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RESEARCH ARTICLE

The relationship between environmental degradation, agricultural crops, and livestock production in Somalia

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Abstract

Climate change is an imminent threat to both developing and developed countries. Various determinants of climate change have been discovered in the literature including, inter alia, the agriculture sector. To this end, this study models the role of agricultural crops — maize, sesame, sorghum, and wheat productions — and livestock production in environmental degradation in Somalia for the period of 1985 to 2017. The study applied the autoregressive distributed lag model (ARDL) for the long-run cointegration between the variables, and vector error correction modeling (VECM) for short- and long-run causalities among the variables. The empirical result revealed the presence of a long-run cointegration between environmental degradation, agricultural crops, and livestock production. All the crops and livestock production increase environmental degradation except wheat production which has a constructive role in reducing environmental degradation in the long run. In contrast, the VECM results detected a short-run causality from sorghum to livestock production. Environmental degradation, sesame, sorghum, and wheat productions cause maize production significantly in the short run as well as in the long run. Moreover, sesame production causes sorghum production in the short run. Likewise, a long-run causality is established from environmental degradation, maize, sesame, livestock, and wheat production to sorghum production. However, Somalia policymakers should institute agricultural policies that are not only sustainable for agricultural production practices to meet the growing food demand but also sustainable to the environment.

Keywords Agriculture · ARDL · Environmental degradation · Somalia · VECM

Introduction

Climate change and global warming have become serious concerns for policymakers worldwide in the past few decades. As a result, the threat of climate change is very broad and has an impact on a wide variety of economic activities and human daily life operations (Warsame et al. 2022b). To mitigate climate change, an immediate evaluation of current technology is unquestionably required, while this problem also necessitates the most precise understanding of factors that contributed to its existence in the expectation of a future that is conceivable, speculative, and sustainable (Decamous 2012). Moreover, it is also widely understood that pollutant emissions into the atmosphere are the main factor that contributes to climate change. The pollutant emissions come from various sources including the agricultural sector. Deforestation, overgrazing, coal consumption, and the change of grasslands to croplands all contribute to increased total green house gas (GHG) emissions (Bellarby et al. 2008; Friel et al. 2009; Warsame 2022). According to Reynolds and Wenzlau (2012), the agricultural sector contributes about 14–30% of worldwide GHG emissions due to its widespread use of fossil fuel energy. Agriculture, forestry, and other land-use emissions were the second-highest source of emissions among all sectors, accounting for 24% of the overall emissions (IPCC 2014). Furthermore, the use of fossil fuels in farm machinery, farm irrigation, livestock breeding in closed structures, and the application of nitrogen-rich

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fertilizers all have a significant impact on emissions (Jebli and Youssef 2017). Therefore, unless effectively handled, these emissions are certain to rise as the world's population grows and the demand for food increases.

The construction of sustainable low-carbon economies is an important goal due to environmental issues (Goh and Ang 2018; Zhu et al. 2016). As a result, Goal 13 of the Sustainable Development Goals was launched to combat climate change and its impacts. Since the establishment of the Millennium Development Goals, there has been a growing worldwide effort to mitigate climate change (Asumadu-Sarkodie and Owusu 2016a; Mohamed et al. 2022). Burney et al. (2010) highlighted that the agricultural sector remains a primary contributor to GHG emissions as a result of unsustainable agricultural cultivation methods (Jebli and Youssef 2017). In both developed and emerging countries, agriculture sector is a major contributor to long-term economic growth. As a result, in many emerging economies, this industry is seen as one of the cornerstones of economic and social development (Agboola and Bekun 2019). The demand for agricultural products is rising globally where its total production in terms of market value increased from \$897.1 billion in 1970 to almost \$3.6 trillion in 2020 (World Bank 2021).

The agricultural sector remains the backbone of the economy and livelihoods of Somalia. It represents 65% of gross domestic product (GDP), 93% of the nation's exports, and creates 65% of employment opportunities for the population. Notably, agricultural cultivation and livestock rearing are still performed as traditional methods in Somalia. Consequently, agricultural production has not improved since the 1960s (Warsame et al 2021, 2022a). And this could be attributed to a lack of technological advancements, political instabilities, and lack of human capital which is necessary for agricultural output growth. Furthermore, these traditional cultivation and rearing methods are not environmentally friendly because they lead to natural resource depletion, environmental degradation, and reduction in the ecosystem (Warsame and Sarkodie 2021). For instance, forest areas in Somalia have declined from 13.2% of the total land area in 1990 to 9.5% in 2020 (World Bank 2021). This implies that arable land — taken as a proxy for deforestation — has increased. Hence, it may be noticed that an increasing arable land area results in only forest degradation but does not stimulate agricultural production in Somalia. Deforestation results from inappropriate agriculture cultivation and unsustainable livestock rearing (Warsame and Sarkodie 2021).

Numerous studies in the literature have examined the relationship between the agriculture sector and environmental pollution (Li et al. 2014; Mourao and Martinho 2017; Sarkodie and Owusu 2017; Ayyildiz and Erdal 2021). These studies examined the agricultural sector's environmental implications in general, taking into account agricultural development, farming activities, crop production, and the processing of agricultural products. More precise and country-level investigations, particularly taking into consideration different components of agriculture, are required in the context of economic and environmental viability. In response to this demand, we focused our research on the country-level crop and livestock production indexes of agriculture, as well as the relationship between crop and livestock production components, and environmental degradation in Somalia.

Even though there are several studies in the context of the present study, there are scanty studies in the context of Somalia. The few studies conducted in Africa and specifically in Somalia have not addressed agriculture-environment nexus (Warsame and Sarkodie 2021; Warsame et al. 2022c). There are various reports highlighting that agricultural crops and livestock production are the main contributors to environmental degradation in Somalia. For instance, a survey conducted in 1980s highlighted that half of Somalia's rangelands in northern regions have been degraded due to a larger number of livestock herds and steep topography (World Bank; FAO 2018). But these studies were neither conducted empirically nor did use advanced econometric methods. Against this backdrop, this study contributes to the literature in several ways. First, our study assesses the role of crops and livestock productions in environmental degradation in Somalia which is limited in the existing literature. Second, unlike previous studies, this study disaggregated agriculture into crops — maize, wheat, sorghum, and sesame productions, and livestock production to determine individual variable contributions to environmental degradation in Somalia. Third, this undertaking examines the casual relationship between agriculture crops, livestock production, and environmental degradation using vector error correction modeling (VECM), since agriculture sector significantly contributes to the GHGs gases which in turn hampers itself. Fourth, the study performs different analyses by utilizing various economic methods such as the autoregressive distributed lag model (ARDL) and Johansen cointegration method for robust analysis. The significance of this study is to the policymakers and international environmental organizations to derive and adopt effective policies to mitigate the adverse consequences of agricultural activities on the environment without sacrificing agricultural production sustainability.

Literature review

A large number of scientific researchers examined agriculture sector and environmental quality nexus. For instance, Rehman et al. (2021a) explained the various environmental consequences of agricultural activities. They first stated that the farming enterprises are substantial generators of carbon dioxide (CO_2) due to trash-talking plants, biodegradation, and organic soil. Secondly, they highlighted that when farming in diverse zones expands and provincial activities such as livestock production intensify, the use of traditional farming in the agricultural sector would harm the environmental situation of developing countries. On the other hand, environmentally friendly farming practices and organic seeds in agriculture would reduce atmospheric CO_2 emissions as evidenced by several studies (see Green et al. 2005; Oenema et al. 2005; Jalil and Mahmud 2009; Rehman et al. 2020). It is argued that global emissions in the agricultural sector are expected to drop by 20–60% in 2030 as a result of reduced environmental degradation, forest restoration, strengthened plant and animal husbandry practices, and increased investment in renewable energy (Liu et al. 2017a).

Besides the above consequences of the agricultural sector, many empirical studies investigating the relationship between the agricultural sector and environmental pollution can also be identified in the literature. The discrepancies in the datasets, the chosen nation or regions, historical periods, and methodologies employed in different studies are mostly attributed to the main discrepancies in the previous findings (Ayyildiz and Erdal 2021). Studies looked into the link between environmental degradation and the agriculture sector have produced inconclusive results. The first contends that agriculture sector and pollutant emissions are positively linked. For example, Mourao and Martinho (2017) investigated the consequences of agricultural activities linked to GHG emissions in Portugal. They concluded that the development of livestock production significantly increases CO_2 emissions in Portugal. Asumadu-Sarkodie and Owusu (2016b) — employing the autoregressive distributed lag (ARDL) and vector error correction (VECM) methods — examined the relationship between CO_2 emissions and the agriculture industry in Ghana. The presence of a causal relationship between agriculture and CO_2 emissions was established. All indicators, notably crop yield, enhance CO_2 emissions. A follow-up study by Sarkodie and Owusu (2017) observed that a 1% rise in the crop production and livestock production lead to 0.52% and 0.81% rise in CO_2 emissions, respectively. It also established a bidirectional causality relationship between crop production and CO_2 emissions. The positive impact of agriculture production environmental pollution is further supported by the study of Waheed et al. (2018) who revealed that agricultural output enhances CO_2 emissions.

Using the Gregory-Hansen cointegration test, bootstrap autoregressive distributed lag (ARDL) approach, fully modified ordinary least squares (FMOLS), and dynamic ordinary least squares (DOLS) long-run estimators, Yurtkuran (2021) investigated the role of agricultural sector in CO_2 emissions in Turkey from 1970 to 2017. Agricultural activities contribute to increased pollution in the long run. A recent study conducted by Ayyildiz and Erdal (2021) explained the link between CO_2 emissions and crop and livestock production indexes of 184 countries — 29 low-income countries, 43 lower-middle-income countries, 52 upper-middle-income countries, and 60 higher-income countries — by applying dynamic common correlated effects (DCCE). Different results were produced for each collection of nations. There was no long-run relationship between CO_2 emissions and crop and livestock production indexes in low-income nations. For upper-middle-income countries, the effect of the crop production index on CO_2 emissions was statistically insignificant in this group, but it was determined that a 1% rise in the livestock production index would increase CO_2 emissions by about 0.49%. Nevertheless, CO_2 emissions is not an issue in the least developed countries including Somalia because these countries do not have big industries that contribute to CO_2 emissions.

The second perspective is that greater agricultural production either lowers or is ineffectual in reducing pollutant emissions. For instance, Rafiq et al. (2016) revealed that agricultural and service sector activities reduce CO_2 emissions. In the same vein, Samargandi (2017) found that the agriculture sector has a constructive role in reducing CO_2 emissions in the long term in Saudi Arabia. The results of these studies are in line with the findings of Jebli and Youssef (2017) who reported that increasing agricultural income will lower CO_2 emissions in the long run in North African countries. Moreover, a bidirectional causality relationship between the two variables was detected in the short and long term. Liu et al. (2017b) assessed the role of agriculture production on CO_2 emissions in ASEAN countries, and they revealed agricultural production inhibit CO_2 emissions. In contrast, a bidirectional causality is established between agriculture production and CO_2 emissions in the long run but not in the short run.

Notwithstanding, most of the previous studies have employed CO_2 emissions as an indicator of environmental pollution because it is the largest contributor of GHG globally. CO_2 emissions is directly linked to issues influencing human life on the planet, such as the GHG effect, climate change, and global warming (Gokmenoglu and Taspinar 2018). However, the case of the least developed countries, including Somalia, is completely different, and CO_2 emissions is no longer an issue. The problem with these countries is the increasing rate of deforestation. Hence, this study adopts deforestation as a determinant of environmental degradation. So, in this study, we utilized VECM and ARDL to examine the link

Table 1 Variable descriptions and sources

Variable code	Description	Source
Deforestation (*ED*)	Arable land (million hectares)	World Bank
Maize (*Mai*)	Production of tons	FAO
Sesame (*Ses*)	Production of tons	FAO
Sorghum (*Sor*)	Production of tons	FAO
Wheat (*Wh*)	Production of tons	FAO
Livestock (*LPI*)	Livestock Production Index	FAO

between environmental degradation and the agriculture sector in Somalia which is limited in the existing literature. This research will try to fill this gap and also will raise knowledge of environmental sustainability in under-developed nations and act as a resource document for the Somali government to incorporate agricultural production, practices, and planning into climate change policies.

Materials and method

Data sources and descriptions

This empirical study assesses the role of agricultural crops — maize, sesame, sorghum, and wheat — and livestock production in environmental degradation in Somalia. The study selected Somalia as a case study, because this East African country is countering severe climate change consequences such as recurrent droughts, floods, and strong winds. Thus, there is a dire need for devising a climate policy related to the determinants of environmental degradation. Deforestation is an alarming issue in Somalia where the majority of the population depends on the cultivation of agriculture and rearing of livestock. Notably, agriculture and livestock production are some of the main sources of environmental degradation. The study employs annual time series data of crops, livestock production, and environmental degradation covering the period from 1985 to 2017. The data sources

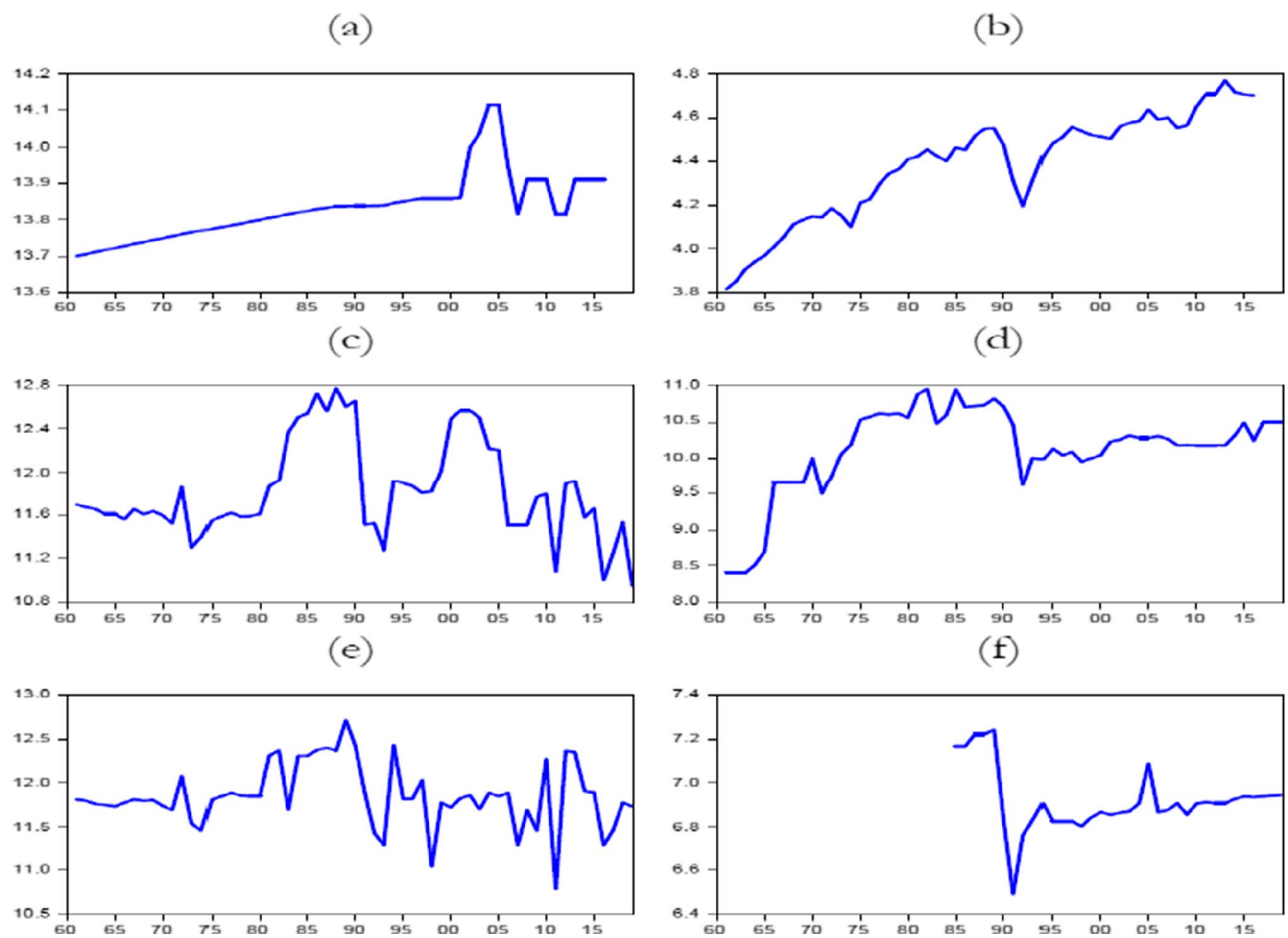

Fig. 1 Trending of the sampled variables. **a** Environmental degradation. **b** Livestock production. **c** Maize production. **d** Sesame production. **e** Sorghum production. **f** Wheat production. Source: FAO (2021)

and descriptions are presented in Table 1. We selected maize, wheat, sesame, and sorghum crops based on their importance to the livelihood of the Somali people. Figure 1 shows the trending of the exogenous and endogenous variables. Sorghum, sesame, wheat, and maize productions are volatile and do not show any significant trend. The volatility of the crop variables is identical. For instance, they reduced during 1970–1975 due to the droughts occurred in the country. Likewise, all the sampled series dramatically plummeted in 1991 owing to the collapse of the military regime, and droughts and famine occurred in the same year. These inconsistent crop production harvesting implies that domestic agricultural and livestock productions mainly depend on rainfall and are adversely affected by natural disasters. Moreover, livestock production has an increasing trend except for some periodical reductions in 1990–1991. On the contrary, deforestation — measured as environmental degradation — has dramatically plummeted in 2006 and 2007 after a sustainable increase before these periods. Since then, deforestation became volatile.

Econometric modeling

This undertaking develops a model that ascertains the role of crops — maize production, sesame production, sorghum production, wheat production — and livestock production in environmental degradation; the model is specified by following the previous studies of Ayyildiz and Erdal (2021) and Asumadu-Sarkodie and Owusu (2016b) as follows:

$$lnED_t = \beta_0 + \beta_1 lnMai_t + \beta_2 lnSes_t + \beta_3 lnSor_t + \beta_4 lnWh_t + \beta_5 lnLPI_t + \varepsilon_t \tag{1}$$

$lnED_t$, $lnMai_t$, $lnSes_t$, $lnSor_t$, $lnWh_t$, and $lnLPI_t$ represent the natural logarithm of environmental degradation, maize production, sesame production, sorghum production, wheat production, and livestock production, respectively. ε_t stands for the disturbance term.

Furthermore, we employ the ARDL bound test of Pesaran et al. (2001) to determine the long-run and short-run effects of crops and livestock production on environmental degradation. The ARDL bound test is chosen because of its efficient estimates of mixed order of integration. Traditional cointegration methods — Johansen and Juselius and Engle and Granger cointegration methods — can estimate only variables which are integrated at the first difference $I(1)$, but the ARDL bound test can regress series which are stationary at level $I(0)$, first difference $I(1)$, or the combination of both. Thus, it is efficient in a mixed order of integration. Moreover, the ARDL bound test addresses the potential problems that arise from the endogeneity through the autoregressive process and produces consistent results. The ARDL bound test is capable of regressing a small sample size unlike other cointegration methods. We specify the ARDL equation of our model — by following the previous studies of Ayyildiz and Erdal (2021) and Asumadu-Sarkodie and Owusu (2016b) — as follows:

$$\begin{aligned}\Delta \ln ED_t = +\alpha_0 &+ \sum_{i=0}^{a} \Delta\alpha_1 \ln ED_{t-k} + \sum_{i=0}^{b} \Delta\alpha_2 \ln Mai_{t-k} \\ &+ \sum_{i=0}^{b} \Delta\alpha_3 \ln Ses_{t-k} + \sum_{i=0}^{b} \Delta\alpha_4 \ln Sor_{t-k} \\ &+ \sum_{i=0}^{b} \Delta\alpha_5 \ln Wh_{t-k} + \sum_{i=0}^{b} \Delta\alpha_6 \ln LPI_{t-k} \\ &+ \beta_1 \ln ED_{t-1} + \beta_2 \ln Mai_{t-1} + \beta_3 \ln Ses_{t-1} \\ &+ \beta_4 \ln Sor_{t-1} + \beta_5 \ln Wh_{t-1} + \beta_6 \ln LPI_{t-1} + \varepsilon_t\end{aligned} \tag{2}$$

where α_0, α_{1-6}, and β_{1-6} stand for the intercept, short-run coefficient parameters, and long-run coefficient parameters respectively. $aandb$ are the lag lengths of dependent and explanatory variables respectively. Δ are differenced variables at the first level that represent the short-run variables, and ECT_{t-1} (error correction term) is the speed of adjustment and ε_t is the error term.

We test the presence of long-run cointegration among the variables using Eq. 2 after determining the best lag length utilizing a general-to-specific approach. Afterward, the F-bound test is applied to the null hypothesis — $H_0 : \beta_1=\beta_2=\beta_3= \beta_4 = \beta_5=\beta_6= 0$ — that the series are not cointegrated. Against the alternative hypothesis — $H_a : \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$ — that the series are cointegrated in the long run.

Granger causality

The ARDL bound test examines only the long-run cointegration among the variables but does not estimate the direction of causality among the series. To address this shortfall, we utilize VECM to investigate the causality of the variables. Before performing the VECM, we test the presence of multivariate cointegration among the variables using Johansen and Juselius cointegration. VECM equations were expressed as follows:

$$\begin{aligned}\Delta lnED_t =\varphi_1 &+ \sum \alpha_b \Delta lnED_{t-b} + \sum \alpha_d \Delta lnagc_{t-d} \\ &+ \sum \alpha_j \Delta lnLPI_{t-j} + \gamma_1 ect_{t-1} + \varepsilon_t\end{aligned} \tag{3}$$

$$\begin{aligned}\Delta lnagc_t =\varphi_1 &+ \sum \alpha_b \Delta lnED_{t-b} + \sum \alpha_d \Delta lnagc_{t-d} \\ &+ \sum \alpha_j \Delta lnLPI_{t-j} + \gamma_1 ect_{t-1} + \varepsilon_t\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta lnLPI_t =\varphi_1 &+ \sum \alpha_b \Delta lnED_{t-b} + \sum \alpha_d \Delta lnagc_{t-d} \\ &+ \sum \alpha_j \Delta lnLPI_{t-j} + \gamma_1 ect_{t-1} + \varepsilon_t\end{aligned} \tag{5}$$

where $\ln agc$ represents the crops such as maize, sesame, sorghum, and wheat productions. γ is the coefficient of the speed of adjustment and *ect* stands for error correction modeling.

The above equations of 3, 4, and 5 can be examined in two different ways. First, we observe the presence of long-run causality between the variables using the error correction term. If the ECT is significant and accompanied by a negative coefficient, we summarize that the variables share a long-run causality. But if it is insignificant, we conclude that variables do not granger cause each other in the long run. Second, we analyze the existence of short-run causality between the series utilizing the significance level of the series. However, Granger causality could be bidirectional, unidirectional, or no causality at all between the series.

Empirical results and discussion

Descriptive statistics

The study scrutinizes the results of summary statistics of the variables of the study as displayed in Table 2. It reports the characteristics of the variables such as mean, median, maximum, minimum, and standard deviation. Deforestation — measured for environmental degradation — is recorded to have the highest average value (13.88), whereas the crops of maize and sorghum have the second and third highest mean values of 11.9 and 11.8 respectively. Likewise, maize production has the highest value of standard deviation which implies that its values are more scattered compared to other variables. Furthermore, environmental degradation, sesame production, and wheat production are positively skewed, whereas the rest of the parameters are negatively skewed. The results show that environmental degradation is the only variable that is not normally and identically distributed compared to other variables which are, as indicated by Jarque–Bera. Besides, Table 2 also presents the correlation between the interested variables. It was established a negative correlation between environmental degradation and sesame, and environmental degradation and sorghum. In addition, another negative correlation is found between livestock production and statisticsmaize.

Table 3 Unit root tests

	ADF	PP
Variable		
LnED	-4.0616**	-2.9042
ΔLnED	-6.2533***	-8.6416***
LnLPI	-3.4178*	-2.8262
ΔLnLPI	-5.4668***	-5.2484***
LnMai	-2.4262	-2.3719
ΔLnMai	-9.0542***	-9.0897***
LnSes	-2.5756	-2.5119
ΔLnSes	-8.4608***	-8.5728***
LnSor	-6.1675***	-6.2677***
ΔLnSor	-12.9360***	-45.1179***
LnWh	-2.7356	-2.2906
ΔLnWh	-5.2613***	-9.7624***

Δ represents the first difference variables. *, **, and *** exhibit the significance level of 10%, 5%, and 1% respectively. The *t*-statistics reported are trend and intercept only

Table 2 Descriptive

	lnED	lnLPI	lnMai	lnSes	lnSor	lnWh
Mean	13.88710	4.547315	11.97777	10.28059	11.88003	6.917770
Median	13.85761	4.551558	11.88837	10.23277	11.87189	6.891525
Maximum	14.11562	4.770854	12.77507	10.94553	12.71758	7.244228
Minimum	13.81551	4.195848	11.00210	9.615805	10.78872	6.492240
Std. Dev	0.079507	0.125216	0.501960	0.290634	0.451284	0.154150
Skewness	1.714663	-0.655471	0.002763	0.481380	0.364637	0.366319
Kurtosis	5.255534	3.765828	1.973136	3.116634	2.712696	4.224006
Jarque–Bera	22.46362	3.073417	1.405972	1.254014	0.819178	2.713266
Probability	0.000013	0.215088	0.495105	0.534188	0.663923	0.257526
Correlation						
lnED	1					
lnLPI	0.3172	1				
lnMai	0.0933	-0.1201	1			
lnSes	0.0775	0.1390	0.5511	1		
lnSor	0.0666	0.0176	0.6446	0.5764	1	
lnWh	0.0029	0.2622	0.5166	0.6359	0.4770	1

Unit root

To avoid spurious results, two-unit root tests — namely ADF (augmented Dickey-Fuller) and PP (Philips Perron) — are conducted. The estimated outcome of the two tests —— presented in Table 3 — produces a remarkably similar nonstationary result of all variables at level *I*(0), except sorghum production. But all the variables turn stationary at first difference *I*(1). Hence, it can be concluded that the interested parameters are free from the unit root problem at the first difference *I*(1). Hence, we can, subsequently, proceed to estimate the long-run cointegration of the variables.

The outcome of the estimated variables in the long run for Somalia is presented in Table 4. The *F*-bound statistics (6.5) are greater than the upper bound critical values (5.636) at 1% significance level. This implies that crops — maize, sorghum, sesame, and wheat — and livestock production are cointegrated into the environmental degradation in Somalia in the long run. It is noteworthy that our sample is small and a Hendry's general-to-specific approach is used for determining the best lag length for the study.

After finding out the presence of long-run cointegration among the variables, we subsequently examine the long-run and short-run dynamic coefficients of the parameters. The results reported in Table 4 indicate that livestock production, maize, sesame, and wheat are significantly related to environmental degradation, while sorghum production is statistically insignificant in the long run. Livestock production, maize, and sesame productions hamper environmental quality in Somalia in the long run, but wheat production enhances environmental quality in the long run. Interpretively, a 1% increase in livestock production, maize, and sesame production undermine environmental quality by about 0.13%, 0.05%, and 0.38%, respectively, in the long run. Sesame production has the highest significant adverse impact on environmental quality in the long run in Somalia compared to other variables. In contrast, wheat production rises the environmental quality by about 0.78% if it is increased by 1% in the long run. Wheat cultivation is essential for mitigating environmental degradation in Somalia in the long run. The positive effect of wheat production on environmental quality could be justified in that wheat production can adapt to different climate ranges. An experiment has shown that roots and stems of wheat left in the ground after harvesting offset emissions and reduce climate change (Civileats 2014).

Our long-run results shed the light on heterogeneous findings of crops and livestock production on environmental degradation. Hence, this is in line with the literature that also failed to reach the same conclusion. For instance, Asumadu-Sarkodie and Owusu (2016b), using disaggregated variables of agriculture production, observed that crop and livestock production induces the CO_2 emissions to increase in Ghana. The positive effect of agriculture on environmental degradation was also affirmed by Gokmenoglu et al (2019) in China using aggregate values of agriculture and Eyuboglu and Uzar (2020) in panel countries. In contrast, there are ample studies that produced contrary results to our findings which indicate that agricultural activities reduce environmental degradation. For instance, Selcuk et al (2021) found that agricultural activities mitigate environmental degradation in panel countries. In the same vein, Gurbuz et al (2021) have documented that agriculture production inhibits CO_2 emissions in Azerbaijan. Moreover, Mahmood et al. (2019) have reached the same conclusion — agriculture production inhibits environmental degradation — in Saudi Arabia both in linear and nonlinear ARDL analysis.

Table 4 Long and short-run results

Variable	Coefficient
Long-run result	
lnLPI	0.1301**
	(-2.2083)
lnMai	0.0542**
	2.3620)
lnSes	0.3812***
	3.5976)
lnSor	0.0203
	(-1.1325)
lnWh	-0.7885***
	(4.5058)
Short-run result	
Constant	4.6371***
	3.8654)
Δ(lnED (-1))	0.2279
	(1.5654)
Δ(lnLPI (-1))	-0.1682
	(-0.8454)
Δ(lnMai (-1))	0.0566**
	(2.2247)
Δ(lnSes (-1))	0.0679
	(1.2267)
Δ(lnSor)	0.0269*
	(1.8801)
Δ(lnWh)	0.0752
	(1.1076)
(lnWh (-1))	0.2651**
	(2.2394)
ECT (-1)	-0.4172***
	(-3.8576)
F-Bound Statistics	6.5029***
Critical value at 1%	(5.636)

*** and ** indicate at 1% and 5% significance levels, respectively. *T*-statistics are reported in parenthesis. Δ = differencing

Furthermore, even though livestock production is considered part of agriculture, it is rarely studied in the literature. Unlike the inconclusive results of crops and environmental degradation nexus, majority oflivestock production and environmental degradation studies have produced that livestock hampers environmental quality. Several empirical studies support our finding of the positive association between livestock production and environmental degradation. For example, Asumadu-Sarkodie and Owusu (2016b) have found that livestock production pollutes the environment in Ghana. Likewise, Ayyildiz and Erdal (2021) have produced the same results in a panel of 184 countries — livestock production rises environmental pollution. In addition, Appiah et al (2018) found that livestock production hampers environmental quality in emerging economies. But it contradicts Rehman et al. (2021b) result which concluded that livestock production mitigates environmental degradation in Pakistan. The various findings of the agriculture sector and environmental quality nexus could be attributed to the discrepancies in methods applied, data utilized, and nature of the sampled country.

Short-run dynamic results and error correction term (ECT) are also presented in Table 4. Its outcome indicates that livestock and sesame productions are not different from zero which implies that they are statistically insignificant in the short run. On the other hand, maize, sorghum, and wheat productions have significant detrimental effects on environmental quality in Somalia in the short run. A 1% increase in maize, sorghum, and wheat crop productions undermine environmental quality by about 0.056%, 0.026%, and 0.26%, respectively, in the short run. It is worthy highlighting that maize and wheat productions are statistically significant at 5%, whereas sorghum production is statistically significant at 10% significance level. More importantly, the ECT, reported in Table 4, has a negative coefficient and is statistically significant which emphasizes the presence of long-run cointegration result of the *F*-bound test. It exhibits that short-run disequilibrium that occurs in environmental degradation will be adjusted in the long run. It is interpreted as any short-run deviation that happens in environmental degradation is adjusted 41.7% by the sampled explanatory variables in the long-run annually.

The long-run cointegration results will be void and null if the model fails to pass the diagnostic tests. Several diagnostic tests, namely, serial correlation, normality test, model misspecification, and heteroskedasticity were performed as reported in Table 5. The model passed all the diagnostic tests. The LM test revealed that variances of error term are not correlated. Breusch-Pegan's test discovered that the variance of errors is constant. Ramsey reset test shredded the light that the model is correctly specified. Finally, Jarque-Bera found that the data set is normally and identically distributed. Moreover, the adjusted *R*-squared, presented in Table 5, measures the goodness fit of the model. It is interpreted as 64% variation occurring in environmental degradation is explained by the scrutinized explanatory variables

Table 5 Diagnostic rests

LM Test	0.1354
	(0.7523)
Heteroskedasticity Test	0.927426
	(0.4562)
Normality Test	0.5851
	(0.7464)
Reset Test	0.5577
	(0.4668)
Adjusted R^2	0.6427

Values in parenthesis indicate the *P*-values

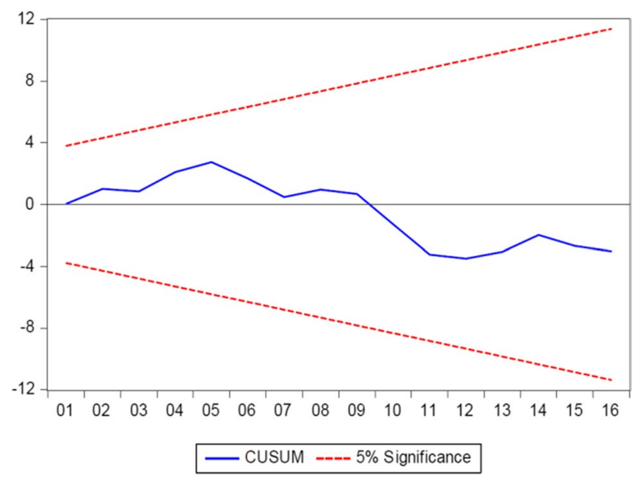

Fig. 2 CUSUM test

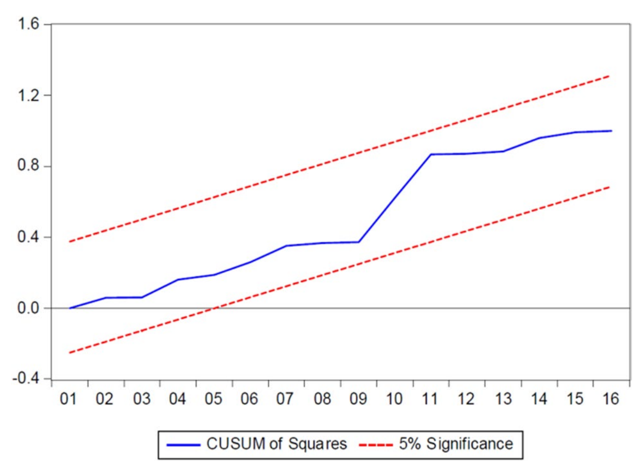

Fig. 3 CUSUM square test

— crops and livestock productions. Furthermore, model stability tests were also conducted using CUSUM and CUSUM square tests as shown by Figures 2 and 3, respectively. And the outcome of CUSUM tests revealed that the model is stable as the blue line is in between the two critical red lines.

Multivariate cointegration and VECM

One of the shortfalls of the ARDL cointegration methods is that it only estimates the short-run and long-run cointegration of variables. It does not examine the causality of series. Hence, to uncover the short-run and long-run causality of the interested variables, we utilize vector error correction modeling (VECM). Examining the causality of the variables with or without VECM, we need to determine if there is a long-run cointegration or not among the scrutinized variables using the multivariate cointegration method. Johansen and Juselius's cointegration method with trace and maximum Eigen-value are utilized to determine the existence of long-term cointegration among the variables. The test statistics of trace and maximum Eigen-value are greater than the critical values at 5% significance level, hence uncovering the presence of long-term cointegration among the scrutinized variables as shown in Table 6. Both trace and maximum Eignen-value revealed the existence of one cointegrating vector which is in line with the results of the ARDL bound test. This implies that environmental degradation and the scrutinized explanatory variables make a co-movement pattern in the long run. Hence, confirming the presence of long-run cointegration among the variables, we can estimate the short-run and long-run causality of the series using VECM.

Table 6 Results of Johansen cointegration

No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value	Prob.**
None	0.942335	155.9778***	95.75366	0.0000
At most 1	0.617915	73.23750**	69.81889	0.0260
At most 2	0.543112	45.33621*	47.85613	0.0846
At most 3	0.338104	22.62004	29.79707	0.2652
At most 4	0.306576	10.65326	15.49471	0.2337
At most 5	0.001239	0.035953	3.841466	0.8496
Max-Eigen Statistic				
None	0.942335	82.74026***	40.07757	0.0000
At most 1	0.617915	27.90129	33.87687	0.2181
At most 2	0.543112	22.71617	27.58434	0.1859
At most 3	0.338104	11.96678	0.5510	0.5510
At most 4	0.306576	10.61731	0.1745	0.1745
At most 5	0.001239	0.035953	0.8496	0.8496

***, **, and * signify significance level at 1%, 5% and 10% respectively

The VECM results — presented in Table 7 — found a short-run causality from sorghum production to livestock production. Sorghum crop is one of the important crops used for pasture by livestock. In contrast, short-run causality, as well as long-run causality, are detected from environmental degradation, sesame, sorghum, and wheat production to maize production significantly. Maize is one of the most cultivated crops in South and central Somalia. Therefore, an increase in environmental degradation — measured in the land clearing — contributes to the land availability for maize cultivation. On the other hand, sesame, sorghum, and wheat productions are used as a substitutefor maize production. Moreover, sesame production granger causes sorghum production in the short-run significantly. Likewise, a long-run causality is observed from environmental degradation, maize, sesame, livestock, and wheat production to sorghum production due to the significance of the ECT which is also accompanied by a negative coefficient.

Conclusion and policy implication

The threat posed by climate change is enormously emerging regardless of geographical location. Nevertheless, it is essential to identify environmental degradation triggers and devise

Table 7 Result of Granger causality based on VECM

	Short-run causality						Long-run causality
	ΔlnED	ΔlnLPI	ΔlnMai	ΔlnSes	ΔlnSor	ΔlnWh	ECTt-1
ΔlnED		0.1895	2.192	1.856	0.204	2.798	-0.099
ΔlnLPI	1.203		1.846	2.264	5.470*	1.525	0.082
ΔlnMai	16.35***	3.894		21.056***	15.57***	20.36***	-3.856***
ΔlnSes	0.253	1.153	0.211		0.383	1.992	-0.303
ΔlnSor	4.408	0.105	3.851	5.577*		4.361	-3.149**
ΔlnWh	0.007	0.268	0.445	0.098	0.498		0.049

*, **, and *** represent significance level at 1%, 5%, and 10%

mitigating policies regarding the sectors and sub-sectors. Despite the agriculture sector being one of the vulnerable sectors to climate change, it also contributes to GHG gases and deforestation. In this regard, this study assessed the role of agricultural crops — maize, wheat, sorghum, and sesame productions — and livestock production in environmental degradation in Somalia. A bound test and VECM method were used to perform the data analysis of the study from 1985 to 2017. The empirical results signify that there is a long run cointegration between environmental degradation and agriculture sector. Furthermore, livestock production, maize, and sesame productions inhibit environmental quality in the long run, while wheat production enhances environmental quality in the long run. But sorghum production is not different from zero which implies that it is statistically insignificant in the long run. Interpretively, a 1% increase in livestock production, maize, and sesame production undermine environmental quality by about 0.13%, 0.05%, and 0.38%, respectively, in the long run. Moreover, wheat production rises the environmental quality by about 0.78% if it is increased by 1% in the long run. Wheat cultivation is essential for mitigating environmental degradation in Somalia in the long run. Furthermore, maize, sorghum, and wheat crops undermine environmental quality in the short run, whereas sesame and livestock production is insignificant in the short run. Besides, The VECM results found a short-run causality from sorghum production to livestock production. Short-run causality, as well as long-run causality, are observed from environmental degradation, sesame, sorghum, and wheat production to maize production. Moreover, sesame production granger causes sorghum production in the short run significantly. Likewise, a long-run causality is established from environmental degradation, maize, sesame, livestock, and wheat production to sorghum production.

Based on the empirical findings, the study recommends several policy implications. First, policymakers should implement policies related to effective pasture management, and the initiation of appropriate feeding animals and grazing which will inhibit the environmental degradation results from the livestock. Second, developing countries such as Somalia should alter its agricultural cultivation techniques and use agricultural technologies which results in sustainable agriculture production and leads to the reduction of environmental degradation induced by poor agricultural practices. Third, implementing policies to encourage wheat production would not only stimulate wheat crops but also enhance sustainable environmental quality. Fourth, the awareness, skills, and education of farmers and pastoralists should be enhanced as this will lead to sustainable agriculture production using sustainable agricultural practices for the environment.

Author contribution Abdimalik Ali Warsame: conceptualization, methodology, data collection and analyzing, writing: original draft preparation. Jama Mohamed: writing the introduction and literature review. Abdinur Ali Mohamed: reviewing and editing.

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

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent to publish Not applicable.

Competing interests The authors declare no competing interests.

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