrm{CP}_t = \alpha_0 + \alpha_1 \ln \mathrm{Co}_{2\,t} + \alpha_2 \ln \mathrm{AL}_t + \alpha_3 \ln \mathrm{Fert}_t + \alpha_4 \ln \mathrm{Temp}_t + \alpha_5 \ln \mathrm{Prec}_t + \alpha_6 \mathrm{LFPR}_t + \varepsilon_t, \tag{1}$$

where

$\ln \mathrm{CP}_t$ − is the logarithm of cereal crops produced at time t.
α_0 − is the intercept of the function.
$\ln\mathrm{CO}_{2t}$− thelogarithmofcarbondioxideemissionattime$t$and.
$\ln\mathrm{AL}_t$−thelogarithmofarablelandusedforcultivation ofcropsattime t.
$\ln\mathrm{Fert}_t$− thelogarithmoftheamountoffertilizerconsumedper arablelandintime$t$.
$\ln\mathrm{Temp}_t$−thelogarithmofannualtemperaturechangeattime$t$.
$\ln\mathrm{Prec}_t$−thenaturallogarithmofprecipitationattime$t$.
LFPR_t−thelaborforceparticipationattime$t$.
$\alpha_1;\alpha_{2;}\ldots\ldots\alpha_6$−areslopecoefficientsofthefunction.
ε_t−isthestochasticterm

Table 1: Study variables, unit of measurement, and sources of data.

Variables	Measurement unit	Source
Dependent variable		
Cereal crops production	Measured in metric tons	WDI (world dev't indicator) and CSA
Explanatory variables		
Temperature	Degree centigrade	FAOSTAT
Precipitation	mm per year	World climatology
Arable land	Hectares	WDI and CSA
Fertilizer	Kilogram per arable land	WDI
Carbon dioxide emissions	Kilo ton (kt)	WDI
Labor force participation rate	Percentage	WDI

To smooth multicollinearity and instability of the yearly time series data, this study uses all the variables in their natural logarithmic form.

3.2.1. Autoregressive Distributed Lag Bounds Testing Approach. The ARDL approach to cointegration explores the presence of a long-run relationship among all variables by estimating the critical bounds. Equation (2) represents the specification of the ARDL model, which is as follows:

$$\begin{aligned}\Delta \ln CP_t = {} & \delta_0 + \delta_1 \sum_{i=1}^{p} \Delta \ln CP_{t-i} \\ & + \delta_2 \sum_{i=1}^{q_1} \Delta Co_{2\ t-i} \\ & + \delta_3 \sum_{i=1}^{q_2} \Delta \ln AL_{t-i} + \delta_4 \sum_{i=1}^{q_3} \Delta \ln Fert_{t-i} \\ & + \delta_5 \sum_{i=1}^{q_4} \Delta \ln Temp_{t-i} \\ & + \delta_6 \sum_{i=1}^{q_5} \Delta \ln Prec_{t-i} + \delta_7 \sum_{i=1}^{q_6} \Delta LFPR_{t-i} \\ & + \gamma_1 \ln CP_{t-i} + \gamma_2 \ln Co2_{t-i} \\ & + \gamma_3 \ln AL_{t-i} + \gamma_4 \ln Fert_{t-i} + \gamma_5 \ln Temp_{t-i} \\ & + \gamma_6 \ln Prec_{t-i} + \gamma_7 LFPR_{t-i} + \varepsilon_t,\end{aligned} \tag{2}$$

where α_0 represents the intercept, i denotes the lag order, Δ stands for the first difference, and ε_t denotes the stochastic term at time t. The ARDL cointegration technique does not require pretests for unit roots, unlike other techniques. To check the existence of a long-run relationship among the variables included in the model, the study employed F-test. If the estimated F-test goes above the upper level of the critical bound, then the null hypothesis is rejected, and the variables are cointegrated. If the estimated F-test is less than the lower level of bound, it fails to reject the null hypothesis, and the variables are not cointegrated. However, if the estimated F-test lies between the lower and upper level of critical bounds, then the decision is inconclusive.

The main expansion of this method lies in its cointegrating vector identification, where there are various cointegrating vectors. If a long-run co-integration between explanatory variables and cereal crops production exists, the long-run relationship coefficients are estimated with the following equation:

$$\begin{aligned}\ln CP_t = {} & \varphi_0 + \varphi_1 \sum_{i=1}^{p} \ln CP_{t-i} \\ & + \varphi_2 \sum_{i=1}^{q_1} \ln Co_{2\ t-i} + \varphi_3 \sum_{i=1}^{q_2} \ln AL_{t-i} + \varphi_4 \sum_{i=1}^{q_3} \ln Fert_{t-i} \\ & + \varphi_5 \sum_{i=1}^{q_4} \ln Temp_{t-i} + \varphi_6 \sum_{i=1}^{q_5} \ln Prec_{t-i} + \varphi_7 \sum_{i=1}^{q_6} LFPR_{t-i} + \varepsilon_t.\end{aligned} \tag{3}$$

Further, to evaluate the short-run relationship between the variables, the formulation of ECT from the ARDL approach is specified as in the following equation:

$$\begin{aligned}\Delta \ln CP_t = {} & \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln CP_{t-i} \\ & + \sum_{i=1}^{q_1} \alpha_{2i} \Delta \ln AL_{t-i} \\ & + \sum_{i=1}^{q_2} \alpha_{3i} \Delta \ln Co_{2\ t-i} \\ & + \sum_{i=1}^{q_3} \alpha_{4i} \Delta \ln Fert_{t-i} + \sum_{i=1}^{q_4} \alpha_{5i} \Delta \ln Temp_{t-i} \\ & + \sum_{i=1}^{q_5} \Delta \ln Prec_{t-i} + \sum_{i=1}^{q_6} \Delta LFPR_{t-i} + \Delta ECT_{t-i} + e_t,\end{aligned} \tag{4}$$

where $\Delta = (1 - \sum_{i=1}^{p} \delta_i)$ speed of adjustement parameter with a − ve sign.

$ECT = (\ln cp_{t-i} - \theta X_t)$, the error correction term.

$\theta = \sum_{i=0}^{q} \beta_i / \alpha$, is the long − run parameter

The method of error correction clarifies the speed of adjustment required to return the equilibrium of the long-run following a short-run tremor. Δ (Error correction coefficient) implies that any short-run disequilibrium among the variables will congregate back to the long-term equilibrium relationship.

4. Findings and Discussion

4.1. Results of Descriptive Statistics. In this study, the number of cereal crops produced was measured in millions of metric tons. The average cereal crops production for the study period is 14.35 million metric tons. On average, a total of nearly 12.76 million hectares of arable land was found in the country. There has been an increasing trend in cereal crop production and arable land starting from 2002 (Figure 1). On average, 18.72 kilograms per hectare of arable land fertilizer was consumed in a study period. In this study, CO_2 emission refers to those stemming from the burning of fossil fuels and the manufacture of cement. There has been an increasing trend in the total amount of CO_2 emitted every year (Figure 1). The result shows that, over the study period, on average, there is an emission of 7036.61 kilotons of CO_2 annually (Table 2). However, Wassie [16] reported 2830.5 kilotons of CO_2 emission annually for the period (1962–2014). This indicates as CO_2 emission shows increment over time in the country.

4.2. Result of the Stationarity Test. Before estimating the model, it is necessary to ensure that the variables used in the equation are stationary. Some variables are subject to strong variability over time, which is why it is necessary to determine their order of integration. The study tested as the selected studied variables were stationary at level/first difference. In the process, this study used the Augmented Dickey-Fuller (ADF) test, and the result is shown in Table 3. The result shows the variables are stationary at their first difference I (1).

4.3. ARDL Bounds Testing for Co-Integration. In order to empirically analyze the long-run relationships and short-run dynamic interactions among the variables (cereal crop production, fertilizer, carbon dioxide emissions, arable land, temperature, precipitation, and labor force participation rate), the ARDL bounds test to cointegration techniques was applied. The ARDL long-run co-integration outcomes, reported in Table 4 show the existence of long-run cointegration relationships among the production of cereal crops and explanatory variables.

4.4. Long-Run Coefficients and Short-Run Dynamics. Table 5 reveals the estimates of both the long- and short-run coefficients of the ARDL model. Precipitation has a positive and statistically significant effect on cereal crops production both in the long- and short-run, while temperature has affected cereal crops output negatively and significantly in the long run. The model result also confirms that arable land, fertilizer application, and CO_2 emissions have a positive and significant effect on cereal crops production in the long run. Additionally, in the short-run, labor force participation had a positive while fertilizer application had a negative and significant impact on the output of cereal crops in Ethiopia during the study period.

The estimated model showed that both in the long and short run, precipitation has a positive and significant impact on cereal crops production. This maybe because, in Ethiopia, agriculture is primarily rain-fed-based with insufficient irrigation works. If precipitation increases by 1%, cereal crops production increases by 0.16% in the long and 0.87% in the short runs at ceteris paribus. This finding is consistent with empirical research findings of Li et al. [32], who reported a positive and significant impact of precipitation on bean farming in China. The ARDL model result also indicated that the increase in temperature has a negative impact on cereal crops production, as a 1% increase in temperature will lead to a decrease in cereal crops production by 1.12%. This negative effect might be enlightened by the fact that cereal crops require a substantial volume of moisture. These effects of temperature are consistent with findings of [21, 25, 33, 34], who argued that high-temperature stress has adverse effects on agricultural production.

In the long run, the coefficient of arable land indicated a positive and significant effect on cereal crops production, as a 1% increase in the area of arable land increases cereal crops production by 1.62% in the long run. This finding implies

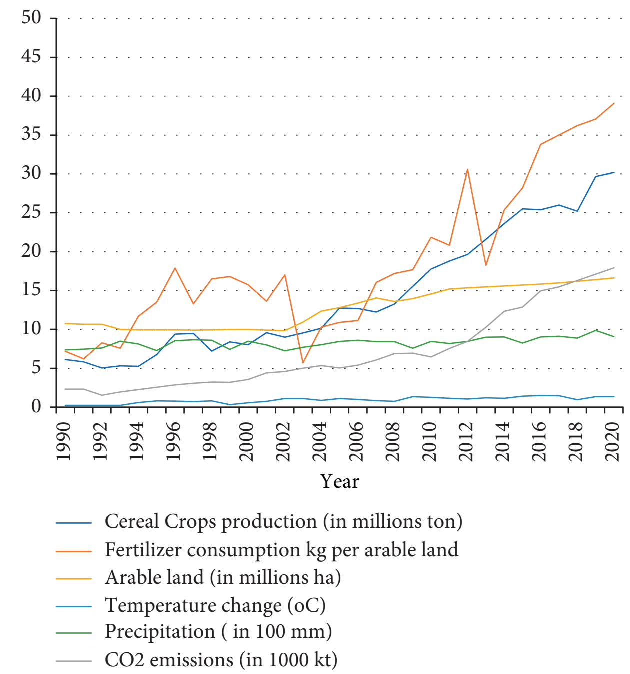

Figure 1: The trend of variables included in the model (1990–2020).

Table 2: Results of descriptive statistics of selected variables.

Variables	Unit of measurement	Mean	Std. dev.	Min	Max
CP	Million metric tone	14.35	7.98	5.03	30.21
CO_2	Kilo ton (kt)	7036.61	5031.89	1520	17905
AL	Million hectare	12.76	2.58	9.85	16.6226
Fert	Kilogram per hectare	18.72	9.80	5.70	39.07
Temp	Degree centigrade	0.91	0.39	0.23	1.45
Prec	Millimeter per year	831.22	63.78	723.25	986.73
LFPR	Percentage	81.63	1.57	78.94	83.71

Source: own computation (2022).

Table 3: Results of the stationarity test.

Variables	ADF at level		ADF at 1^{st} difference	
	Z (t)-statistics	P value for Z (t)	Z (t)-statistics	P value for Z (t)
lnCP	0.119	0.9673	-6.569^{***}	0.0000
lnTemp	−2.461	0.1254	-4.205^{***}	0.0006
lnPrec	−2.354	0.1552	-6.441^{***}	0.0000
$\ln CO_2$	0.628	0.9883	-4.309^{***}	0.0004
lnAL	−0.659	0.8571	-3.164^{**}	0.0222
lnFert	−1.852	0.3552	-6.170^{***}	0.0000
LFPR	−2.135	0.2307	-3.621^{***}	0.0054

Source: own computation (2022).

Table 4: ARDL bounds test results.

$\ln CP_t = f(\ln CP_t/\ln Co_t, \ln AL_t, \ln Fert_t, \ln Temp_t, \ln Prec_t, LFPR_t)$			
Significance	I (0) bound	I (1) bound	F-statistics (b)
Critical value bounds			
10%	2.12	3.23	
5%	2.45	3.61	7.970^{b}
2.5%	2.75	3.99	
1%	3.15	4.43	

Note. [b]Significant at 1%; source: own computation (2022).

Table 5: The estimated results of the ARDL model (long- and short-run coefficients).

Variables	Coefficient	Std. err.	t-statistics	$P > \|t\|$
Estimated long-run coefficients				
$\ln CO_2$	0.2314^{***}	0.0848	2.73	0.016
lnAL	1.6187^{***}	0.3449	4.69	0.000
lnFert	0.3395^{***}	0.0872	3.89	0.002
lnTemp	-1.1234^{*}	0.5644	−1.99	0.066
lnPrec	0.1653^{**}	0.0688	2.40	0.031
LFPR	−0.0208	0.0194	−1.08	0.300
Estimated short-run coefficients				
$\Delta \ln AL(D1)$	−1.1526	0.7886	−1.46	0.166
$\Delta \ln Temp(D1)$	−0.0768	0.0636	−1.21	0.247
$\Delta \ln Fert(D1)$	-0.222^{**}	0.0755	−2.94	0.011
$\Delta \ln Prec(D1)$	0.8721^{*}	0.4477	1.95	0.072
$\Delta \ln Prec(LD)$	0.5406	0.3140	1.72	0.107
$\Delta LFPR(D1)$	−0.0607	0.1484	−0.41	0.689
$\Delta LFPR(LD)$	0.4495^{**}	0.1901	2.36	0.033
ECM (L1)	-1.1243^{***}	0.1723	−6.52	0.000
Adjusted R2	0.628			

Note. The symbols ***; **, and *represent statistical significance at 1, 5, and 10% levels, respectively. Source: own computation (2022).

that cereal crops output is highly responsive to changes in the area cultivated, which is in line with the theory. This finding is consistent with the empirical research findings of Wassie [16] (Ethiopia), Shita et al. [35] (Ethiopia), Chandio et al. [20] (Pakistan), Chandio et al. [21] (Pakistan), Warsame et al. [14] (Somalia), and Abbas Ali et al. [13] (India) who reported a positive and significant impact of arable land on agricultural production.

Besides, the long-run estimates of the model revealed that carbon dioxide emissions have a positive and statistically significant effect on cereal crops production at a 1% significance level. Specifically, a 1% increase in carbon dioxide emission increases cereal crops production by about 0.23%. This may be due to the implementation of the Climate Resilient Green Economy (CRGE) strategy for the period 2010 to 2030 to reduce the risks of climate change. This strategy is planned to foster development and sustainability while limiting greenhouse gas emissions, where more trees are planted or afforestation that absorbs carbon dioxide for photosynthesis underway. This finding goes in line with the empirical research findings of Ahsan et al. [24], who studied climate change impacts on cereal crop production in Pakistan and found a positive and significant impact of CO_2 emissions on cereal crops production in the long run. Besides, the research report in India by Abbas Ali et al. [13] also supported as CO_2 emissions have a positive and significant impact on cereal crop production and yield in the long run.

The result revealed that in the long-run, fertilizer consumption has a positive and statistically significant impact on cereal crops production at a 1% significance level in Ethiopia, which implies that a 1% increase in fertilizer consumption per arable land increases cereal crops production by about 0.34% in the long run. This result is consistent with the empirical research findings of Ketema [15] and Chandio et al. [20], who reported a positive and significant effect of fertilizer on agricultural production in the long run. However, this study showed, in the short run, that the estimated lag of fertilizer has a negative and significant effect on cereal crops production at a 5% significance level. This result may happen because, in the short-run, cultivated lands are fertile, and excessive application of fertilizer can destroy the crop and lead to overflow into rivers and seas, initiating poisonous algal blooms that are hurtful to aquatic life and even people and their pets.

The coefficient of labor force participation showed a positive and significant effect on cereal crops production at a 5% probability level in the short run. This may reveal the labor-intensive nature of agricultural production in the country. Specifically, the model showed a 1% increase in labor force participation in agriculture would increase cereal crops production by 0.45%. This finding is in line with the research reports of Musafiri and Mirzabaev [36], who found positive and significant effects of the labor force on agricultural production. The coefficient of the estimated ECT is negative and statistically significant, which infers the existence of cointegration among the variables included in the

Table 6: Diagnostic test of the ARDL model.

Diagnostic tests	Chi^2/F-statistics	$P > \|t\|$
Serial correlation	0.189	0.6635
Normality	0.56	0.7542
Functional form	0.30	0.8245
Heteroscedasticity	29.00	0.4125

Source: own computation (2020).

model, and it directs that 112% of the short-run disequilibrium is adjusted towards its long-run equilibrium within a year, that recommends a good adjustment speed.

4.5. Diagnostic Tests. After examining the ARDL model, the study performed various diagnostic tests, such as the Breusch-Godfrey LM test (for Serial Correlation), Ramsey RESET (for Model specification or omitted variables), Jarque-Bera (for Normality), and Breusch–Pagan–Godfrey test (for Heteroscedasticity) and the results are shown in Table 6. Breusch-Godfrey LM test signifies that there is no serial autocorrelation in the model. The Jarque- Bera test also shows us that the error term in the model is normally distributed. In addition, the Ramsey RESET and Breusch–Pagan–Godfrey tests indicated that the form of the ARDL functional model is correct with no misspecifications and that the model is free from heteroscedasticity problems.

5. Conclusion and Policy Implications

This study examined the long-run effects of climate change on cereal crops production in Ethiopia by using time series data over 31 years. The study used the Autoregressive Distributed Lag (ARDL) model. The bounds test and the estimated coefficient of ECT indicated the existence of cointegration between cereal crop production, precipitation, temperature, labor force participation rate, fertilizer consumption, carbon dioxide emissions, and arable land. The result of the model showed precipitation has a significant and positive effect on cereal crops production both in the long and short runs, while temperature has a negative effect in the long run. Besides, fertilizer consumption, arable land, and carbon dioxide emissions have a positive and significant impact on cereal crops production in the long run, while the labor force participation rate has a positive effect in the short run. A positive and significant effect on the labor force participation rate shows the labor-intensive nature of cereal crops production in the country. However, the impact of fertilizer consumption was found negative and significant in the short run. The coefficient of ECT implies that 112% of the disequilibrium error is corrected toward equilibrium annually. The output of this research might benefit policymakers and scholars. CRGE should have to strengthen in the country. All countries should have to work hand-in-hand to mitigate the effect of climate change.

Abbreviations

ADF: Augmented Dickey Fuller
ARDL: Autoregressive distributive lag
CO_2: Carbon dioxide emissions
CRGE: Climate resilient green economy
CSA: Central statistical authority
ECM: Error correction model
GDP: Gross domestic product.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

All authors contributed to the study's conception and design. MA prepared the material, analyzed, interpreted, and wrote the final report. AB supervised, commented, and proofread the prepared manuscript, performed the histological examination of the kidney, and was a major contributor to writing the manuscript. All authors read and approved the final manuscript.

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