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Assessing the impact of agricultural production and institutional quality on environmental degradation in Somalia

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Abstract
Environmental degradation poses a significant threat to the well-being of all living beings and ecosystems. This paper investigates the impact of agricultural production, institutional quality, energy consumption, and domestic investment on environmental degradation in Somalia. Using ARDL and Dynamic OLS models, we analyze data from 1990 to 2020 and find significant contributions from agriculture, institutions, and energy. Granger causality tests reveal strong bidirectional relationships between institutions and environmental degradation, and a unidirectional effect of agriculture on the environment. The findings indicate a need for targeted policies aimed at enhancing institutional quality while mitigating potential negative environmental impacts. Additionally, there is a call to promote sustainable agricultural practices and the adoption of clean energy in Somalia.

Keywords ARDL · Environmental degradation · Agricultural production · Institutional quality · Somalia

1 Introduction

The world is currently facing an urgent and critical challenge of environmental degradation and climate change, which requires a collective and collaborative effort from all sectors of society [1]. International forums serve as platforms for robust discussions and debates on environmental concerns, promoting global cooperation to combat climate change and promote sustainable development. Key agreements, such as the Kyoto Protocol and the Paris Agreement, have been established to encourage and enforce responsible actions towards environmental conservation and preservation [2].

Regrettably, the impacts of global warming have been exacerbated in recent years, leading to detrimental effects on human communities as well as the natural world [3]. The need for collaboration and action to address these challenges has never been more urgent [4, 5]. Agriculture has a crucial role in ensuring food security, promoting economic growth, and preserving cultural heritage. However, it is important to note that it is also the second-largest contributor to global greenhouse gas emissions, amounting to an estimated 10% to 30% of the total emissions. Some regions, such as Brazil, China, India, and Africa, have disproportionately higher emissions due to the use of agricultural machinery, livestock, fertilizers, and deforestation [6, 7]. These emissions have far-reaching consequences, including food and water scarcity, displacement of populations from rising sea levels and extreme weather events, loss of biodiversity, increased health risks, and economic instability.

The pursuit of sustainable food security has sparked considerable debate, highlighting the need to implement strategies that increase agricultural productivity while reducing environmental impacts [8, 9]. Agriculture is a significant contributor to the gross domestic product, employment, and overall economic growth of many Sub-Saharan African

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countries. However, Somalia, like many other countries in the region, is highly vulnerable to the impacts of climate change due to its heavy reliance on rainfed agriculture, making it susceptible to droughts [10]. Consequently, Somalia has experienced recurrent humanitarian crises that require emergency responses and relief efforts to address issues such as food shortages, malnutrition, and displacement [11]. The intensification of agricultural production to meet food security demands exacerbates the challenge of rising carbon emissions, underscoring the imperative for sustainable agricultural practices with minimal environmental footprints [8, 12].

Somalia, like many African nations, relies heavily on rainfed agriculture, making it especially vulnerable to climate variability and extreme weather events, such as droughts and floods. The country's dependence on traditional farming methods, coupled with deforestation for farmland and overuse of water resources, has led to significant soil degradation, loss of biodiversity, and increased carbon emissions. These environmental challenges are further compounded by inadequate infrastructure and insufficient investment in renewable energy, which intensifies the degradation associated with energy consumption in agricultural practices. Recent research has increasingly highlighted the link between agricultural practices and environmental degradation, emphasizing the urgent need for sustainable solutions in regions like Somalia [13].

This study is grounded in the Environmental Kuznets Curve (EKC) hypothesis and institutional theory. The EKC posits an inverted U-shaped relationship between economic development and environmental degradation, where environmental degradation initially increases with economic growth but eventually decreases as higher income levels support stronger environmental regulations and sustainable practices [14]. We extend this framework by incorporating institutional quality, hypothesizing that better institutions should lead to improved environmental outcomes. However, in a developing country like Somalia, institutional improvements might initially prioritize economic growth over environmental protection, potentially leading to a 'race to the bottom' scenario [15]. This suggests that while institutional reforms can foster environmental regulation, there may be short-term trade-offs between economic development and environmental sustainability.

Chen et al. [16] assessed carbon emission peaks in China's major industries, utilizing the logarithmic mean Di visit index and the carbon Kuznets curve, revealing agriculture as a significant contributor. The study identifies economic output growth as a primary driver of agricultural carbon emissions, indicating a direct relationship between economic expansion and increased emissions due to heightened demand for agricultural products. Similarly, [17] analyzed the influence of globalization, agriculture, and renewable energy production on CO2 emissions in Turkey from 1970 to 2017 involved employing statistical methodologies like the bootstrap autoregressive distributed lag (ARDL) approach and the Gregory-Hansen cointegration test. The analysis incorporates economic, social, and political KOF indicators as explanatory variables. Findings reveal a cointegration relationship among the variables, with long-term estimations indicating that environmental pollution is influenced by agriculture, renewable energy development, and economic globalization.

On the contrary, [18] conducted a study on the effect of economic globalization on carbon dioxide (CO2) emissions in G7 nations from 1996 to 2017, taking into account the significance of natural resources, value-added agriculture, and financial development. By using advanced econometric techniques, the research revealed that value-added agriculture helps to reduce CO2 emissions. This is because these nations adopt a comprehensive strategy towards sustainable agriculture, including climate-resilient methodologies. The study also found that economic globalization, financial expansion, and abundant natural resources all contribute to increased CO2 emissions. Others such as [19] analyzed the impact of Pakistan's forestry, agricultural practices, and renewable energy utilization on its carbon dioxide (CO2) emissions. The Autoregressive distributed lag (ARDL) examination of qualitative time-series data spanning from 1990 to 2014 validates the significance of agricultural carbon emissions solely over the long term. This finding is consistent with the economic Kuznet curve hypothesis, which suggests that agricultural expansion promotes economic growth but has negative effects on the environment in the short term.

The inconsistent performance of the agricultural sector can arguably be attributed to deficiencies in institutional quality. Regulatory frameworks and targeted interventions, such as incentivizing farmers to mitigate their adverse environmental impacts, are imperative for effecting substantial environmental outcomes [20]. Robust and effective institutions facilitate formulating and implementing policies aimed at reducing pollution, preserving natural resources, and promoting sustainable development, thus contributing to enhanced environmental protection and management practices.

Developing nations face a significant technical hurdle when it comes to balancing economic and environmental concerns in the pursuit of sustainable development [21]. This challenge requires the implementation of policies and strategies that reconcile economic growth with environmental conservation, all while contending with competing priorities and limited resources [22]. In this regard, strong institutions are essential in fostering global collaboration and securing financial resources and technical support. Therefore, the environmental impact of institutional practices must be carefully considered [23].

Despite various obstacles such as low governmental capacity, corruption, and a lack of transparency due to a prolonged civil war, Somalia has made notable strides in reform efforts. The country has been recognized for its efforts in clearing arrears to international financial institutions and achieving the Highly Indebted Poor Countries Initiative (HIPC) Decision point status [24]. Hussain and Dogan, [25] establishing institutions with clear mandates and efficient governance structures can play a crucial role in enforcing environmental regulations and ensuring compliance with environmental standards. Academic research extensively examines the relationship between institutional quality and environmental protection, with enhancing government institutions believed to yield substantial benefits for environmental well-being.

Researchers such as [26] investigated the impact of institutional quality and financial development on the environment in South Asia. The study found that factors such as trade openness, energy consumption, foreign direct investment (FDI), economic growth, and institutional quality influence environmental quality. Using panel data spanning from 1984 to 2015, the empirical analysis revealed that improvements in institutional quality led to a reduction in pollution levels in South Asia. Ibrahim and Law, [27] utilizing the system generalized method of moments, explored the impact of trade, institutional quality, and their interplay on carbon dioxide emissions across a panel sample of forty Sub-Saharan African nations. The findings unequivocally illustrate that institutional reforms significantly contribute to environmental improvement.

On the contrary, [28] analyzed data spanning from 1991 to 2017 to investigate the influence of institutional quality on the environment and energy consumption across 66 developing nations. The study found that there is a positive correlation between institutional quality and various environmental indicators, including CO_2 emissions. This suggests that as institutional quality improves, emissions tend to increase. This phenomenon is attributed to the likelihood of enhanced institutional quality coupled with accelerated economic growth in emerging economies, thereby leading to heightened energy demand and carbon emissions. Others such as [29] Conducted multiple investigations on emissions levels across 147 nations from 1990 to 2012. The findings illustrate that although democratization within a nation does not exert identical inhibitory effects as it does globally, democratic regimes typically exhibit lower emissions compared to non-democratic counterparts. Furthermore, this study uncovers tentative evidence suggesting that the specific electoral system can significantly impact the relationship between democratization and emissions across different nations.

This study explores the relationship between agricultural production, institutional quality, and environmental degradation in Somalia, a country often overlooked in existing research. Much of the literature has focused on these relationships in developed or emerging economies, leaving a gap in empirical studies concerning fragile states like Somalia. This research illustrates how institutional quality influences agricultural practices and environmental outcomes, particularly in a context characterized by improving governance and ongoing humanitarian crises. Additionally, the study utilizes the Autoregressive Distributed Lag (ARDL) model and Granger causality tests to provide new insights into the interrelationships among these variables, thereby enhancing our understanding of how to align agricultural practices with environmental sustainability in developing countries.

To address these gaps, this study aims to answer the following research questions: How does institutional quality affect agricultural production and its environmental impact in Somalia? What are the short- and long-term effects of agricultural production and institutional quality on environmental degradation? How can policy interventions be designed to mitigate the negative environmental impacts of agricultural practices while enhancing food security ? By posing these questions, this research seeks to present a framework for understanding the complex dynamics at play and to inform sustainable policy development tailored to Somalia's unique challenges.

2 Methodology

2.1 Data

For our analysis, we collected annual time series data from 1990 to 2020 from reputable sources, including the Energy Institute, World Bank, Freedom House, and the SESRIC database of the Organisation of Islamic Cooperation (OIC). These sources ensure the reliability of the information used in our study. The dataset includes five key variables: environmental degradation, agricultural production, institutional quality, energy consumption, and domestic investment. Environmental degradation is measured using indicators like carbon emissions, which are essential for understanding the ecological impact of various economic activities [1, 30]. Agricultural production is included to evaluate its role as a significant driver of both economic growth and environmental stress [31]. Institutional quality is important for examining how governance influences environmental policies and practices [32]. Energy consumption is considered due to its substantial contribution to greenhouse gas emissions [33, 34]. Lastly, domestic investment reflects the economic capacity to implement sustainable practices and technologies, affecting both agricultural productivity and environmental outcomes [35].

This dataset enables us to explore the dynamic relationships among these variables over a significant period, providing insights into the socio-economic factors influencing environmental sustainability in Somalia. The time frame of 1990 to 2020 is particularly relevant, as it covers a crucial period of recovery and reform in Somalia following years of conflict, allowing us to identify trends and shifts in governance, economic activity, and environmental conditions (see Table 1).

2.2 Econometric modeling

The study adopts a systematic approach to investigate the impact of agricultural production, institutional quality, energy consumption, and domestic investment on environmental degradation. It begins by presenting descriptive statistics to provide an overview of the dataset's central tendencies and variability, aiding in the comprehension and assessment of data quality. The study also employs unit root testing to evaluate the stationarity of variables, which is critical for ensuring that the statistical analyses and forecasting models are robust and reliable.

The research uses the Autoregressive Distributed Lag (ARDL) approach to model the relationships between environmental degradation (LnED), agricultural production (LnAP), institutional quality (LnIS), energy consumption (LnENC), and domestic investment (LnDI). ARDL models are known for their ability to capture dynamic interdependencies over time and include lagged variables to examine both short-term and long-term effects, accommodating stationary and non-stationary data. The versatility and resilience of ARDL models to misspecification make them highly reliable for elucidating complex social and economic phenomena. Additionally, ARDL offers robust short- and long-term estimations and is applicable even with small sample sizes [36].

Furthermore, the integration of an Error Correction Mechanism (ECM) enhances the ARDL model's capacity to capture dynamic adjustments toward long-run equilibrium. This feature renders ARDL models comprehensive tools widely employed in time series analysis. The specified ARDL model offers a robust framework to explore the intricate relationships between the variables, shedding light on the multifaceted dynamics driving environmental degradation and informing policy interventions aimed at sustainable development.

$$LnED_t = \beta_0 + \beta_1 LnAP_t + \beta_2 LnIS_t + \beta_3 LnENC_t + \beta_4 LnDI + \varepsilon_t \tag{1}$$

The equation represents the logarithm of environmental degradation, agricultural production, institutional quality, energy consumption, and domestic investment at time t respectively. The coefficients β_0,β_1,β_2,β_3, and β_4 are to be estimated, and ε_t denotes the error term.

$$\begin{aligned} \Delta LnED_t &= \beta_0 + \beta_1 \Delta LnED_{t-1} + \beta_2 \Delta LnAP_{t-1} + \beta_3 \Delta LnIS_{t-1} + \beta_4 \Delta LnENC_{t-1} \\ &+ \beta_5 \Delta LnDI_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \mathrm{LnED}_{t-1} + \sum_{i=1}^{q} \gamma_i \Delta \mathrm{LnAP}_{t-1} + \sum_{i=1}^{r} \tau_i \Delta \mathrm{LnIS}_{t-1} \\ &+ \sum_{i=1}^{s} \lambda_i \Delta \mathrm{LnENC}_{t-1} + \sum_{i=1}^{T} \theta_i \Delta \mathrm{LnDI}_{t-1} + \mu ECT_{t-1} \end{aligned} \tag{2}$$

The model presented establishes a comprehensive relationship between changes in environmental degradation and lagged changes in agricultural production, institutional quality, energy consumption, and domestic investment. Utilizing the initial difference operator Δ and lag lengths p, q, r, s, and t for each variable, the model quantifies both the immediate

Table 1 Variable descriptions

Variables	Code	Measurement	Source
Environmental degradation	ED	Carbon emissions(kt)	World Bank
Agricultural production	AP	Crop production	World Bank
Institutional quality	IS	Civil and Political Liberties	Freedom House
Energy consumption	ENC	Energy use per capita (kWh per capita)	Our world in data
Domestic investment	DI	Gross fixed capital formation (Constant 2015)	Sesric

effects (coefficients β_1 to β_5) and enduring impacts (coefficients α_i, γ_i, τ_i, λ_i, and θ_i across varying lag lengths) of these determinants on environmental degradation. Furthermore, an error correction term (ECT) is incorporated to capture the pace of adjustment towards long-term equilibrium, with coefficient μ indicating its magnitude.

This comprehensive framework provides valuable insights into the nuanced interplay between environmental degradation and its determinants, encompassing both transient fluctuations and enduring equilibrium adjustments. To ensure the rigor of our analysis, we conducted a series of diagnostic procedures, including residual, stability, and specification tests, to safeguard the reliability and robustness of the model. Additionally, we deployed Granger causality tests to probe the dynamic interdependencies between environmental degradation, agricultural production, institutional quality, energy consumption, and domestic investment. These analytical endeavors unveil the temporal dynamics and causal pathways underpinning the interactions among the studied variables, enriching our understanding of their interconnectedness and informing targeted policy interventions for sustainable development.

3 Empirical results

3.1 Descriptive statistics

Table 2 provides a comprehensive overview of the dataset, offering both descriptive statistics and a correlation matrix. The descriptive statistics illuminate various characteristics of the data and the interrelationships between variables.

In terms of central tendency, the mean values indicate that agricultural production, energy consumption, and domestic investment exhibit relatively high levels. Conversely, environmental degradation shows a negative mean, indicating lower average levels of degradation. Regarding variability, the standard deviation reveals that domestic investment demonstrates the highest variability among the variables, while institutional quality exhibits the lowest. Examining skewness, institutional quality appears negatively skewed, suggesting an asymmetric distribution with a tail toward lower quality. Conversely, energy consumption, domestic investment, and agricultural production show positive skewness, indicating distributions skewed toward higher values.

Furthermore, kurtosis measures indicate the peakedness of the distributions. Energy consumption demonstrates the highest peakedness, while institutional quality exhibits the lowest. Lastly, the Jarque–Bera test indicates departures from normality for energy consumption and domestic investment, suggesting non-normal distributions. In contrast, institutional quality and agricultural production show a closer adherence to a normal distribution.

Correlation analysis reveals a positive correlation between energy consumption and domestic investment, as well as between agricultural production and energy consumption, suggesting a tendency for these variables to rise together.

Table 2 Descriptive statistics and correlation matrix

Variables	LnED	LnAP	LnIS	LnENC	LnDI
Descriptive statistics summary					
Mean	− 0.510	4.561	1.929	5.706	6.045
Median	− 0.494	4.559	1.946	5.713	5.932
Maximum	− 0.315	4.881	1.946	6.365	6.880
Minimum	− 0.734	4.269	1.872	5.357	5.531
Std. Dev	0.097	0.127	0.031	0.186	0.415
Skewness	− 0.574	− 0.239	− 1.312	1.109	0.657
Kurtosis	3.439	3.491	2.720	6.434	2.301
Jarque–Bera	1.953	0.607	8.989	21.585	2.862
Probability	0.377	0.738	0.011	0.000	0.239
Observations	31	31	31	31	31
Correlations					
LnED	1				
LnAP	0.225	1			
LnIS	0.152	0.038	1		
LnENC	0.398	− 0.259	− 0.258	1	
LnDI	0.415	0.393	− 0.670	0.340	1

Table 3 Augmented Dickey-Fuller (ADF)

Variables	With Constant	With Constant and Trend
At level		
LnED	2.478	2.634
LnAP	– 3.940***	– 5.745***
LnIS	– 1.696	– 1.745
LnENC	– 3.980***	– 6.913***
LnDI	1.262	– 2.766
At fist difference		
Δ LnED	– 3.130**	– 2.920
Δ LnAP	– 6.508***	– 6.274***
Δ LnIS	– 5.196***	– 5.161***
Δ LnENC	– 11.255***	– 10.697***
Δ LnDI	– 4.472***	– 3.790**

Asterisks are to indicate significance levels based on the p-values *** p < 0.01, ** 0.01 ≤ p < 0.05, * 0.05 ≤p<0.1

Additionally, there is a moderate positive correlation between environmental degradation and energy consumption, implying a tendency for higher degradation to coincide with increased energy consumption. However, institutional quality displays weaker correlations with other variables, indicating a less pronounced relationship.

3.2 Unit root test

*Asterisks are to indicate significance levels based on the p-values *** p < 0.01, ** 0.01 ≤ p < 0.05, * 0.05 ≤ p < 0.1.*

In Table 3, we present the results of the unit root test, focusing on the Augmented Dickey-Fuller (ADF) test, which provides crucial insights into the stationarity of the variables under examination. Ensuring stationarity in the time series data is essential for the application of the Autoregressive Distributed Lag (ARDL) model, as it allows for accurate estimation of both short- and long-term relationships among the variables. This, in turn, provides reliable insights into the interactions between agricultural production, institutional quality, and environmental degradation in Somalia.

As shown in Table 3, the ADF test results indicate that agricultural production (AP) and energy consumption (ENC) are stationary at levels, while environmental degradation (ED), institutional quality (IS), and domestic investment (DI) become stationary after first differencing. This combination of I(0) and I(1) variables justifies our choice of the ARDL model. For the model, agricultural production and energy consumption exhibit significant negative values at the level, indicating high confidence in their stationarity. However, environmental degradation, institutional quality, and domestic investment do not exhibit significant values in the ADF test at the level, indicating non-stationarity. This implies that these variables contain trends or stochastic components that affect their statistical properties and may lead to spurious regression results if not addressed.

Fortunately, applying first differences offers a solution to this issue. After differencing, all variables show significant negative values in the ADF test, indicating their stationarity. Differencing removes trends or stochastic components from the variables, making them stationary and ensuring that their statistical properties remain consistent over time.

This approach supports the use of ARDL modeling, which is well-suited for analyzing relationships among variables in non-stationary time series data. By ensuring that all variables are stationary through differencing, the model can accurately capture both long-run and short-run dynamics between the variables. This leads to reliable estimates of their relationships and coefficients, enhancing the validity and usefulness of the model in understanding the dynamics of the examined variables over time.

Table 4 F bound test

F-bounds test				
Model specification	Lower bound	Upper bound	F-statistics	Conclusion
Linear	2.56	3.49	10.825	Cointegration

3.3 F-Bound test

The F-bound test is a crucial analysis that evaluates cointegration in econometric models. In Table 4, the F-statistics range from 2.56 to 3.49, with the observed F-statistic being 10.825. This value surpasses the upper limit, indicating strong long-term cointegration within the model. Additionally, the statistical significance of the obtained F-statistics is evaluated using critical values derived from a 5% significance level.

3.4 Optimal lag length

Based on Table 5, lag 1 emerges as the optimal choice for several reasons. Although the log-likelihood for lag 1 is lower than that for lag 2, the difference is not significant. The likelihood ratio (LR) for lag 1 is not significantly different from zero, suggesting that the improvement in fit compared to a model without lags is not statistically meaningful. Additionally, lag 1 yields the lowest values across all information criteria (FPE, AIC, SC, and HQ), indicating a better balance between model fit and simplicity.

Therefore, we conclude that a first-order autoregressive model (AR(1)) is the most suitable for this time series. This conclusion is supported by the log-likelihood, likelihood ratio test, and information criteria, which together demonstrate that a lag of 1 offers the best trade-off between model fit and parsimony.

3.5 Autoregressive distributed lag

*Asterisks are to indicate significance levels based on the p-values ***: $p < 0.01$, **: $0.01 \leq p < 0.05$, *: $0.05 \leq p < 0.1$.*

Table 6 provides a comprehensive analysis of the interplay between variables over time, elucidating both their short-term and long-term effects within the model framework. The long-term coefficients for agricultural production, institutional quality, energy consumption, and domestic investment indicate a significant positive influence on environmental degradation. Specifically, a 1% increase in energy consumption and institutional quality is associated with a deterioration of the environment by approximately 0.78% and 1.64%, respectively, underscoring their substantial impact on environmental outcomes. Notably, institutional quality emerges as a robust influencer in both the short and long term. Conversely, agricultural production and domestic investment exhibit lower significant coefficients compared to other variables, with a 1% increase in these leading to environmental degradation of 0.78% and 0.32%, respectively.

In the short term, the first differences in agricultural production, institutional quality, and energy consumption reveal immediate effects. These variables exhibit significant positive coefficients, indicating their quick impact on environmental degradation. Institutional quality appears to have the most significant impact compared to other variables, suggesting a 1.46% change in environmental degradation for a 1% change in institutional quality. Additionally, energy consumption and agricultural production show significant coefficients, indicating changes of 0.61% and 0.15% in environmental degradation for a 1% change in energy consumption and agricultural production, respectively. However, domestic investment does not appear to have a significant coefficient, suggesting its limited influence in

Table 5 Optimal Lag

Lag	LogL	LR	FPE	AIC	SC	HQ
0	164.957	NA	1.11e-11	– 11.032	– 10.796	– 10.956
1	282.192	185.959*	1.98e-14*	– 17.393*	– 15.978*	– 16.950*
2	301.525	23.999	3.47e-14	– 17.002	– 14.407	– 16.190

Significance levels are denoted by ***,**, and *, indicating increasing significance levels at 10%, 5%, and 1%,respectively

Table 6 Long run and short run effects

Explanatory	Coefficient	Stand. error	T-statistics
Long-run effects			
LnAP	0.788**	0.296	2.666
LnIS	1.643**	0.721	2.279
LnENC	1.153***	0.261	4.413
LnDI	0.326***	0.070	4.679
Short-run effects			
Δ LnAP	0.155***	0.436	3.543
Δ LnIS	1.469***	0.248	5.915
Δ LnENC	0.613***	0.076	8.051
Δ LnDI	0.021	0.447	0.463
ECM(-1)	− 0.389***	0.043	− 9.011

Diagnostic check	P-value
Jarque–Bera	0.593
Serial correlation	0.143
Heteroskedasticity	0.151
Reset test	0.354
R2	0.950

Asterisks indicate significance levels: *** for $p < 0.01$, ** for $0.01 \le p < 0.05$, and * for $0.05 \le p < 0.1$

Fig. 1 Cusum test

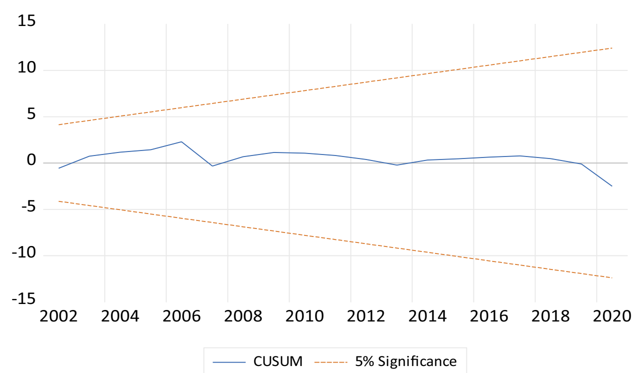
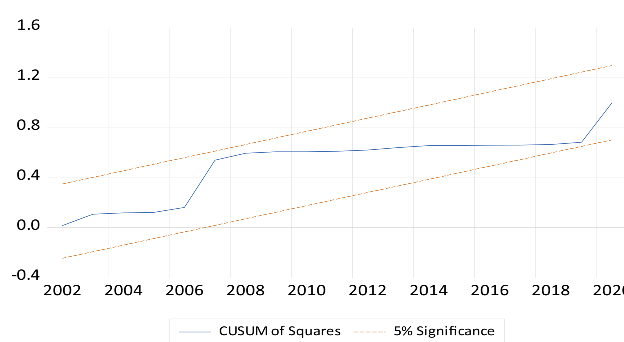


Fig. 2 CusumSQR test



the short term. Furthermore, the Error Correction Mechanism (ECM) term demonstrates a significant negative

Table 7 DOLS

Explanatory	Coefficient	Stand. error	T-statistics
Long-run effects			
LnAP	0.288*	0.152	1.894
LnIS	0.155**	0.062	2.489
LnENC	0.679***	0.181	3.752
LnDI	0.280***	0.049	5.660
R2	0.95		
Adujested R2	0.87		

Asterisks indicate significance levels: three asterisks indicate a *p*-value less than 0.01, two asterisks indicate a *p*-value between 0.01 and 0.05, and one asterisk indicates a *p*-value between 0.05 and 0.1

Table 8 Granger causality test

Null hypothesis	F-statistics	P-value
LnAP does not Granger Cause LnED	6.873**	0.0142
LnED does not Granger Cause LnAP	3.772*	0.0626
LnIS does not Granger Cause LnED	6.039**	0.0207
LnED does not Granger Cause LnIS	6.088**	0.0202
LnENC does not Granger Cause LnED	0.02719	0.8703
LnED does not Granger Cause LnENC	11.407***	0.0022
LnDI does not Granger Cause LnED	2.32	0.1393
LnED does not Granger Cause LnDI	4.108*	0.0527

Asterisks indicate significance levels: *** for $p < 0.01$, ** for $0.01 \le p < 0.05$, and * for $0.05 \le p < 0.1$

coefficient of − 0.38, reflecting the rapid correction of any deviations from long-run equilibrium and indicating a tendency for the system to adjust back to its long-term relationship swiftly.

Diagnostic checks affirm the model's robustness, with the Jarque–Bera test yielding a non-significant p-value, indicating the normality of residuals. Similarly, tests for serial correlation, heteroskedasticity, and the reset test all yield non-significant p-values, suggesting the absence of these issues in the model. The high R-squared value of 0.950 reinforces the model's ability to explain a significant proportion of the variance in the dependent variable, increasing confidence in its predictive capacity and analytical validity. Figures 1 and 2 illustrate CUSUM and CUSUMSQ plots, both of which indicate normalcy and stability. These plots remain within predetermined control limits, indicating no significant shifts in the mean or variance of the time series. Consequently, confidence in the stability of the analyzed process is reinforced. Together, these diagnostic measures provide compelling evidence for the reliability and validity of our analytical framework.

3.6 Dynamic ordinary least squares

In Table 7, the Dynamic Ordinary Least Squares analysis provides insights into the long-run relationships between the variables, confirming the significant long-term impacts of agricultural production, institutional quality, energy consumption, and domestic investment on environmental degradation.

The coefficients in the DOLS model indicate that a 1% increase in agricultural production, institutional quality, energy consumption, and domestic investment is associated with a 0.288%, 0.155%, 0.679%, and 0.280% increase in environmental degradation, respectively, in the long run. The DOLS model also offers a high R-squared value of 0.95, indicating that the model explains a substantial portion of the variation in the dependent variable, thereby enhancing its predictive power and analytical validity. Overall, the DOLS analysis provides additional evidence supporting the significant long-term impacts of agricultural production, institutional quality, energy consumption, and domestic investment on environmental degradation. The findings from this model are consistent with those from the ARDL model, reinforcing the robustness of the identified relationships.

3.7 Granger causality test pairwise

*Asterisks indicate significance levels: *** for p < 0.01, ** for 0.01 ≤ p < 0.05, and * for 0.05 ≤ p < 0.1.*

In Table 8 Granger causality test reveal significant connections between environmental degradation and various factors, including agricultural production, institutional quality, energy consumption, and domestic investment. This test was employed because it allows us to determine whether one time series can predict another, helping us understand the causality between agricultural production, institutional quality, and environmental degradation over time. Agricultural production has a unidirectional influence on environmental degradation, indicating that sustainable agricultural practices could reduce environmental impacts. The bidirectional relationship between institutional quality and environmental degradation highlights the need for improving governance and resource management frameworks. Enhancing institutional quality can tackle environmental challenges while promoting better governance.

The unidirectional effect of environmental degradation on energy consumption suggests that increasing environmental challenges may influence energy consumption patterns, underscoring the necessity for energy policies that prioritize sustainability. The impact of domestic investment on environmental degradation appears to be less significant, indicating that increasing investments may not suffice; instead, it is crucial to focus on the quality and alignment of investments with sustainable development goals.

These findings emphasize the interconnectedness of these factors and provide essential insights for policymakers seeking to implement strategies to combat environmental degradation.

4 Discusssion of the results

The empirical results of our study provide valuable insights into the intricate dynamics between agricultural production, institutional quality, energy consumption, domestic investment, and environmental degradation in Somalia. These results align with existing literature while shedding new light on the situation in Somalia.

Regarding the connection between agriculture and environmental degradation, this study supports previous research indicating that agricultural activities significantly contribute to environmental deterioration [5]. The positive coefficients for agricultural production in both the short and long term underscore its role as a driver of environmental degradation. However, the magnitude of its impact appears to be lower compared to that of institutional quality and energy consumption, highlighting the need for sustainable agricultural practices to mitigate adverse environmental effects.

Interestingly, the positive relationship between institutional quality and environmental degradation was unexpected. This counterintuitive result could be explained by the "race to the bottom" hypothesis, where improving institutions in developing nations like Somalia might initially focus on economic growth at the expense of environmental sustainability. Alternatively, this result might indicate limitations in how our measure of institutional quality captures environmental governance specifically [28]. It suggests that improvements in institutional quality can lead to environmental deterioration. Domestic investment exhibits a positive coefficient in the long term [37]. But does not appear to have a significant impact on environmental degradation in the short term.

The significant influence of energy consumption on environmental degradation resonates with global concerns about the environmental impacts of energy production and consumption [17]. The positive coefficients indicate that increases in energy consumption exacerbate environmental degradation, highlighting the need for energy efficiency measures and renewable energy sources to mitigate environmental harm.

5 Conclusion and policy implication

Our study delves into the intricate connections between environmental degradation, agricultural production, institutional quality, energy consumption, and domestic investment in Somalia from 1990 to 2020. Through robust econometric modeling and rigorous analyses, we have uncovered valuable insights. Our findings suggest that all variables contribute to environmental degradation to varying degrees, with institutional quality emerging as a significant factor, which runs counter to conventional expectations. These results emphasize the importance of nuanced policy interventions to address the complex relationship between governance structures and environmental outcomes.

Our research has significant policy implications. Firstly, it is essential to improve regulatory oversight mechanisms to prevent environmental degradation resulting from poor institutional quality in Somalia. To achieve this objective, the country must prioritize transparency, accountability, and the rule of law within its institutions. This can be accomplished by strengthening regulatory frameworks, combating corruption, and encouraging public participation in environmental decision-making.

Furthermore, enhancing institutional capacity can enable Somalia to implement environmental regulations and encourage sustainable development practices. To mitigate environmental degradation caused by agricultural activities, it is crucial to adopt sustainable agricultural practices such as conservation agriculture and agroforestry. Farmers should be encouraged to implement practices that reduce soil erosion, conserve water resources, and minimize chemical inputs to preserve natural ecosystems. Accelerating the transition to renewable energy sources can reduce reliance on fossil fuels and mitigate the environmental impact of energy consumption.

Finally, to combat climate change and environmental degradation, it is essential to incentivize investment in renewable energy infrastructure and promote energy efficiency measures. Policymakers should recognize the long-term implications of domestic investment on environmental degradation and incorporate environmental impact assessments into investment decisions. Sustainable development strategies should prioritize projects that minimize negative environmental externalities and promote ecosystem resilience.

6 Limitation of the study

The availability of reliable data, particularly for Somalia, presents a significant challenge. The country's political instability and underdeveloped data-collection infrastructure hinder the accurate measurement of key variables, such as institutional quality. This may lead to a less comprehensive understanding of governance structures and environmental regulations. Moreover, the absence of granular, sector-specific data limits the precision of our findings regarding the impact of agricultural practices on environmental degradation.

Although the study incorporates essential variables like agricultural production, institutional quality, and energy consumption, it neglects other crucial factors that could significantly influence the relationship between agriculture and environmental degradation. Notable omissions include technological advancements in agriculture, foreign direct investment (FDI), economic growth, and climate policies, all due to data limitations. Including these variables would have enhanced the study's explanatory power and provided a more nuanced understanding of the interplay between agricultural activities and the environment.

Additionally, the use of the Autoregressive Distributed Lag (ARDL) model, while effective for capturing long-run relationships among variables, has notable limitations. A significant drawback is the assumption of homogeneity among the sampled units, which may not be applicable in the context of Somalia, where regional disparities in agricultural practices and institutional quality are prevalent. This assumption of homogeneity can obscure important variations in regional responses to agricultural production and environmental degradation. Furthermore, the ARDL model is sensitive to the selection of appropriate lags; any mis-specification in this regard may result in biased estimates and unreliable inferences.

Author contributions a*Omar Ahmedqani Hussein: Introduction, literature review, Methods, Data analysis and results b Abdulkadir Mohamed Abdullahi: Assisting with Data Analysis, Conclusions, and Policy Implications.

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Data availability The authors confirms that all data generated or analysed during this study are included in this published article. Example from: https://ourworldindata.org/grapher/per-capita-energy-use?tab = chart&country = ~ SOM https://freedomhouse.org/country/somalia https://databank.worldbank.org/source/world-development-indicators https://www.sesric.org/query.php.

Declarations

Ethics approval and consent to participate This article reports analysis of secondary data.

Competing interests The authors declare no competing interests.

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