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Original Article

The Interaction of Environment with Agriculture Sector in Ethiopia: Time-series Analysis

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Abstract

Ensuring environmental sustainability is one of the most important Millennium Development Goals, which aims to integrate the principles of sustainable development into national policies and programs and to reverse the loss of environmental resources. Ethiopia is committed to building a climate-resilient green economy and aims to become a carbon-neutral middle-income nation by 2025. Having this in mind, the main objective of the study is to examine the interaction of the environment with the agriculture sector in Ethiopia by using a data set from 1990 to 2020. The Autoregressive Distributed Lag (ARDL) bound test has indicated that there is a long-run cointegration among the environment, economic growth, agriculture, and population growth. The Autoregressive Distributed Lag model output reveals that agriculture induced nitrous oxide has a long-run relationship with agricultural land allocation and population growth rate. Finally, the same model also assures the environmental Kuznet curve had occurred in the nexus between environment and agriculture in Ethiopia. So, the economic policies should strengthen environmentally friendly production technologies by employing low external agricultural inputs and strive for environmental quality.

Keywords: Nitrous oxide; Agriculture; Autoregressive Distributed Lag Model; Environment Kuznets Curve; Ethiopia

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1. INTRODUCTION

Ensuring environmental sustainability is one of the most important Millennium Development Goals, which aims to integrate the principles of sustainable development into national policies and programs and to reverse the loss of environmental resources. Ethiopia is committed to building a climate-resilient green economy and aims to become a carbon-neutral middle-income nation by 2025. In line with this, important steps are taken towards mainstreaming the principles of sustainable development in its development process through the medium-term strategy and the Climate Resilient Green Economy (CRGE) strategy. The nation's plan to do so comprises actions to reduce greenhouse gas emissions while safeguarding economic growth ("green economy") as well as adaptation initiatives to reduce vulnerability to the effects of climate change ("climate resilience" (Federal Democratic Republic of Ethiopia (FDRE), 2011).

Ethiopia's contribution to greenhouse gas (hereafter GHG) emissions is very low on a global scale. However, the projected environmental impact of conventional economic development in Ethiopia risks following the pattern observed around the globe. If current practices prevail, GHG emissions in Ethiopia will more than double from 150 Mt CO_2e in 2010 to 400 Mt CO_2e in 2030. On a per capita basis, emissions are set to increase by more than 50% to 3.0 t CO_2e and will thus exceed the global target to keep per capita emissions between 1 and 2 t per capita to limit the negative effects of climate change. Ethiopia's development could result in the unsustainable use of natural resources, being locked into outdated technologies, and losing an ever-increasing share of GDP to fuel imports. In this "business as usual" (BAU) scenario, GHG emissions are strongly and positively correlated with economic development and population growth, which would rob Ethiopia of the opportunity to make its development sustainable (FDRE, 2011).

According to the Global Catastrophic Risk Index (GCRI), Ethiopia ranks 21st on the 2022 list of most to least at risk with a 42.7 overall index score (Dahl *et al*., 2022). Its climate change vulnerabilities include droughts, flooding, desertification, water scarcity, and increased incidence of pests, affecting the agriculture, energy, and health sectors. The 2011 CRGE strategy provides a framework for lowering GHG emissions (African Development Bank Group (ADBG), 2022).

Over the past fifteen years, Ethiopia's economy has been the fastest growing in the region, at an average of 9.5% per year. However, it is one of the poorest countries, with a per capita gross national income of USD 890 (World Bank, 2020). The Ethiopian economy registered 6.3% growth

in 2020/21 amid the instability in the northern part of the country and the impact of the COVID-19 pandemic. Agriculture accounts for 32.5% of Ethiopia's total real GDP, which was 2,114.2 billion birrs in the same fiscal year (National Bank of Ethiopia (NBE), 2021).

Ethiopia's economy is highly agrarian and depends on the exploitation of natural resources. The exploitation of these natural resources may generate large economic benefits in the short term. However, in the long term, unsustainable use of these natural resources increases not only environmental degradation but also decreases economic growth and livelihood opportunities (Adem *et al*., 2020). Agriculture is an important component for economic growth, but it is also associated with significant environmental issues. Agriculture both causes and is affected by climate change (Rahman *et al*., 2018; Tsangas *et al*., 2020). Agriculture's negative environmental impacts are significant, and they can include pollution, soil, water, and air contamination. The environmental impact of agriculture will make meeting the increased demand for agricultural production in the coming decades difficult. This is because global climate change threatens to destabilize many of the natural systems that enable modern agriculture (Organization for Economic Cooperation and Development (OECD), 2021).

Ethiopia has registered a positive economic growth and on the other hand a lot of environmental related problems are there even if the nation has environmental policies. Currently, what kind of relationship does environment and agricultural sector has in Ethiopia? is the main focus of this study. So far, a lot of research has been devoted to investigating the nexus between economic growth and environment using the environmental Kuznets curve (EKC) hypothesis in Ethiopia using different pollution indicators and periods as indicated by various studies such as (Adedoyin *et al*., 2020; Getachew and Assefa, 2020; Adem *et al*., 2020; Adugna, 2022). Though in my knowledge, the nexus between agricultural production and environment is not yet studied and all of the above empirical studies in Ethiopia have taken CO_2 emissions as a proxy variable for the environment, though the importance of nitrous oxide (N_2O) emissions is immense. N_2O is one of the most hazardous gases present in the ambient atmosphere. It has an equivalent mass basis, which can reside for a longer time (300 times greater warming potential than CO_2) in the ambient atmosphere (Solomon *et al*., 2007; Sinha and Shahbaz, 2018). Finally, majority of the studies in Ethiopia were conducted using a data set until 2014. In doing so, this paper has an objective to examine the interaction of the environment with the agriculture sector in Ethiopia by

employing the data set from 1990 to 2020, using different indicators and proxies that have not been applied so far.

2. MATERIALS AND METHOD

2.1. Description of data and its source

In this study, annual time series data spanning the years 1990 through 2020 was used. Agriculture-induced nitrous oxide, agricultural land use, the square of agricultural land use, GDP, and population growth rate, were the variables presented for analysis purposes. Data on these macro-variables was retrieved from the World Bank's collection of development indicators database via the link of https://databank.worldbank.org/source/world-development-indicators#.

Agricultural nitrous oxide emissions are emissions produced through fertilizer use (synthetic and animal manure), animal waste management, agricultural waste burning (nonenergy, on-site), and savanna burning. They are measured in thousand metric tons of CO_2 equivalent. This variable can be used as proxy variables for the environment.

Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures. This variable is used as a proxy variable for the agriculture sector.

Gross domestic product is the sum of the gross values added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products at constant 2015 purchased prices, expressed in U.S. dollars. This macroeconomic variable is included in the model as a control variable.

The population growth rate is the annual population growth rate for year t, which is the exponential rate of growth of the midyear population from year t-1 to t, expressed as a percentage. This was included in the model as a control variable.

Table 1. Description of variables

Name of variables	Code	Unit	Expected sign
Agricultural nitrous oxide emissions	AN_2O	Metric tons in thousand	
Agricultural land use	Agri	Square kilometer	+
Square of Agricultural land use	$Agri^2$	Square kilometer	-
Gross domestic product	GDP	Us $	+
Population growth rate	Popn	Annual %	+

NB: definition and unit of measurement is taken from the world bank.

2.2. Unit root test

To select the appropriate model that shows the nexus between economic growth and the agriculture sector, first check whether the data is stationary or not. Because nonstationary data has its own limitations. When the variables in a regression are nonstationary, we face the problem of spurious regression, where R-square values and t-statistics no longer follow the usual distributions and can be wildly inflated (Granger *et al.,* 2001). To do so, a lot of unit root tests are there including the Dicky-Fuller test, Augmented Dicky-Fuller test, Phillips Perron test, and KPSS test. By the size and power of its test, the Dicky-Fuller test is sensitive to the way it is conducted, while the Augmented Dicky-Fuller and Phillips Perron tests are more advantageous by take care of the serial correlation in the error terms (Gujarati, 2005).

2.3. Model specification

The theoretical framework of the Environmental Kuznet Curve is applied to specify the nexus between the environment and the agriculture sector. The Environmental Kuznet Curve of the conventional inverted-U shape is modeled as a second-degree polynomial in logarithmic terms (Hilton and Levinson, 1998). The model was employed to explain the relationship between agriculture-induced nitrous oxide with agricultural land, GDP, and the population growth rate. All variables were transformed logarithmically. Because logarithmically transforming variables in a regression model is a very common way to handle situations where a non-linear relationship exists between the independent and dependent variables. Logarithmic transformations are also a convenient means of transforming a highly skewed variable into one that is more or less normally distributed (Benoit, 2011). Then, model was specified as:

$$lnAN_2O_t = \beta_0 + \beta_1 lnAgri + \beta_2 lnAgri^2 + \beta_3 lnGDP + \beta_4 lnPopn + \varepsilon_t \qquad 1$$

where AN_2O are agriculture-induced nitrous oxide. Agri and $Agri^2$ are the agricultural land and its square, respectively. GDP is the gross domestic product, and Popn is the annual population growth rate. The subscript t is a time index, ln stands for natural logarithm, and ε is a normally distributed white noise error term.

i. If $\beta_1 = \beta_2 = 0$, it means that there is no relationship between agricultural production and environment.
ii. If $\beta_1 > 0$ and $\beta_2 = 0$, it means that there is a monotonic increasing or linear relationship.

iii. If $\beta_1 < 0$ and $\beta_2 = 0$, there is a monotonically decreasing relationship.

iv. If $\beta_1 > 0$ and $\beta_2 < 0$, there is an inverted-U-shaped relationship, i.e. Environmental Kuznet Curve have satisfied.

v. If $\beta_1 < 0$ and $\beta_2 > 0$, there is a U-shaped relationship.

2.4. Cointegration test

Cointegration means the long-run relationship between the two variables under study (Engle and Yoo, 1987). Many time-series models assume that the relationship between these variables stays constant across the entire period. However, there are cases where changes in factors outside of the model cause changes in the underlying relationship between the variables in the model. In applied econometrics, the Granger (1981) and, Engle and Granger (1987), Autoregressive Distributed Lag (ARDL) cointegration technique, or bound test of cointegration (Pesaran and Shin, 1999 and Pesaran *et al*., 2001) and, Johansen and Juselius (1990) cointegration techniques have become the solution to determining the long run relationship between series. Under the conventional Granger and, Engle and Granger cointegration analysis is not applicable in cases of variables that are integrated of different orders (i.e, series-A is I (1) and series-B is I (0)) while in Johansen and Juselius (1990) and ARDL cointegration procedure, it is applicable. When one cointegrating vector exists, Johansen and Juselius (1990) cointegration procedure cannot be applied. Hence, the Autoregressive Distributed Lag (ARDL) approach to cointegration or bound procedure for a long-run relationship is applied, irrespective of whether the underlying variables are I (0), I (1) or a combination of both. In such situation, the application of ARDL approach to cointegration will give realistic and efficient estimates (Nkoro and Uko, 2016). Unlike other tests, the ARDL is a more statistically significant approach for determining cointegrating relationships in small samples (for instance, the Johansen co-integration techniques still require large data samples for the purposes of validity) (Ghatak and Siddiki, 2001).

Among them, the Autoregressive Distributed Lag (ARDL) Bounds testing approach developed by Pesaran and Shin (1995) and later modified by Pesaran *et al.* (2001) was employed in this paper to determine both the short-run and long-run cointegration of the environment with economic and agricultural growth in Ethiopia. Then, the ARDL model can be specified as:

$$\Delta lnAN2O_t = \beta_0 + \beta_1 lnAN2O_{t-1} + \beta_2 lnAgri_{t-1} + \beta_3 lnAgri^2{}_{t-1} + \beta_4 lnGDP_{t-1} + \beta_5 lnPopn_{t-1} + \sum_{i=1}^{\rho} \alpha_i \Delta lnAN2O_{t-i} + \sum_{i=1}^{q} \alpha_i \Delta lnAgri_{t-i} + \sum_{i=1}^{q} \alpha_i \Delta lnAgri^2{}_{t-i} + \sum_{i=1}^{q} \alpha_i \Delta lnGDp_{t-i} + \sum_{i=1}^{q} \alpha_i \Delta lnPopn_{t-i} + \varepsilon_t \quad 2$$

ρ and q are max lag length for the dependent and independent variables, respectively

The null hypothesis is that there is no co-integration in the long-run among the variables against the alternative hypothesis of the existence of co integrating relationship between the variables in equation 2 above.

H_0: $\beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$

H_1: $\beta_0 \neq \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$

2.5. Diagnostic tests

After all, diagnostic tests are required to check if the assumptions of the model are violated or not. The most diagnostic tests applied in this study include the stability test, autocorrelation test, and normality test.

3. RESULT AND DISCUSSION

3.1. Descriptive statistics

The summary descriptive statistics of variables applied for analysis in terms of mean, standard deviations, minimum, and maximum values is presented in Table 2. Those variables are agriculture-induced nitrous oxide, agricultural land use, GDP, and population growth in Ethiopia. The mean value of agriculture-induced nitrous oxide from 1990 to 2020 was 30,865.19 metric tons in thousand having a minimum and maximum value of 20,020 and 44,670.82, respectively. The agriculture land use also has a mean of 361,222 square kilometer. Similarly, GDP and population growth rate have a mean value of 35.669 billion USD and 3.001%, respectively.

Table 2. Descriptive statistics of variables

Variables	Observation	Mean	Standard deviation	Minimum	Maximum
AN_2O	31	30,865.19	8,789.18	20,020	44,670.82
Agri	31	361,222	72,634.6	304,720	563,120
GDP	31	35.669	25.772	11.216	95.072
Popn	31	3.001	0.381	2.655	4.211

Source: (own computation, 2023)

3.2. Unit root tests

To check whether there is a unit root problem in the series or not, the Augmented Dicky-Fuller unit root test was employed. The model is conducted with three options having unit root with drift, without drift, and with trend component. The null hypothesis says that the data has a unit root test, while the alternative is that the data has no unit root and is stationary. The decision rule is that if the t statistic's absolute value is greater than the critical values at the 1%, 5%, and 10% levels of significance, reject the null hypothesis, implies that there is no unit-root problem in the data set.

Table 3. Augmented Dicky-Fuller unit root test result

At its level					At its 1st difference		
Variables	Models	Test statistics	Critical values (1%)	Decision	Test statistics	Critical values (1%)	Decision
lnAN_2O	With drift	0.099	-2.467	Accept Ho	-5.561	-2.473	Reject Ho
	Without drift	2.626	-2.652		-4.572	-2.654	
	Trend	-2.949	-4.334		-5.542	-4.343	
lnAgri	With drift	-3.085	-2.467	Reject Ho	-5.191	-2.473	Reject Ho
	Without drift	-0.652	-2.652	Accept Ho	-5.217	-2.654	
	Trend	-3.039	-4.334		-5.660	-4.343	
lnGDP	With drift	2.221	-2.467	Accept Ho	-4.340	-2.473	Reject Ho
	Without drift	6.468	-2.652	Reject Ho	-2.047	-1.950	
	Trend	-3.223	-4.334	Accept Ho	-4.589	-4.343	
lnPopn	With drift	-8.004	-2.467	Reject Ho	-5.169	-2.473	Reject Ho
	Without drift	40.021	-2.652		-2.754	-2.654	
	Trend	-12.150	-4.334		-4.643	-4.343	

Source: (own computation, 2023)

The Augmented Dicky-Fuller unit root test presented (Table 3) clearly indicates that at 1% critical values, the variable agriculture induced nitrous oxide in Ethiopia has a unit-root problem in their level series. But, population growth rate does not have a unit-root problem. If we incorporate a trend term in agricultural land use and GDP, there is a unit-root problem. So, to avoid the unit root problem in the data set, I have transformed the data into its first difference. After differencing the data, we strongly reject our null hypothesis meaning that all variables are stationary and ready for any model's applicability.

3.3. The nexus between environment and agriculture

The ARDL bound test was employed to analyze the cointegration between the environment and the agriculture sector. The findings in the ARDL bound test, the F-statistic value (6.031) is higher than the upper critical value (5.06) at a 1% level of significance and we are in a position to reject the null hypothesis of no cointegration. This means there was a long-run cointegration among agriculture-induced nitrous oxide with agricultural land use, GDP, and the population growth rate in Ethiopia during the study period. So, we can go further to analyze the short-run and long-run relationship among agriculture-induced nitrous oxide, agricultural land, GDP, and population growth rate.

Table 4. The ARDL bound test and ARDL model output

Lag order: 1,1,1,1,1	Sample: 1991 to 2020	number of observations=30	
F value = 6.031	Critical value=5.06		Reject H0***
Variables	Long-run	Short-run	Statistics
ΔlnAgri	9.900 (3.781) ***	7.825 (3.77) **	R^2 =0.625
Δ$\mathbf{lnAgri^2}$	-3.815 (1.466)***	-3.025(1.457) **	Adjusted R^2=0.456
ΔlnGDP	0.089 (0.085)	-0.412 (0.258)	L.likelihood = 63.218
ΔlnPopn	-0.025 (0.48)**	-0.169 (0.249)	Root MSE= 0.036
Constant		41.099(17.146) ***	
Adjusted dlnAN_2O	-0.649 (0.201) ***		

Source: (own computation, 2023)
NB: *** indicate significant at 1% and ** denotes significance level at 5% level of significance.

The ARDL model output (Table 4) reveals that agricultural land use with its square and population growth rates' long-run coefficients are statistically significant at a 1% and 5% level of significance, respectively. That means agriculture induced nitrous oxide has a long-run relationship with agricultural land allocation and population growth rate. Agricultural land use and its square also have a statistically significant short run effect on total nitrous oxide at a 5% level of significance. The adjustment coefficient for the agriculture induced nitrous oxide is statistically significant at a 1% level of significance, which implies the errors of the previous year on nitrous oxide emission from agriculture sector are corrected and decreased by -0.649 percentage points in the current year.

More specifically, agricultural land use has a strong and statistically significant positive short-run and long-run relationship with agriculture induced nitrous oxide. However, the quadratic term, agricultural land use squared has statistically significant negative effect both on the short-run and long-run. Other thing remains constant, a 1% increase in agricultural land use will increases nitrous oxide emission by 9.9% in the long run and 7.83% in the short run. A percentage change in the

square of agricultural land use will decrease the nitrous oxide emission by 3.82% in the long-run implies that as practices and usage of agricultural land becomes more balanced in the long run, nitrous oxide decreases by 3.82%. This result is consistent with the theoretical hypothesis of the Environmental Kuznet Curve (Kuznet, 1955). Majority of the population in Ethiopia practices agriculture as a mainstay in improving their living standards or decreasing their poverty status. All of those economic practices have deteriorated environmental qualities through expansion of arable land, the exploitation of natural resources, and people do not worry that much about the environment. But once they achieve stable and efficient application of agricultural land in the long run, peasants would start to think more about the environment and try to apply environmentally friendly agricultural technologies. Then, the practice of agriculture and the emission of nitrous oxide has positive relationship in the short run and inverse relationship in the long run. Empirically, the study is also consistent with the findings obtained by (Endeg, 2015; Adem *et al*., 2020). They remarked that agriculture based economic growth would loss bio-diversity loss invariably contribute for environmental degradation. This result, of course, contrasts the findings of (Adedoyin *et al*., 2020). Their result implies that agriculture enhances environmental quality. The contradictory finding may be due to the difference in the method of analysis or difference in variables to represent environment and agriculture.

3.4. Causality among variables

The pairwise Granger causality test is used to test which macroeconomic variable granger cause the other variable. The null hypothesis of the test is no granger causality between the two variables and we reject this hypothesis if the probability of chi square test is statistically significant at less than 5% level of significance.

The first row of Table 5 shows that lagged values of agricultural land use, GDP, and population growth cause the agricultural induced nitrous oxide emission as the p-value is statistically significant at 1% level of significance. The direction of causality is therefore from agricultural land use, GDP, and population growth to agricultural induced nitrous oxide emission. Similarly, Adem *et al*. (2020) revealed population growth and GDP per capita have 'Granger cause' on carbon dioxide emission. Haider *et al*. (2022) also justify that agricultural land use Granger causes total N_2O emissions.

In the second row, p-value for agricultural induced nitrous oxide emission and population growth is very small (less than the 5% level of significance). Therefore, the null hypothesis stating that

"lagged values of agricultural induced nitrous oxide emission and population growth do not cause agricultural land use" can be rejected at a 5% level of significance. However, the null hypothesis that "lagged values of GDP do not cause agricultural land use" cannot be rejected as the corresponding p-value (0.486) is greater than 0.05. This implies that GDP does not Granger-cause agricultural land use and the direction of causality is from agricultural induced nitrous oxide emission and population growth to agricultural land use.

The results in the third-row show that lagged values of both agricultural land and population growth rate cause GDP. Since the p values for both variables are less than 0.05, reject the null hypothesis 'lagged values of agricultural land and population growth rate do not cause GDP' at a 5% level of significance. However, agricultural induced nitrous oxide emission does not cause GDP. The direction of causality is from both agricultural land and population growth rate to GDP. Similar to the findings obtained by Agboola and Bekun (2019), agriculture is also a major contributor to economic growth in Ethiopia.

In the fourth row, p-value for agricultural induced nitrous oxide emission and GDP is large (greater than the 5% level of significance). Therefore, the null hypothesis stating that "lagged values of agricultural induced nitrous oxide emission and GDP do not cause agricultural land use" cannot be rejected at a 5% level of significance. However, the null hypothesis that "lagged values of agricultural land do not cause population growth rate" can be rejected as the corresponding p-value (0.000) is less than 0.05. This implies that agricultural land Granger-cause population and the direction of causality is from agricultural land use to population growth.

Table 5. The pairwise Granger causality test result

Equation	Excluded	Chi2	Df	Prob > Chi2
ΔAN_20	ΔAgril	10.149	2	0.006
ΔAN_20	ΔGDP	9.7584	2	0.008
ΔAN_20	ΔPopn	7.5176	2	0.023
ΔAN_20	All	34.074	6	0.000
ΔAgril	ΔAN_20	7.2894	2	0.026
ΔAgril	ΔGDP	1.4432	2	0.486
ΔAgril	ΔPopn	174.71	2	0.000
ΔAgril	All	358.11	6	0.000
ΔGdp	ΔAN_20	4.0949	2	0.129
ΔGdp	ΔAgril	7.3376	2	0.026
ΔGdp	ΔPopn	9.5697	2	0.008
ΔGdp	All	20.976	6	0.002

ΔPopn	ΔAN_20	2.9709	2	0.226
ΔPopn	ΔAgril	61.818	2	0.000
ΔPopn	**ΔGDP**	4.1883	2	0.123
ΔPopn	All	192.96	6	0.000

Source: (own computation, 2023)

In summary, agriculture induced nitrous oxide emission and agricultural land has bidirectional Granger causality. This is compatible with the existing theory; agriculture is both the cause and effect of environmental degradation or climate change in broad term. Agricultural land use also has bidirectional Granger causality with population growth rate in Ethiopia, while the other variables have a unidirectional Granger causality among them. Both agricultural land and population growth rate Granger causes agriculture induced nitrous oxide emission and GDP. Agriculture induced nitrous oxide emission do not Granger cause GDP and population growth. At the same time, GDP do not Granger cause agricultural land use and population growth.

3.5. Postestimation Diagnosis

Under this section, different post-estimation tests were conducted to check the absence of serial correlation, the stability of the model, and the normality of the error term. The Breusch-Godfrey LM test for autocorrelation is conducted to check whether there is a serial correlation in the data set or not. The null hypothesis of the Breusch-Godfrey LM test for autocorrelation is that there is no serial correlation. The P-values for the agriculture-induced nitrous oxide emissions are statistically insignificant (0.96), and there is no evidence to reject the null hypothesis (Table 6). Confidently, it implies there is no serial correlation in the analyzed data set.

Table 6. Breusch-Godfrey LM test for autocorrelation and Jarque-Bera normality test

Variables	**lags(p)**	**Df**	**chi2**	**Prob > chi2**
AgriN2O	1	1	0.003	0.9557
Jarque-Bera	-	-	0.4502	0.7985

Source: (own computation, 2023)

The Jarque-Bera normality test also conducted to check the normality of the residuals after the ARDL model. Its null hypothesis is that the error terms are normally distributed. The Jarque-Bera normality test value is 0.4502 and its chi square probability is statistically insignificant (0.7985) (Table 6). So, the null hypothesis is not rejected.

The cumulative sum squared stability test results also reveals the agriculture-induced nitrous oxide emissions lie comfortably with the 5% boundary line, meaning that the model is stable as in (Figure

1). The histogram of the residuals Figure 2 is also depicted that the residuals are normally distributed.

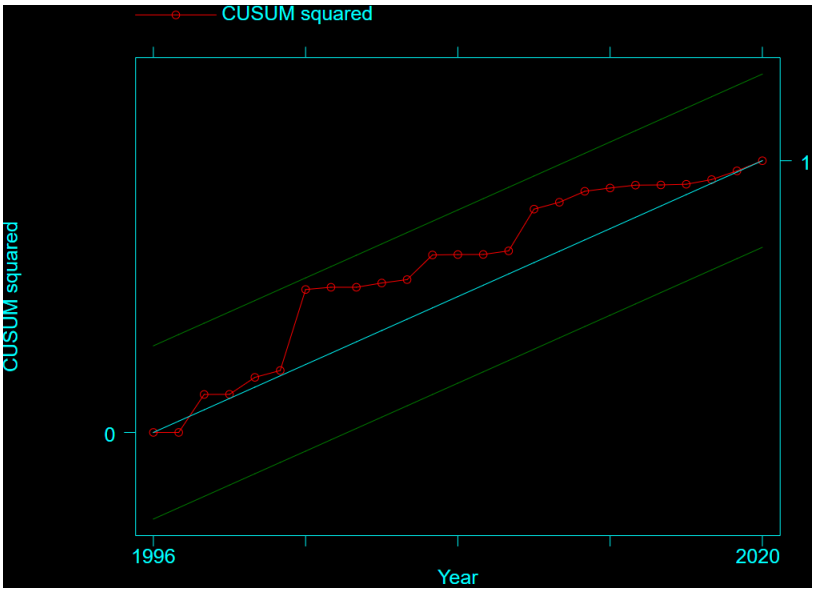


Figure 1. Cumulative sum test for AN_2O

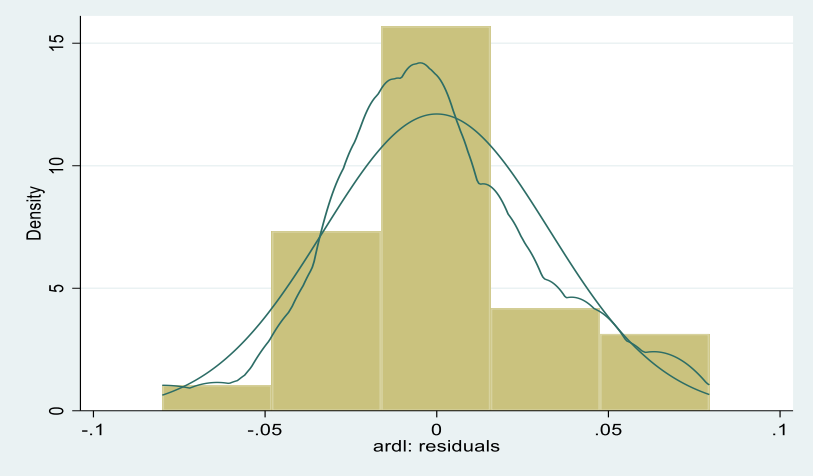


Figure 2. Histogram of residuals

4. CONCLUSION AND RECOMMENDATIONS

During the last decade, Ethiopia's economy has been the fastest growing in the region at an average of 9.5% per year, and its economy is highly agrarian. Ethiopia's contribution to greenhouse gas emissions is very low on a global scale. However, the projected environmental impact of conventional economic development in Ethiopia risks following the pattern observed around the globe. If Ethiopia followed the practices of the past decade, GHG emissions there will more than

double in 2030. By understanding it, Ethiopia is committed to building a climate-resilient green economy by aiming to become a carbon-neutral middle-income nation by 2025.

Having in mind this scenario, this paper aimed to examine the nexus between the environment and agriculture using data spanning from 1990 to 2020. To do so, agricultural nitrous oxide emissions is used as a proxy variable for the environment, and the agriculture sector is also denoted by agricultural land use. The ARDL bound test was applied to infers the cointegration between environment, agriculture, economic growth, and population growth rate in Ethiopia. The ARDL model output reveals that agricultural land use and its square long-run coefficients are statistically significant at the 1% level of significance. The model also assures, the practice of agriculture and the emission of nitrous oxide has positive relationship in the short run and inverse relationship in the long run. The nexus between the environment and agriculture in Ethiopia during the study period had satisfied the existence of environmental Kuznet curve. This is might be as a result of agricultural practices have deteriorated environmental qualities through expansion of arable land, the exploitation of natural resources, and people do not worry that much about the environment. But once they achieve stable and efficient application of agricultural land in the long run, peasants would start to think more about the environment and try to apply environmentally friendly agricultural technologies.

Furthermore, the pairwise Granger causality test was used to test which macroeconomic variable granger cause the other variable. The test reveal agriculture induced nitrous oxide emission and agricultural land has bidirectional Granger causality that is compatible with the existing theory, agriculture is both the cause and effect of environmental degradation. Agricultural land use also has bidirectional Granger causality with population growth rate in Ethiopia, while the other variables has a unidirectional Granger causality among them.

As a general, this research has taught me that the environment and agriculture in Ethiopia are inextricably linked and are two sides of the same coin. So, our economic policy should encourage environmentally friendly production agricultural technologies and strive for environmental quality by employing low external agricultural inputs.

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