Measuring the effect of land degradation and environmental changes on agricultural production in Somalia with two structural breaks

Received 23 February 2020
Revised 29 April 2020
Accepted 20 June 2020

Abdinur Ali Mohamed and Ahmed Ibrahim Nageye
Faculty of Economics, SIMAD University, Mogadishu, Somalia

Abstract

Purpose – The purpose of this study is to measure the effect of land degradation and the environmental changes on agricultural productivity in Somalia, as well as the other factors that affect crop production in Somalia.

Design/methodology/approach – Cobb-Douglas production function assumes crop production as a dependent variable and land degradation, labor, capital, fertilizer and climate change as the explanatory variables. In this study time-series data (1962–2017) collected from the Food and Agriculture Organization and World Development Indicators were used. The unit root of the data was examined using Ng-Perron and the Lee-Strazicich methods to explore the unit root property of the breaks. Structural breaks are observed using the Chow test, and the long-run relationship between the variables is examined using Gregory and Hanssen's approach.

Findings – This study found that land degradation and climate change have a negative relationship with agriculture production in Somalia. Land degradation leads to the decline in agricultural production as the loss of one hectare of land due the depletion causes agriculture production of Somalia to fall by about five percent. Climate changes and warming of the environment lead to the reduction of agriculture production. One degree Celsius rise in the temperature leads to a three percent decline in agricultural production. Capital contributes immensely to agricultural production as one unit of additional capital raises production by seven percent. The contribution of labor to agricultural production is limited because of land contraction

Practical implications – Land degradation is a significant contributor to the decline of agricultural production. As land degradation continues to worsen, rural poverty increases, which in turn causes the rural migration and the social conflict. The government should develop land improvement programs such as increasing market orientation of the farmers, encourage private sector engagement in agribusiness and establish a regulatory framework of the land uses.

Originality/value – This study examines the structure of the time-series and specifies the break periods to determine when and where significant and sudden changes occurred within land degradation and agricultural production. The study employs advanced econometric methods, namely, Ng-Perron method and the Lee-Strazicich method to test the unit root property of the breaks. It also examines the long-run relationship between the variables using Gregory and Hanssen's approach.

Keywords Land degradation, Climate change, Crop production, Structural break

Paper type Research paper

Introduction

Land degradation significantly affects the economic and social circumstances of large sections of the population to varying degrees. The degradation of natural resources and increasing environmental unsuitability have led to extreme poverty in many parts of the world. Land degradation has emerged as a universal problem that arises from the changes in the land that is adversely affected by human activities in farming and the settlements.

The growth in agricultural productivity has been slowing in the previous decades of the 21st century. This growth has declined to 2.7% from 4.4% in the 1990s, which was lower than 5.4% in the 1980s. The decline in agricultural production is attributed to the abysmal fertility

Management of Environmental Quality: An International Journal

1477-7835
DOI 10.1108/MEQ-02-2020-0032

of agricultural land, which has impoverished the people in developing countries (Odhiambo *et al.*, 2004). The problem of agricultural productivity can be addressed by increasing investment in agriculture through subsidies and global cooperation in meeting the food demand of the increasing population (AFDB, 2011). Apart from the absence of investment in the agricultural sector, land degradation remains a significant cause of lower agricultural productivity in the countries in eastern Africa (UNEP, 2000).

Land degradation in Somalia is increasing sharply as one-thirds of Somalia's arable land has degraded and lost its high fertility. The major forms of degradation in Somalia are loss of the topsoil, soil erosion and the loss of vegetation due to overgrazing and the cutting of trees for producing charcoal and for use as construction materials (FAO, 2009). The poor fertility of the land is associated with rural poverty and food insecurity. Both were already high in Somalia.

Land degradation has negative implications and reveals the loss of something valuable within ecology and the economic system. The lost value is directly linked to the productivity of land for farming. Agricultural land degradation is associated with damage to the biological productivity of the land and the usefulness of the land as a resource (Gretton and Salma, 1996). Maintenance of the quality of land quality is essential for the sustainable development of the agriculture sector. It enhances agricultural productivity and thereby, improves the livelihood in rural areas and food security in Somalia. On the contrary overuse and the exploitation of the ecosystem in quest of higher agricultural production leads to unintended land degradation. Appalling agronomic practices, such as the burning of the animal manure, and the lack of soil and water conservation are major causes of the poor agricultural productivity in Somalia (Omuto *et al.*, 2011). There is a severe scarcity of the literature on the Agri-environmental issues that are hindering the agricultural development in Somalia. Determining the effect of land degradation and environmental changes on agricultural productivity in the country helps to understand the precise circumstances in agricultural development (Ahrorov and Niyazov, 2015). The purpose of this study is to measure the effect of land degradation and the environmental changes on agricultural productivity in Somalia, as well as the other factors that affect crop production in Somalia. This study examines the structure of the time-series and specifies the break periods to determine when and where significant and sudden changes occurred within land degradation and agricultural production. The study employs advanced econometric methods, namely, Ng-Perron method and the Lee-Strazicich method to test the unit root property of the breaks. It also examines the long-run relationship between the variables using Gregory and Hanssen's approach. The rest of this paper is structured as follows: second section reviews the related literature; the third section presents the theoretical framework and the methodology; the fourth section presents the results and discussion, and the fifth section presents conclusions and policy implications.

Review of the related literature

Land degradation and its relation to agricultural productivity have attracted much attention since the 1970s. Consequently, the number of studies related to the environment has increased greatly and their quality has improved over time. For instance, Bojö (1996) studied the cost of land degradation in terms of loss of agricultural productivity in seven sub-Saharan African countries and found that annual productivity loss was modest. Pagiola (1999) studied soil erosion and crop production in Morocco and concluded that the reduction in yield was higher in the sloping areas, and the annual productivity loss increased year after year. Huang (2000) found that a third of the cultivated land in China was degraded by salination, which reduced agricultural productivity. Lindert (2000) examined the interaction between soil quality and farm productivity. This study found that intensive use of the agrarian land led to nitrogen depletion. However, land degradation did not severely impact crop production in China and Indonesia.

Ali and Byerlee (2001) argued that total productivity growth in the agriculture sector was an inadequate factor as a measure of resource depletion because the effect of land degradation was disguised because of technological improvement. Batjes (2001) found that more than half of the sub-Saharan land degraded as a result of depletion of water resources and soil erosion combined with the chemical and physical abrasion. Rao (2015) found that land degradation harms poor societies that cannot recover from the loss of land productivity. Lal (2011) found that soil erosion harms food security and biodiversity, especially in poor parts of Africa, where people lack access to agricultural inputs like fertilizers. Wiebe *et al.* (2003) examined the land quality and agricultural productivity in 110 countries using econometric analysis of farm input and output. The study found that labor productivity declined as a result of land contraction.

Hillyer *et al.* (2006) conducted a soil survey in Namibia to assess the impact of the erratic rainfall on grain production; this study emphasized the need for land conservation. Okoba and de Graaff (2005) found that soil erosion and land degradation in highland Kenya lead to crop reduction from the seasons. Stringer and Dougill (2013) suggested that soil is a limited and nonrenewable resource so that conservation of fertile soil is essential as it helps meet the human needs of food. Warren (2002) concluded that land degradation becomes more intense on the local scale as with a steep increase in population more people come to depend on natural resources. Bai *et al.* (2008) stated that environmental sustainability is at risk unless land and soil management are put in place to enhance land productivity.

Nachtergaele *et al.* (2010) stated that more than one and half billion people now rely on the degraded areas for their primary livelihood. Furthermore, a large part of the world's most impoverished population lives in degraded areas. Vlek *et al.* (2010) examined the causes of land degradation in sub-Saharan African and concluded that socio-economic activities cause land degradation. Moreover, most human-driven land degradation results from the interaction between the land and its human users.

Berry (2009) examined the land degradation in Ethiopia and found that soil erosion was accelerated by variations of the land ownership patterns among different ethnic groups. Coxhead *et al.* (2001) examined soil conservation and economic decision in the Philippines and showed that human activities like farming in the upland areas are the major contributor to soil depletion in most of the developing countries. Previous studies showed that land degradation is linked to the reduction of crop yields and lead to extreme poverty. Land quality and productivity are very important in Africa since other inputs are very limited. According to Matsumoto and Yamano (2009) stated the fertilizers used in agriculture becomes ineffective once the land is degraded. Marenya and Barrett (2009) stated that African farmers use few fertilizers as compared to the farmers in the developing economies.

Biggelaar *et al.* (2003) showed that the causal relationship between land degradation and agriculture is bidirectional as the loss of land quality leads to a reduction in agricultural production and vice versa. Hutchsinson and Herrmann (2005) found evidence that transition from the use of the degraded land to more productive land improves crop yield and reduces rural poverty.

The reduction in agricultural production due to land degradation and the deterioration of the ecosystems have a negative consequence for the country's economic growth and development. Several previous studies highlighted the link between agriculture and economic growth. For example, Timmer (2002) found that agriculture has a positive relationship with economic growth as it reduces food prices and enhances the nutrient intake of the laborers. Self and Grabowski (2007) concluded that there is a positive correlation between the growth of agricultural productivity and the rate of growth of per capita income. Loayza and Raddatz (2010) found that agricultural productivity growth has a large impact on poverty alleviation since agriculture is a labor-intensive activity by its nature. Christiaensen *et al.* (2006) suggested that growth in agricultural productivity reduces poverty thrice as much as growth in the other economic sectors. Dercon and Christiaensen (2005) found that the agriculture sector has reduced poverty and it is an employment generating engine in Ethiopian villages. Christiaensen *et al.* (2011) concluded that agriculture is effective in poverty reduction and its effect is even large among the people living in extreme poverty. Tiffin and Irz (2006) suggested that value-added per laborer in the agriculture sector has a positive effect on per capita growth in developing countries. They also suggested that agriculture is the main driver of economic growth through consumption and non-agricultural employment. Bravo-Ortega and Lederman (2005) examined the role of the growth in agriculture on the country's growth rate and found that an increase in the GDP growth rate in the agriculture increases the GDP growth rate of non-agricultural sectors. Mellor (2001) found that poverty reduction is achieved through general economic growth, and the direct effect of the growth in agriculture is a major contributor to poverty reduction. Datt and Ravallion (1998) stated the higher productivity in agriculture reduces both absolute and relative poverty.

Timmer (2008) emphasized that the agriculture sector leads to growth in terms of capital flows and food security. Land preservation and soil conservation have a pervasive impact on agricultural productivity growth which is linked to economic growth and poverty reduction. The literature on land degradation and environmental issues affecting the agriculture sector is limited in Africa and it is rare in East Africa and Somalia. Ellis-Jones and Tengberg (2000) examined the impact of soil and water conservation practices on soil productivity in East African countries. This study found that there is a significant loss of productivity due to soil degradation. Omuto *et al.* (2011) assessed the land degradation in Somalia and found that one-third of Somalia's land was degraded due to the loss of vegetation and the resultant loss of the soil moisture, which had led to the decline in crop production. The study indicated improper agronomic practices and tree cutting as the major causes of land degradation in Somalia.

Theoretical framework and methodology

Definitions of the terms

Land degradation is defined as an irreversible deterioration of the biological potentials of the land and soil erosion is the degradation of the land surface (Eswaran *et al.*, 2001). Land degradation is biophysical and socio-economic issues affecting humans and their lands in the developing countries (Abdi *et al.*, 2013). Agricultural production is defined as the utilization of the land for farming to produce food and products that are essential to human life.

Cobb-Douglas production function

The natural resources such as land, soil and their contribution to productivity growth are absent from the Solow growth model. Harking back to Malthus's classic argument about population control, the natural resources were considered to be critical to long-run productivity growth. Extending the argument to include natural resources such as land, we start with the Cobb-Douglas production function as follows:

$$Y(t) = F(K(t) + A(t) + L(t) \tag{1}$$

Where Y is the output that changes over time with the changes of input. K, A *and* L are capital, technology and labor, respectively. Technological progress occurs when knowledge increases. A and L are inter-multiplicative, and AL is referred to as effective labor. By inserting natural resource and land into the production function equation (1) becomes:

$$Y(t) = F(K(t)^{\alpha} + (R(t)^{\beta} + N(t)^{\gamma}[A(t)L(t)]^{1-\alpha-\beta-\gamma} \tag{2}$$

Assuming that α, β and $\gamma > 0$ where $\alpha + \beta + \gamma < 1$. R represents the resources used for production, while N is the amount of land used for agricultural production.

Since the amount of land is fixed and the quantity used in the long-run cannot grow, we assume that:

$$\dot{N}(t) = 0 \tag{3}$$

The land resource is endowed and fixed, and it is used for production, which implies that land resource degrades eventually, so we assume that:

$$\dot{R}(t) = -bR(t) = b > 0 \tag{4}$$

The presence of the land in the production function denotes that K/AL does not conserve the same value over time, so we cannot use K/AL to analyze the behavior of the farmers. If we assume that A, L, R and N grow at a constant rate, then the balanced growth path requires K and Y to grow at a regular growth rate. The motion capital equation $\dot{K}(t) = sY(t) - \theta K(t)$ states that the growth rate of k is:

$$\frac{\dot{K}(t)}{K(t)} = s\frac{Y(t)}{K(t)} - \theta \tag{5}$$

The constant growth rate k requires Y/K to be constant, which means that the growth of k and Y must be constant. By manipulating the production function specified in equation (1), we can find when the constant growth rate of Y and k occurs. We do this by taking a logarithm on both sides of equation (1).

$$\ln Y(t) = \alpha \ln K(t) + \beta \ln R(t) + \gamma \ln N(t) + (1 - \alpha - \beta - \gamma)[\ln A(t) \ln + N(t)] \tag{6}$$

If we differentiate equation (6) with respect to the given time, and that the time derivatives of log variable are the same as variable growth rate, we find that:

$$gY(t) = \alpha gK(t) + \beta gR(t) + \gamma gN(t) + (1 - \alpha - \beta - \gamma)[gA(t) + gN(t)] \tag{7}$$

Knowing that growth rate of R, A, N and L is $-b$, 0, g and n, equation (7) can be simplified:

$$gY(t) = \alpha gK(t) - \beta b + (1 - \alpha - \beta - \gamma)(n + g) \tag{8}$$

We can apply the findings of equation (8) that gY and gK must be equal if the agricultural productivity is on the balanced growth path. We impose that $gY = gK$ and solve

$$gY^{bgp} = -\frac{(1 - \alpha - \beta - \gamma)(n + g) - \beta b}{1 - \alpha} \tag{9}$$

In equation (9), gY^{bgp}, tells us that the growth rate of y is on a steady growth path. So, gY converges onto the steady growth path and the agriculture sector follows a stable growth path. We observe from equation (9) that the growth rate of the agricultural output per worker on the balanced growth path is:

$$\begin{aligned} g\frac{bgp}{\frac{y}{L}} = g\frac{bgp}{Y} - g\frac{bgp}{L} &= \frac{(1 - \alpha - \beta - \gamma)(n + g) - \beta b}{1 - \alpha} - n \\ &= \frac{(1 - \alpha - \beta - \gamma)(n + g) - \beta bn}{1 - \alpha} \end{aligned} \tag{10}$$

Equation (10) expresses that the income growth of per worker can be positive or negative. The resources used in agriculture production and the land are declining and causing output per worker to fall as well. Land degradation and environmental changes are dragging the output growth. If technological improvement can compensate for the diminished quantity of other resources and the land, then there is sustainable agricultural productivity growth. In case there are no technological spurs, land degradation causes agricultural productivity to decline.

Resource and land degradation cause a decline in agricultural productivity by triggering land per worker to decline. The question that needs to be addressed is how much growth could be realized if the resource and land were conserved and were constant over time. The answer to this question shows us a way to measure to what extent does land and resource degradations reduce growth.

If we assume that $\dot{N}(t) = nN(t)$ and $\dot{R}(t) = nR(t)$, in this assumption, there resources and land are not limited and they are assumed to grow with the growth of the population. Thus, output growth per worker can be derived as follows:

$$\tilde{g}Y^{bgp} = -\frac{1}{1-\alpha}(1-\alpha-\beta-\gamma)g. \tag{11}$$

The amount of reduction in growth from land degradation is equal to the difference between growths under the conditions of limited land and constant one. Mathematically this can be calculated as:

$$\begin{aligned} \tilde{g}\,Y^{bgp} - gY^{bgp} &= \frac{(1-\alpha-\beta-\gamma)\mathrm{g} - [(1-\alpha-\beta-\gamma)\mathrm{g} - \beta\mathrm{b} - (\beta+\gamma)\mathrm{n}]}{1-\alpha} \\ &= \frac{\beta\mathrm{b} + (\beta+\gamma)\mathrm{n}}{1-\alpha} \end{aligned} \tag{12}$$

Equation (12) shows the growth-drag is increasing in resource share (β), the land's share (γ), the rate that resource is declining (b), the capital's share, the population (α), and the rate of the population growth (n). The framework presented here shows that land degradation and resource limitation cause output per worker to decline and, as a result, cause a decline in agricultural productivity.

Data sources and the measurement of variables

This study utilizes time-series (1962–2017). Crop production is the dependent variable in the study. Labor, capital, land and fertilizers and climate change are the explanatory variables. Agricultural production is measured by crop production, tons of the different crops harvested from the agriculture sector. Crop data are collected from WDI.

Labor is the number of laborers employed by the agriculture sector. The rural population is used as a proxy for agricultural labor. Capital is the tool that labor uses for production; the number of tractors measures the capital used for agriculture production.

Land degradation is measured by the permanent decline of the arable land, and it includes land under temporary crops, land under meadow for pasture and the fallow land. The land is measured in the hectares, and its data were collected from FAO. Fertilizers are chemicals and pesticides applied to the soil, and they are measured in tons. The percentage of changes in temperature is the measure of climate change.

Econometric model specification

$$\ln CRP_t = \beta_0 + \beta_L \ln L_t + \beta_N \ln N_t + \beta_K \ln K_t + \beta_F \ln F_t + \beta_F \ln CCH_t + u_t \tag{13}$$

Where; *CRP* is crop production, *L* is labor, *K* is capital, *N* land degradation, *F* is fertilizers, *CCH* is climate change.

Econometrics methods

Unit root test in structural breaks

Time-series data need to be checked from the existence of the unit root to avoid the risk of spurious regression. If model variables contain a unit root, then they are non-stationery, and regression reveals the existence of meaningful economic relations when such relation is contemporaneous. It is essential to test the order of integration between the variables to determine how many times a variable needs to be differentiated to fallow turned into a stationary series. There are several ways to examine the presence of the unit root. In this study, we use the Ng-Perron approach. This method has an advantage over the conventional methods used to investigate the stationarity of the time-series data (Dejong *et al.*, 1992). Ng-Perron method is robust when dealing with small sample sizes. However, this method can produce a biased result since it ignores the likely structural break in the time-series data (Perron, 1989). Therefore, additional properties of the unit root are examined using the Lee-Strazicich method. This approach can avoid the spurious rejection of the null hypothesis and can determine the breakpoints endogenously.

Lee-Strazicich approach, Unit roots test statistics can be estimated by this equation;

$$\Delta x_t = \gamma' \Delta Z_t + \O\tilde{H}_{t-1} + \mu_t \tag{14}$$

Where $\tilde{H}_{t-1} = x_t - \tilde{\varphi}_x - Z_t\tilde{\gamma},\ t = 2 \ldots T.\tilde{\gamma}$ denotes the coefficients of the Δx_t regression on ΔZ_t and $\tilde{\varphi}_x = x_1 - Z_1\tilde{\gamma}$. To correct the serial autocorrelation, the terms $\O\tilde{H}_{j-1}\, j = 1, j \ldots k$ are included in the model with the null hypothesis of the $\gamma = 0$, test statistics of the $\overline{\rho} = t$ are assumed. The LM unit root enables accounting for the structural breaks. In the case of one structural break, $Z_t = [1, t, D_{1t}, DT_{1t}]$, or two structural breaks, in the case of $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}DT_{2t}]$, where $D_{jt} = 1$ and $t \geq T_{Bj} + 1$ and $j = 1$, 2 and 0. Null hypothesis is H_0: $x_t = \mu_0 + d_1\, B_{1t} + d_2\, B_{2t} + x_{t-1} + v_{1t}$.

LM unit root test is as follows:

$$LM_\theta = \text{Inf}_\lambda \tilde{\theta};\ LM_t = \text{Inf}_\lambda \tilde{\tau}(\lambda) \tag{15}$$

Cointegration test with structural break

Gregory and Hansen (1996) presented a cointegration test that holds a single endogenous break in the existing cointegration relationship. Gregory and Hansen proposed equations that contain two variables, and the structural break is assumed. Equations are as follows:

$$y_t = \mu_1 + \mu_2 f_{ik} + \alpha_1 X_t + \varepsilon_t \tag{16}$$

$$y_t = \mu_1 + \mu_2 f_{ik} + \beta_1 t + \alpha_1 X_t + \varepsilon_t \tag{17}$$

$$y_t = \mu_1 + \mu_2 f_{ik} + \beta_1 t + \alpha_1 X_t + \alpha_2 X_t f_{ik} + \varepsilon_t \tag{18}$$

$$y_t = \mu_1 + \mu_2 f_{ik} + \beta_1 t + \beta_2 t f_{tk} + \alpha_1 X_t \alpha_2 + X_t + \alpha_2 X_t f_{tk} + \varepsilon_t \tag{19}$$

Equation one is a level shift, while equation two is a level shift with the trend; the third equation is regime change with intercept and coefficient of the change. The fourth equation is regime shift, with intercept, coefficient and trend changes. The null hypothesis of no cointegration with a structural break is tested, and a single endogenous break date is determined. The break date is obtained by checking all possible break dates in the data. The break date is chosen with minimum statistics or maximum statistics of the augmented Dickey-Fuller test (ADF).

Structural break: Chow test

The structural beak is the unexpected changes that occur at a point of time. Such changes may come in the mean or parameters that generate the series. If we cannot detect the structural breaks in the data, we fail to get insight into where and when significant changes in the data occurred. The testing for a structural break helps us identify the sudden changes that come in the time-series data. In this study, we examine the presence of the structural breaks in the data by using the Chow test (Chow, 1960). Chow test stipulates that the number of sub-samples in all observations is required to be equal or so. And in case that observations are not equal and there is a fear of the error variability in the data sets, homoscedasticity of the data should be ensured before the test (Ghilagaber, 2004). Chow can also be used to detect the existence of more than one break as the intercept is allowed to change over time (Wooldridge, 2012).

The main restriction that Chow assumes is equality of the error variance in the linear regression models which can be illustrated in these two equations;

$$y = \beta_{g0} + \beta_{g.1}X_1 + \beta_{g.2}X_2 \ldots \beta_{g.k}X_k + u_k \tag{20}$$

Where the vectors of the dependent variable X are the matrices of the independent variable, β for the regression coefficients and ε is the error term, while i and j are the number of observations. The main hypothesis in the Chow test is that the coefficients are equal in all sub-samples and the null hypothesis is:

$$H_0 : \beta_1 - \beta_2 = 0 \tag{21}$$

The test statistics is done through the normal computation of the F-statistics:

$$F = \frac{\{RSS_p - (RSS_1 + RSS_2)\}}{(RSS_1 + RSS_2)^*} . \frac{[n - 2(k + 1)]}{K + 1} \tag{22}$$

F is the test statistics, RSS_p residual sum square of the whole sample, RSS_1 and RSS_2 are residual sum squares of the first and the second groups.

Results and discussion

Unit root test with structural breaks

The stationarity of the data was examined by applying the Ng-Perron unit root test. The null hypothesis of that $\varphi = 0$; data were unit root tested. A model with an intercept and the trend was used to test the unit root. Perron t-test is compared to the critical value of 1%, and the result is presented in Table 1.

Table 1 shows two variables; land and climate change are stationary at the level. Crop production is stationary at the first difference. While fertilizers and agricultural labor are integrated into order two, meaning that they need to be differenced twice to remove the unit root from them. The capital variable can only be stationary for the second difference in the constant model. However, Ng-Perron cannot control the structural break in the data. So, the Lee-Strazicich unit root test is employed to examine the unit root properties of the data. The result of the Lee-Strazicich unit root test with two structural breaks is presented in Table 2.

The result of the Lee-Strazicich with lag (0) shows that only two variables, namely, agricultural land and climate changes, are stationary at the level. Crop production, labor, capital and the fertilizers are integrated at the first difference I (1). Structural breaks in the crop production stem from 1972, and it reflects the change in the regime and the nationalization of most of the agriculture sector.

During the 1990s, agriculture in Somalia was affected by many factors, including the collapse of the socialist government, droughts, internal displacements, and above all, economic downturn. Agricultural land had been exposed to erosion and the loss of the soil quality induced by human activities. Changes in the temperature are strongly influenced by seasonal changes and the rainfall patterns where the absence of the rain contributes to the warming of the environment and loss of agricultural production.

Variables	Ng-Perron	MZ_a	MZ_t	*MSB*	*MPT*
CRP	*t*-statistics	9.796	2.179	0.222	9.452
	CV	23.800	3.420	0.143	4.0300
ΔCRP	*t*-statistics	25.487	3.569	0.1400	3.576
	CV	23.800	3.420	0.143	4.0300
L	*t*-statistics	19.427	3.100	0.159	4.791
	CV	23.800	3.420	0.143	4.0300
ΔL	*t*-statistics	25.869	3.596	0.139	3.522
	CV	23.800	3.420	0.143	4.0300
N	*t*-statistics	33.316	4.068	0.122	2.807
	CV	23.800	3.420	0.143	4.0300
C	*t*-statistics	1.532	0.8036	0.5243	52.336
	CV	23.800	3.420	0.143	4.0300
ΔC	*t*-statistics	15.027	2.734	0.1819	1.656
	CV	13.800	2.580	0.1740	1.780
FRT	*t*-statistics	4.414	1.291	0.2924	19.073
	CV	23.800	3.420	0.143	4.0300
ΔFRT	*t*-statistics	32.021	4.001	0.124	2.847
	CV	23.800	3.420	0.143	4.0300
CCH	*t*-statistics	27.700	3.720	0.1343	3.295
	CV	23.800	3.420	0.143	4.0300

Table 1.
The result of the unit root test

	CRP	*L*	*N*	*C*	FRT	CHTMP
Series A: Level						
Test–statistics	1.786	2.342	13.302	2.112	3.762	11.763
TB1	1972	1974	2004	1985	2005	2003
TB2	1993	2007	2007	1999	2006	2008
Series B: First difference						
Test–statistics	34.356	89.876	67.33	12.112	23.762	78.763
TB1	1989	1991	2002	1975	2000	2004
TB2	1993	1999	2005	1992	2002	2009

Table 2.
Lee-strazicich unit root test

Estimation of the model parameters

The model parameters were estimated through equation (13), and the result is presented in Table 3.

The result in Table 3 shows that all variables are different from zero and within a significance level of 1%; that labor, capital and the fertilizers are positively contributing to agricultural production, while land degradation and climate change are dragging down agricultural production in Somalia. The result indicates that one unit increase in the rural population causes agricultural productivity to increase three percent. On the other hand, one unit of growth in capital leads to seven percent growth in agricultural production. About six percent of the agricultural production results from one unit increase in the use of fertilizers. Land degradation leads to the decline in agricultural production as the loss of the hectare of land due the depletion causes agriculture production of Somalia to fall by about five percent. Climate changes and warming of the environment lead to the reduction of agriculture production. One degree Celsius rise in the temperature leads to a three percent decline in agricultural production. *F*-statistics is significant at a level of 1%, and it is showing that variables are jointly significant. We examined the presence of multicollinearity by using the variance inflation factor (VIF). The coefficient variances were less than 5, meaning that there was no risk of the perfect collinearity.

The heteroscedasticity was also tested using the Breusch-Pagan_Godfrey approach. The result showed that the model is Homoscedastic. We failed to reject the null hypothesis of autocorrelation. We used the heteroscedasticity and autocorrelation (HAC) method to remove the serial correlation. Thus, the standard robustness test was used instead of the standard error. The result of this study shows that capital is the dominant factor of production in agriculture in Somalia, while fertilizers are the second major contributor to the agriculture sector in Somalia. Labor makes a small contribution to the agriculture sector as a result of land degradation and the decline in the agricultural resources (Mohamed and Nageye, 2019).

Land degradation makes a negative contributing to agricultural productivity. Erratic rainfall, depletion of the river water and many other human-induced undesirable changes escalate the loss of land productivity in Somalia. The result of this study is consistent with the findings from several previous studies, including; Wiebe *et al.* (2003), Hillyer *et al.* (2006) and Vlek *et al.* (2010), who found that land degradation is negatively associated with the agricultural production.

Structural break analysis

This study examined the structural breaks using the Chow test. The break dates and their significance and the result are presented in Table 4:

Table 4 shows 1991 as a significant break date. That year, the economic system of the country changed from socialism to a market-based economy. Besides that, the rural migration declined and people re-engaged in agricultural activities. Armed conflicts that had erupted in the late 1980s had negatively impacted the industrial production and created a market for the agriculture sector that became the pivot on which the household consumption depended. Another structural break date was 1993 when drought caused

Variable	Coefficient	Std. robust error	*t*-statistic	Prob.
ln*CRP*	9.364	2.736287	3.422	0.0099
ln*L*	3.706	0.143079	25.901	0.0080
ln*N*	−5.082	0.435668	11.667	0.0035
ln*C*	7.0057	0.024768	282.852	0.0000
ln*FRT*	5.967	0.064978	91.835	0.0036
ln*CCH*	−3.613	0.097369	37.106	0.0097

Table 3.
Result of the model parameters

Variables	Significant years	*F*-statistic	Prob.	Log-likelihood ratio	Prob.
N	1991	28.628	0.0000	25.371	0.0000
L	1991	27.127	0.0000	24.332	0.0000
C	1991	24.806	0.0000	22.678	0.0000
FRT	1991	13.431	0.0007	13.607	0.0002
CCH	1991	11.666	0.0015	12.028	0.0005
Variables	Significant years	*F*-statistic	Prob.	Log-likelihood ratio	Prob.
N	1993	10.087	0.0029	10.569	0.0011
L	1993	9.123	0.0044	9.6565	0.0019
C	1993	10.352	0.0026	10.818	0.0010
FRT	1993	5.269	0.0270	5.816	0.0159
CCH	1993	4.672	0.0367	5.192	0.0227

Table 4.
Structural break of date one and two

famine and malnutrition in rural areas. The armed conflict in 1990 negatively impacted other sectors in the economy and the agriculture sector became dominant among economic activities. Droughts that occurred on that date hit the agriculture sector hard and exposed thousands of people to food insecurity and lack of potable water. Hence, 1993 was the beginning of the economic slump that lasted for decades in Somalia.

The long-term relationship between the variables

The study scrutinized the existence of the long-term relationship between the variables to discover if the relationship among variables could come to equilibrium or drift apart in the short run. Gregory and Hansen's (1996) method was used to examine such a relationship. This approach has an advantage over other tools as it can examine long-run relationships in the presence of the structural breaks in time-series data. The null hypothesis of no cointegration was tested, and the result is presented in Table 5.

We fail to reject the null hypothesis at the significance level of one percent, which indicates that variables had a long-run relationship in 1991. We did not find other significant years in which a long-run relationship existed. Agriculture in Somalia accounts for more than 70% of the country's GDP and employs a large proportion of the rural population. Agriculture in Somalis is exposed to natural disasters and human-made catastrophes such as tree cutting and social conflicts. The result of this study is consistent with the results of some previous studies conducted in East and sub-Saharan Africa (Berry, 2009; Okoba and de Graaff, 2005; Ellis-Jones and Tengberg, 2000; Batjes, 2001). These studies found that land in Africa. In East Africa especially was degrading and losing fertility, leading to a severe reduction in crop production.

Conclusion and policy implications

This study examined the effect of land degradation and the environmental change on agricultural production in Somalia using time-series data from 1962 to 2017 obtained from FOA and WDI. Cobb-Douglas production function was used to frame the model of the study. The unit root of the data was examined using Ng-Perron and the Lee-Strazicich method to explore the unit root property of the breaks. Structural breaks were observed using the Chow test. Long-run relationships between the variables were examined using Gregory and Hanssen's (1996) approach. The study found that variables, land and climate change were stationary at a level, and all other variables needed to be differenced to convert them to stationarity. The study also found that land degradation and climate change make a negative contribution to agricultural production in Somalia. We also found that capital has the most substantial contribution to agricultural production. Labor makes a limited contribution to agricultural production as a result of the land contraction. The Chow test showed that 1991 and 1993 were statistically significant years, and the most import structural breaks occurred during these periods. Gregory and Hanssen's method showed that the variables considered in this study had a long-run-term relationship in 1991, and they were arriving at an equilibrium.

Test method	Break date	t-test	CV (1%)
ADF	1991	−5.31	4.91
Z_t	1991	−5.03	4.78
Z_a	1991	−80.94	60.2

Table 5. Cointegration test with structural breaks

Policy implications

(1) Land degradation is a significant contributor to the decline of agricultural production. As land degradation continues to worsen, rural poverty increases, which in turn causes the rural migration and the social conflict. The government should develop land improvement programs such as increasing market orientation of the farmers, encourage private sector engagement in agribusiness and establish a regulatory framework of the land uses.

(2) Climate change negatively affects agricultural production in Somalia, and it continues to threaten life in rural areas. Hence the government should support the use of renewable energy such as biomasses and take measures to minimize landfill emissions.

(3) There is a disparity between labor and capital productivity in the agriculture sector in Somalia. Capital is scarce for farming, which is causing a decline in agricultural output; hence, access to finance, such as in the form of agricultural credit should be made available to the farmers.

References

Abdi, O.A., Glover, E.K. and Luukkanen, O. (2013), "Causes and impacts of land degradation and desertification: a case study of Sudan", *International Journal of Agriculture and Forestry*, Vol. 3 No. 2, pp. 40-51.

AFDB (2011), "African development report", available at: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/African%20Deveopment%20Report%202011.pdf.

Ahrorov, F. and Niyazov, I. (2015), "The nonarable Aral: loss of productivity in Uzbek agriculture", in *Disaster by Design: The Aral Sea and its Lessons for Sustainability*.

Ali, M. and Byerlee, D. (2000), *Productivity Growth and Resource Degradation in Pakistan's Punjab: A Decomposition Analysis*, Policy Research Working Paper No. 2480, World Bank, available at: https://openknowledge.worldbank.org/handle/10986/19758.

Bai, Z.G., Dent, D.L., Olsson, L. and Schaepman, M.E. (2008), "Proxy global assessment of land degradation", *Soil Use and Management*, Vol. 24 No. 3, pp. 223-234, doi: 10.1111/j.1475-2743.2008.00169.x.

Batjes, N.H. (2001), "Options for increasing carbon sequestration in West African Soils: an explanatory study with special focus on Senegal", *Land Degradation and Development*, Vol. 12 No. 2, pp. 131-142, doi: 10.1002/ldr.444.

Berry, L. (2009), *Land Degradation in Ethiopia: Its Extent and Impact*, Global Mechanism and the World Bank.

Biggelaar, C., Lal, R., Wiebe, K. and Breneman, V. (2003), "The global impact of soil erosion on productivity", *Advance in Agronomy*, Vol. 81, pp. 1-48.

Bojö, J. (1996), "The costs of land degradation in Sub-Saharan Africa", *Ecological Economics*, Vol. 16 No. 2, pp. 161-173, doi: 10.1016/0921-8009(95)00087-9.

Bravo-Ortega, C. and Lederman, D. (2005), *Agriculture and National Welfare Around the World: Causality and International Heterogeneity since 1960*, Policy Research Working Paper 3499, World Bank, Washington, DC.

Chow, G.C. (1960), "Tests of equality between sets of coefficients in two linear regressions", *Econometrica*, Vol. 28 No. 3, p. 3, doi: 10.2307/1910133.

Christiaensen, L., Demery, L. and Kuhl, J. (2006), *The Role of Agriculture in Poverty Reduction: An Empirical Perspective*, Policy Research Working Paper No. 4013, World Bank, available at: https://openknowledge.worldbank.org/handle/10986/9306.

Christiaensen, L.J., Demery, L. and Kuhl, J. (2011), "The (evolving) role of agriculture in poverty reduction—an empirical perspective", *Journal of Development Economics*, Vol. 96 No. 2, pp. 239-254, doi: 10.1016/j.jdeveco.2010.10.006.

Coxhead, A., Rola, K., Kim, E.B. and Barbier, J.C.B. (2001), "How do national markets and price policies affect land use at the forest margin? Evidence from the Philippines", *Land Economics*, Vol. 77 No. 2, pp. 250-267.

Datt, G. and Ravallion, M. (1998), "Farm productivity and rural poverty in India", *Journal of Development Studies*, Vol. 34 No. 4, pp. 62-85, doi: 10.1080/00220389808422529.

DeJong, D.N., Nankervis, J.C., Savin, N.E. and Whiteman, C.H. (1992), "Integration versus trend stationarity in time series", *Econometrica*, Vol. 60 No. 2, pp. 423-433, doi: 10.2307/2951602.

Dercon, S. and Christiaensen, L.J. (2005), *The Impact on Poverty of Policies to Stimulate Modern Input Adoption: The Case of Fertilizer in Ethiopia [Mimeo]*, World Bank.

Ellis, J.J. and Tengberg, A. (2000), "The impact of the indigenous soil and water conservation practices on soil productivity: examples from Kenya, Tanzania and Uganda", *Land Degradation and Development*, Vol. 11 No. 1, pp. 19-36.

Eswaran, H., Lal, R. and Reich, P.F. (2001), "Land degradation: an overview", in Lastname, F.M. and Lastname, F.M. (Eds), in *Responses to Land Degradation: Proceedings of the 2nd International Conference on Land Degradation and Desertification*, Oxford Press, Khon Kaen.

FAO (2009), "Rebuilding resilient and sustainable agriculture in Somali", available at: http://www.fao.org/3/I8841EN/i8841en.pdf.

Ghilagaber, G. (2004), "Another look at Chow's test for the equality of two heteroscedastic regression models", *Quality and Quantity*, Vol. 38 No. 1, pp. 81-93, doi: 10.1023/B:QUQU.0000013246.83707.6f.

Gregory, A.W. and Hansen, B.E. (1996), "Residual-based tests for cointegration in models with regime shifts", *Journal of Econometrics*, Vol. 70 No. 1, pp. 99-126, doi: 10.1016/0304-4076(69)41685-7.

Gretton, P. and Salma, U. (1996), *Land Degradation and the Australian Agricultural Industry*, Industry Commission Staff Information Paper, AGPS, Canberra.

Hillyer, A.E.M., McDonagh, J.F. and Verlinden, A. (2006), "Land-use and legumes in northern Namibia—the value of a local classification system", *Agriculture, Ecosystems and Environment*, Vol. 117 No. 4, pp. 251-265, doi: 10.1016/j.agee.2006.04.008.

Huang, J. (2000), *Land Degradation in China: Erosion and Salinity Component*, Working Paper WP. 00 E17, Center for Chinese Agricultural Policy, Beijing.

Hutchsinson, C.F. and Herrmann, L.M. (2005), "Introduction: the greening of Sahel", *Journal of Arid Environments*, Vol. 63 No. 3, pp. 535-537.

Lal, R. (2011), "Soil degradation and food security in South Asia", in *Climate Change and Food Security in South Asia*, Springer, Dordrecht, pp. 138-152.

Lindert, P.H. (2000), *Shifting Ground: The Changing Agricultural Soils of China and Indonesia*, MIT Press, London.

Loayza, N.V. and Raddatz, C. (2010), "The composition of growth matters for poverty alleviation", *Journal of Development Economics*, Vol. 93 No. 1, pp. 137-151, doi: 10.1016/j.jdeveco.2009.03.008.

Marenya, P.P. and Barrett, C.B. (2009), "State-conditional fertilizer yield response on Western Kenyan farms", *American Journal of Agricultural Economics*, Vol. 91 No. 4, pp. 991-1006, doi: 10.1111/j.1467-8276.2009.01313.x.

Matsumoto, T. and Yamano, T. (2009), *Soil Fertility, and the Maize Green Revolution in East Africa*, Policy Research Paper 5158, World Bank.

Mellor, J.W. (2001), "Faster more equitable growth—agriculture, employment multipliers and poverty reduction", Agricultural Policy Development Project Research Report, Vol. 4.

Mohamed, A.A. and Nageye, A.I. (2019), "Relationship between environmental degradation, resource scarcity, and civil conflicts in Somalia", *Journal of Environmental Management and Tourism*, Vol. 10 No. 3, pp. 640-650, doi: 10.14505//jemt.10.3(35).18.

Nachtergaele, F., Petri, M., Biancalani, R., van Lynden, G. and van Velthuizen, H. (2010), *Global Land Degradation Information System (GLADIS), Beta Version, an Information Database for Land Degradation Assessment at the Global Level, Land Degradation Assessment in Drylands*, Technical Report 17, Food and Agriculture Organization of the United Nations.

Odhiambo, W., Nyangito, H.O. and Nzuma, J. (2004), *Sources and Determinants of Agricultural Growth and Productivity in Kenya*, Productive Sector Division, Kenya Institute for Public Policy, Research and Analysis, KIPPRA, Discussion Paper 34, pp. 1-67.

Okoba, B.O. and de Graaff, J. (2005), "Farmers' knowledge and perceptions of soil erosion and conservation measures in Central Highlands, Kenya", *Land Degradation and Development*, Vol. 16 No. 5, pp. 475-487.

Omuto, C.T., Balint and Alim, M.S. (2011), "A framework for national assessment of land degradation in the drylands: a case study of Somalia", *Land Degradation and Development*, Vol. 25 No. 2, pp. 105-119, doi: 10.1002/ldr.1151.

Pagiola, S. (1999), *The Global Environmental Benefits of Land Degradation Control on Agricultural Land*, World Bank Environment Paper No. 16, The World Bank, Washington, DC.

Perron, P. (1989), "The great crash, the oil price shock, and the unit root hypothesis", *Econometrica*, Vol. 57 No. 6, pp. 1361-1401, doi: 10.2307/1913712.

Rao, B.K.R. (2015), "Kinetics of potassium release in sweet potato cropped soils: a case study in the highlands of Papua New Guinea", *Solid Earth*, Vol. 6 No. 1, pp. 217-225, doi: 10.5194/se-6-217-2015.

Self, S. and Grabowski, R. (2007), "Economic development and the role of agricultural technology", *Agricultural Economics*, Vol. 36 No. 3, pp. 395-404, doi: 10.1111/j.1574-0862.2007.00215.x.

Stringer, L.C. and Dougill, A.J. (2013), "Channeling science into policy: enabling best practices from research on land degradation and sustainable land management in dryland Africa", *Journal of Environmental Management*, Vol. 114, pp. 328-335, doi: 10.1016/j.jenvman.2012.10.025.

Tiffin, R. and Irz, X. (2006), "Is agriculture the engine of growth?", *Agricultural Economics*, Vol. 35 No. 1, pp. 79-89, doi: 10.1111/j.1574-0862.2006.00141.x.

Timmer, C.P. (2002), "Agriculture and economic development", in Gardner, B.L. and Rausser, G.C. (Eds), *Handbook of Agricultural Economics*, North Holland, Vol. 2A, pp. 1487-1546.

Timmer, C.P. (2008), *Causes of High Food Prices*, Economics Working Paper Series 128, Asian Development Bank.

UNEP (2000), "UNEP annual report", available at: https://www.unenvironment.org/resources/annual-report/unep-annual-report-2000.

Vlek, P.L., Le, Q.B. and Tamene, L. (2010), "Assessment of land degradation, its possible causes, and the threat to food security in Sub-Saharan Africa", in Lal, R. and Stewart, B.A. (Eds), *Food Security and Soil Quality*, CRC Press, pp. 57-86.

Warren, A. (2002), "Land degradation is contextual", *Land Degradation and Development*, Vol. 13 No. 6, pp. 449-459, doi: 10.1002/ldr.532.

Wiebe, K., Soule, M.J., Narrod, C. and Breneman, V.E. (2003), "Resource quality and agricultural productivity: a multi-country comparison", in Wiebe, K. (Ed.), *Land Quality, Agricultural Productivity, and Food Security: Biophysical Processes and Economic Choices at Local, Regional, and Global Levels*, Edward Elgar, Northampton, pp. 147-165.

Wooldridge, J.M. (2012), *Introductory Econometrics: A Modern Approach*, South Western Cengage Learning, Natorp Boulevard.

Further reading

Ng, S. and Perron, P. (2001), "Lag length selection and the construction of unit root tests with good size and power", *Econometrica*, Vol. 69 No. 6, pp. 1519-1554, doi: 10.1111/1468-0262.00256.

Corresponding author

Abdinur Ali Mohamed can be contacted at: cabdinur80@gmail.com