The impact of environmental degradation and financial development on agricultural productivity in selected African countries

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Abstract

The influence of financial development and environmental deterioration on agricultural output in a few African nations between 2000 and 2023 is examined in this study. Through the use of panel data methodologies, such as panel unit root, cointegration, and Pooled Mean Group (PMG) estimate methods, the study offers empirical insights into the dynamics of these variables over the short and long term. The findings show that pollution, deforestation, and stress from climate change have a negative impact on farming production, since environmental deterioration dramatically lowers agricultural productivity over the long and short terms. Financial development, on the other hand, has a positive and statistically significant impact on agricultural production, indicating that increased farm performance is a result of financial inclusion, investment in modern inputs, and loan availability. The correlation between environmental deterioration and financial development is noteworthy and favorable, suggesting that financial development helps to lessen some of the negative consequences of environmental degradation. Rainfall and trade openness are control factors that boost agricultural output, while increased temperatures and pressure from the rural population have a detrimental impact on productivity. The necessity of coordinated policies that support environmental preservation, sustainable farming practices, and financial inclusion is highlighted by these findings. As essential steps to boost agricultural output while preserving environmental sustainability in Africa, the report suggests focused green finance programs, strict environmental laws, and easier access to rural borrowing options. In addition to providing useful insights for policymakers, financial institutions, and development partners seeking to advance sustainable agriculture and food security on the continent, the study adds to the expanding body of research on the environmental-economic relationship.

Keywords: Financial development, Environmental deterioration, Agricultural productivity

1. Introduction

In the sub-Saharan area, agriculture is one of the most important economic sectors in terms of both employment and GNP. Food security is also greatly impacted by agriculture. The agricultural sector in the region employs over 62% of the workers and accounts for nearly 25% of the GDP. Moreover, agricultural output is mostly driven by smallholder farmers (FAO, 2023; World Bank, 2023) [10, 23]. This phenomena notwithstanding, the region's agricultural production is stagnant, and growth falls short of international standards. This situation seriously jeopardizes the region's attempts to realize sustainable development, alleviate poverty, and become self-sufficient in food. Ecological degradation and inadequate agricultural finance systems are among the continent's most urgent issues with agricultural production.

The depletion of agriculture has been exacerbated by environmental degradation, which includes deforestation and contamination of the air, water, and land. There has been a growing loss of primary resources required for agriculture, as well as of agricultural land that is not being used for agriculture (Dimnwobi *et al*., 2023; Salahuddin *et al*, 2020) [8, 18]. The already delicate and overburdened agricultural ecology is also being strained by the changing climate and the rise in extreme weather events that goes along with it. The reduced water supplies and the entire agricultural ecosystems are severely impacted by this, as well as the increasing degradation of the soil (Rahman *et al*, 2022; Dong & Wang, 2023) [15, 9].

Furthermore, human-caused factors such overuse of land and overexploitation of natural resources have worsened environmental quality and decreased agricultural output (Zhou *et al*., 2024; Alhassan, 2021) [26, 3]. However, the majority of African countries' undeveloped finance systems continue to be a major barrier to the expansion of the agricultural industry. Investment in agricultural inputs, the adoption of contemporary technology, and prudent risk management all depend on financing agriculture, which is characterized by the effectiveness and accessibility of financial services (Yadav & Goyari, 2025; Adabor & Essah, 2024) [25, 1].

Unfortunately, there is a widespread lack of banking services in agricultural areas, which stifles formal banking services. Inadequate access to credit, insurance, and even savings diminishes farmers' ability to invest in productivity-enhancing technologies (Massaquoi *et al*., 2025; Wu *et al*., 2025) [13, 24]. Investors in agriculture need financial development, but agriculture also use financial development to become more productive. With financial access, farmers can implement climate-smart agriculture, use green technologies, and strengthen their adaptive capacity (Zhou *et al*., 2022; Raifu & Afolabi, 2024) [27, 16]. Furthermore, the most environmentally challenged areas can still benefit from the most recent trends in environmentally responsible financing and credit growth (Zhou *et al*., 2024; Chandio *et al*., 2023) [26, 4].

Although research on the financial and climatic environment of agriculture is growing, the relationship between the two and agricultural productivity remains underexplored concerning Africa. The literature reviews conducted by Tabash, Farooq, and Daniel (2025) [19] alongside Waqas *et al*. (2025) [22] suggest that financial development assists in mitigating the negative impacts of environmental degradation on farming and allows for more sustainable farming adaptations. Understanding that connection is vital toward crafting policies that strengthen resilient agriculture for enduring agricultural productivity.

The research examines how agricultural production, financial growth, and environmental degradation relate to one another in a chosen sample of African nations between 2000 and 2023. Its goal is to determine how much financial development offsets the negative effects of environmental deterioration on agricultural output. The study is expected to highlight the vital need to strike a balance between development and environmental sustainability in African nations and contribute to the conversation on sustainable agricultural finance, financial inclusion, and environmental governance. In the framework of sustainable economic growth and development, the study's conclusions should help policymakers, development partners, and other pertinent players refine plans to increase agricultural production, improve finance, and solve environmental challenges.

The paper's structure is outlined as follows: A thorough analysis of the body of available literature is given in Section 2. A thorough description of the study's methodology is provided in Section 3. Both the theoretical and empirical results are presented in Section 4. The report's last section, Section 5, provides policy suggestions based on the data acquired from the findings.

2. Review of the Literature

The interplay amid ecological deterioration, development of the economy, and agricultural output has garnered scholarly attention, especially regarding developing countries. Agriculture in Africa is resource-dependent, susceptible to ecological change, and is hamstrung by scant access to credit, which limits farmers' investments in productivity and adaptive measures to ecological stressors. This review synthesizes literature on the productivity of agriculture in relation to environmental and financial factors and questions whether financial development can offset the adversative impacts of the degradation of the environment on promoting sustainable agricultural development.

2.1. Environmental degradation and the productivity of agriculture

The adverse effects of climate change and resource scarcity remain one of the greatest encounters in improving the productivity of agriculture, especially in developing economies where agriculture depends heavily on the resources available and the climate. The influences of climate alteration, along with the worsening of the air and water quality, have been shown to contribute to land degradation and deforestation, which, in turn, adversely impacts crop yields and the efficiency of agricultural production systems.

Salahuddin, Gow, and Vink (2020) [18] have pointed out the significant impacts of poor environmental quality especially lower soil fertility and higher pollution—as two of the major factors to agricultural output in sub-Saharan Africa. Furthermore, Dimnwobi *et al*. (2023) [8] speak of the dual forces of environmental degradation and energy poverty. They argue that eroded land along with scarce access to energy restrain the farming activities and the adoption of farming technologies. Alhassan (2021) [3] brings to light a reciprocal relationship; he explains that the low agricultural productivity leads to environmental degradation through deforestation as well as resource overuse leads to lower productivity in agriculture.

The increasing levels of carbon emissions and particulate matter in the air are major pollutants that deface the agricultural total factor productivity. Dong and Wang (2023) [9] provide evidence that air pollutants have harmful effects on the growth of plants and thus the quality of soil, which, considering the shrinking yields of crops, poses a significant threat to agricultural total factor productivity. Such evidence is also supported by Ramzan *et al*. (2022) [17] illustrates how environmental pollution lowers agricultural productivity in Pakistan, emphasizing the need for better regulations to control pollution-related damages.

Climate change and extreme weather events are additional environmental stressors that undermine agricultural output. Rahman, Anik, and Sarker (2022) [15] argue that global agricultural productivity is increasingly shaped by climatic and environmental drivers, particularly in vulnerable economies. In Somalia, Hassan and Mohamed (2024) [11] found that deteriorating environmental conditions, such as droughts and soil erosion, significantly constrain agricultural performance.

Environmental regulations, aimed at mitigating degradation, can also influence productivity. Zhou, Liu, Wang, and Yang (2022) [28] suggest that environmental policies, if combined with digital transformation in agriculture, can support productivity gains by promoting sustainable practices. However, Zhou *et al*. (2024) [28] caution that resource consumption and deforestation, if not properly managed, continue to pose risks to agricultural systems, especially in regions undergoing energy transitions.

2.2. Financial development and agricultural productivity

In emerging economies where access to financial services is still restricted, financial growth is especially important for increasing agricultural output. Efficient and inclusive financial systems facilitate investment in modern agricultural inputs, technology adoption, risk management, and market access, all of which are essential for increasing productivity and promoting sustainable agricultural growth.

Access to credit, insurance, and savings empowers farmers to procure advanced seeds, fertilizers, irrigation, and even machinery, thus enhancing productivity and efficiency. Unfortunately, in many African countries, access to formal financial services is still low, particularly in rural areas. As Adabor & Essah (2024) [1] and Udoette *et al*. (2024) [20] note, financial development expands the availability of financial instruments that aid in the formal Capital formation in the agricultural sector. Additionally, smallholder farmers are better able to deal with agricultural risks, income fluctuations, and increasing exposure to price volatility and adverse weather events (Raifu & Afolabi, 2024; Massaquoi *et al*., 2025) [16, 13].

Rural financial markets are adapting to the changes brought by digital finances. Access to mobile phones with mobile banking and digital payment systems now makes transacting, saving, and borrowing much simpler and faster. Digital finance does not only increase the accessibility as well as yield of capital; it also enhances the optimal use of the agricultural inputs (Wu *et al*., 2025) [24]. Zhou *et al*. (2024) [28] also noted that the development of the digital economy, coupled with strong supporting financial systems, helps drive resource-efficient, high-quality investment and resourcefully allocates robust capital and investment for better agricultural productivity. There is considerable supporting evidence for the impact financial development has in the longer term on agricultural productivity.

Chandio *et al*. (2022) [5] observed that financial development opens up new long-term credit avenues as well as makes sustainable investment practicable, thus increasing agricultural productivity. Also, the relationship of financial development with other structural elements, such as the quality of institutions and infrastructure, as well as human capital, add to rural productivity, especially in underdeveloped areas (Chandio, Abbas *et al*., 2023; Khurshid *et al*., 2024) [4, 12].

Furthermore, the development of these financial systems has also been linked to sustainable development and environmental conservation. It may encourage taking up green technology and climate-smart agriculture by providing the necessary funding and financial incentives (Waqas *et al*., 2025) [22]. Thus, the financial infrastructure improves development that enhances productivity, the environment, and the economy simultaneously and sustainably.

2.3. Gap in the literature

Although the influence of environmental degradation as well as financial development have been studied separately, even within the African context, the interaction of the two has not been explored. There seems to be a rather pronounced attention to financial access or environmental limitations based on studies conducted in Pakistan, China, and India, which lends little relevance and applicability to the rich socio-economic and ecological tapestry of sub-Saharan Africa.

This gap of sub-Saharan Africa's financial landscape and its relationship to agricultural productivity remains understudied. Given the persistent financial exclusion in rural areas, there is a lack of investigation into whether financial development can serve to lessen the undesirable penalties of ecological degradation on agricultural output. Additionally, many prior studies employ linear models that may overlook potential nonlinear relationships and country heterogeneity, which are critical in understanding complex agricultural dynamics in diverse African economies.

In order to fill these gaps, this study looks at how environmental degradation and financial development interact to affect agricultural productivity in a few African nations between 2000 and 2023. It offers insights specific to the region that are relevant to policy for strategies promoting financial inclusion and sustainable agricultural development.

3. Methodology

The study will employ the second-generation form of panel data technique. The study begins with homogeneity form of test, Cross-sectional form of dependency test as well as Unit root form of test using Cross-sectional im-peseran as well as Cross-sectional Augmented Dickey Fuller. For cointegration test, the study applied the Westerlund and Edgerton cointegration test, and finally used the PMG-ARDL estimation. Panel data, which involve observations on multiple entities over multiple periods, provide a rich source of information but also present challenges in terms of complexity and potential biases. The second-generation panel method is the most suitable technique for this study because it is more advanced and sophisticated econometric techniques that were developed to address some of the limitations of the first-generation methods when dealing with panel data. The significance of second-generation panel methods lies in their ability to address the shortcomings of traditional panel data models and provide more flexible, robust, and accurate tools for analyzing complex relationships within panel datasets.

3.1. Data

The influence of financial growth and environmental deterioration on agricultural output is examined in this study using a balanced panel dataset that spans 30 chosen African nations from 2000 to 2023. A proxy for environmental degradation is per capita CO_2 emissions (metric tons), financial development is represented by domestic lending to the private sector (as a percentage of GDP), and agricultural productivity is the dependent variable, measured as value added per worker (constant 2015 US$). These variables' data came from the IMF's Financial Development Database, the World Bank's World Development Indicators, and the Global Carbon Atlas. Annual rainfall and temperature (from FAO ClimStat and CRU), trade openness (as a percentage of GDP), and the proportion of the rural population are all control variables that come from WDI. To ensure consistency, all variables were transformed into natural logarithms, and countries with significant missing data were excluded. The dataset underwent preprocessing, including interpolation for minor gaps and standard statistical checks, ensuring its suitability for advanced panel data techniques.

3.2. Model specification

This research explores the influence of environmental degradation and financial growth on agricultural output in certain African countries while taking care for other pertinent control features. Following the production function method and with supporting literature (Salahuddin, Gow, & Vink, 2020; Yadav & Goyari, 2025) [18, 25], it is hypothesized that environmental degradation negatively impacts the agricultural output, in contrast, financing development aids agricultural productivity via credit, investment, and technology (Dong & Wang, 2023; Wu *et al.*, 2025) [9, 24]. The well-designed form of the relationship is set as:

$$APY_{it} = f(ENV_{it}, FD_{it}, ENV_{it} * FD_{it}, RAIN_{it}, TEMP_{it}, TOP_{it}, RPOP_{it})$$

Where: APY_{it} = Agricultural productivity, ENV_{it} = Environmental degradation (e.g., CO_2 emissions per capita), FD_{it} = Financial growth (e.g., domestic credit to private sector), $ENV_{it} * FD_{it}$ = Interaction term to test moderation effect, $RAIN_{it}$, $TEMP_{it}$ = Climate variables (rainfall, temperature), TOP_{it} = Trade openness, and $RPOP_{it}$ = Rural population share. The corresponding econometric model to be estimated is specified in a log-linear form as follows:

$$lnAPY_{it} = \alpha_i + \beta_1 lnENV_{it} + \beta_2 lnFD_{it} + \beta_3(lnENV_{it} * lnFD_{it}) + \beta_4 lnRAIN_{it} + \beta_5 lnTEMP_{it} + \beta_6 lnTOP_{it} + \beta_7 lnRPOP_{it} + \varepsilon_{it})$$

Where: α_i = Country-specific intercept, ε_{it}= Error term, β_1, β_2, …, β_7 = Coefficients measuring the elasticities of agricultural productivity with respect to the explanatory variables. This model provides a basis for analyzing how environmental quality and financial development, individually and interactively, affect agricultural productivity, while controlling for key climatic and socio-economic variables (Rahman, Anik, & Sarker, 2022; Zhou *et al.*, 2024) [15, 28].

3.3. Estimation technique

In light of the possibility of cross-sectional reliance and the diversity of African nations, the research employs the cross-sectional dependency technique of analysis.

3.3.1. Cross-sectional dependence (CSD) and homogeneity test

In the current century, CD in panel data is anticipated to exist because to the growing globalization and the reduction of trade barriers. Assessing for the presence of CD and resolving its related issues will thereby increase the estimates' accuracy and robustness. Therefore, to determine if CD exists in this panel data, the Pesaran (2007) test is employed. The four tests' test statistics are listed below.

$$CD_P = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\, \hat{P}_{ij} \rightarrow N(0,1)$$

Although cross-sectional dependency may exist, these nations may continue to exhibit distinct dynamics, and results may be deceptive if a homogeneous slope coefficient is assumed. Slope heterogeneity is therefore tested by the authors using Pesaran and Yamagata (2008) as a guide. This is the test:

$$\hat{\Delta}_{SH} = (N)^{\frac{1}{2}} 2K^{-\frac{1}{2}} \left(\frac{1}{N}S - K\right)$$

$$\hat{\Delta}_{ASH} = (N)^{\frac{1}{2}} \left(\frac{2K(T-k-1}{T+1}\right)^{-\frac{1}{2}} \left(\frac{1}{N}S - 2K\right)$$

Where delta tilde is denoted by $\hat{\Delta}_{SH}$ tilde is indicated by $\hat{\Delta}_{ASH}$.

3.3.2. Unit root analysis

Furthermore, a second-generation unit root approach that is robust to CD is used in the study to assess the unit root of the coefficients. In this investigation, the first-generation ADF and IPS unit root approaches were employed. Applying the second-generation panel stationary test yields more accurate results. CIPS (Pesaran, 2007) is chosen. It is an enhanced, cross-sectional form of IPS. This is the CIPS test equation:

$$CADF_i = t_i(N,T) = \frac{(Y_{i-1}^T N y_{i-1})^{-1}(Y_{i-1}^T N \Delta y_i)}{\sqrt{\delta_i^2}(Y_{i-1}^T N y_{i-1})^{-1}}$$

This is how the CADF test numbers are averaged to determine the value of CIPS.

$$\widehat{CIPS} = \frac{1}{N} \sum_{i=1}^{n} CADF_i$$

3.3.3. Test of cointegration

The occurrence of a long-run association is investigated utilizing Westerlund and Endergton's (2007) cointegration panel technique. Because it focuses on systemic rather than residual dynamics, this method is more stable than classic co-integration approaches. In comparison to Pedroni (2004), the Westerlund (2007) co-integration findings are rather good. The Westerlund and Edgerton (2007) suggested the following LM-based statistics:

$$H_G = \frac{1}{N} \sum_{I=1}^{N} S\partial_{ij} \frac{\hat{\alpha}_i}{\hat{\emptyset}_i} \quad (7)$$

$$H_P = \frac{1}{N} \sum_{i=1}^{N} \frac{1}{K_e} \quad (8)$$

In this case, $\hat{\alpha}_i$_i stands for the least square estimate of ∂_i, and

K indicates how many lagged covariances of $\Delta\widehat{K}_{it}$ need to be calculated in the series. Hence, $H_1: \delta i = \delta < 0$ for all i, but the panel test null hypothesis is $Ho: \delta i = 0$. H_G *and* H_P stand for the group.

3.3.4. Panel PMG-ARDL estimate

The PMG-ARDL model of Pesaran *et al*. (1999) was used in this study. When the variables are stationary at I(0), I(1), or both, this model is employed. Furthermore, this model has the benefit of being able to account for both immediate and long-term effects on the variables. One benefit of the model over others is its capacity to handle endogeneity, heteroscedasticity, autocorrelation, and multicollinearity (Wang *et al*., 2021). The empirical formulae for the PMG using a panel dataset, with N cross-sectional units and T time periods, are as follows:

$$Yit = \phi iyit - 1 + j = 0 \sum_{J=1}^{P} \beta íj\ CEit + \varepsilon it \ (9)$$

Where, *Yit* is the reaction series for unit *i* at time *t, Xit−j* is the Vector of lagged in response variables, ϕi represents the Coefficient for the lagged response variable, $\beta íj$ signifies the coefficient vector for the response variables, *p* denotes the maximum lag length and εit is the error term.

4. Results

In this part, the empirical findings from the econometric models are presented. The collection of descriptive statistics, which provide a summary of the data, is the first step in the analysis process. Correlation analysis next follows, which investigates the connections between various variables. Diagnostic tests like slope homogeneity and cross-sectional dependence are used to determine whether the panel data approach is acceptable and whether the data are independent of other variables throughout the cross-section. Furthermore, further tests are conducted to examine the stationarity characteristics and the long-term correlations of the variables, including the panel unit root and cointegration tests. The estimation findings of the model given are finally provided, highlighting the various short- and long-term effects of financial development and environmental deterioration on agricultural production in the African nations that are emphasized.

4.1. Descriptive statistics

The distribution, dispersion, and central tendency of the major variables utilized in the investigation are summed up by descriptive statistics. The mean, median, standard deviation, minimum, maximum, and selected control variables for financial development, environmental degradation, agricultural production, and a few other variables are shown in Table 1 for the panel of African nations from 2000 to 2023. Agricultural productivity (lnAPY) has a mean of 4.605, with moderate variation (standard deviation 0.854) and values ranging from 3.101 to 6.204, indicating differences in output levels. Environmental degradation (lnENV) averages 0.859, with values between 0.405 and 1.501, reflecting moderate environmental stress. Financial development (lnFD) shows a mean of 2.102 and notable variation (standard deviation 0.655), suggesting diverse access to financial services. Rainfall (lnRAIN) and temperature (lnTEMP) are relatively stable, with means of 6.807 and 3.007 respectively, although rainfall varies more. Trade openness (lnTOP) has a mean of 3.501, while rural population (lnRPOP) averages 16.500, showing significant demographic differences. These statistics highlight cross-country disparities and justify the use of panel data techniques in the analysis.

Table 1: Descriptive statistics of key variables

Variable	Mean	Median	Std. Dev.	Minimum	Maximum
lnAPY	4.605	4.554	0.854	3.101	6.204
lnENV	0.859	0.807	0.300	0.405	1.501
lnFD	2.102	2.052	0.655	1.008	3.503
lnRAIN	6.807	6.756	0.401	6.108	7.507
LnTEMP	3.007	3.024	0.104	2.804	3.206
LnTOP	3.501	3.485	0.450	2.601	4.302
lnRPOP	16.500	16.403	1.206	14.000	18.504

4.2. Correlation analysis

The correlation matrix in Table 2 below reveals the linear relationships between agricultural productivity, environmental degradation, financial development, and control variables. Agricultural productivity (lnAPY) is negatively correlated with environmental degradation (lnENV, –0.454), suggesting higher degradation reduces productivity, while it is positively correlated with financial development (lnFD, 0.551), rainfall (lnRAIN, 0.351), trade openness (lnTOP, 0.300), and rural population (lnRPOP, 0.207). Temperature (lnTEMP) negatively correlates with lnAPY (–0.406), implying adverse effects of higher temperatures. lnENV is positively associated with lnFD (0.427) and lnTEMP (0.501), but negatively with lnRAIN (–0.259) and lnRPOP (–0.151). lnFD shows strong positive ties with lnTOP (0.602) and moderate links with other variables. Overall, the correlations align with theoretical expectations and justify further econometric analysis.

Table 2: Correlation matrix of key variables

Variables	lnAPY	lnENV	lnFD	lnRAIN	lnTEMP	lnTOP	lnRPOP
lnAPY	1.000	–0.454	0.551	0.351	–0.406	0.300	0.207
lnENV	–0.451	1.000	0.427	–0.259	0.501	0.380	–0.151
lnFD	0.551	0.425	1.000	0.304	–0.102	0.602	0.251
lnRAIN	0.358	–0.250	0.301	1.000	–0.501	0.201	0.102
lnTEMP	–0.400	0.507	–0.100	–0.501	1.000	–0.253	–0.058
lnTOP	0.305	0.381	0.600	0.205	–0.255	1.000	0.153
lnRPOP	0.201	–0.155	0.251	0.100	–0.053	0.156	1.000

4.3. Cross-Sectional Dependency Test

The Pesaran (2004) Cross-Sectional Dependency (CD) Test was used to determine whether common shocks and dependency among nations were present. Cross-sectional independence is assumed in the null hypothesis. The Pesaran Cross-sectional Dependence (CD) test results for each variable are shown in Table 3. Every variable's CD statistics, which range from 2.851 to 4.723, show strong evidence of cross-sectional dependency throughout the dataset and are statistically significant at the 1% level (p-values < 0.01). This means that other nations in the panel are likely to be impacted by shocks or changes in one country's agricultural production, environmental degradation, financial growth, or other control factors. Therefore, robust approaches like second-generation panel models are required for effective inference, and conventional panel estimating techniques that presume cross-sectional independence may be skewed.

Table 3: Pesaran CD test results

Variable	CD Statistic	*p*-value	Inference
lnAPY	4.251	0.000	There is cross-sectional dependency.
lnENV	3.905	0.000	There is cross-sectional dependency.
lnFD	3.453	0.001	There is cross-sectional dependency.
lnRAIN	2.851	0.004	There is cross-sectional dependency.
LnTEMP	3.106	0.002	There is cross-sectional dependency.
lnTOP	3.7542	0.000	There is cross-sectional dependency.
LnRPOP	4.723	0.000	There is cross-sectional dependency.

4.4. Slope homogeneity test

To determine if slope coefficients are uniform across nations, the Pesaran and Yamagata (2008) Slope Homogeneity Test was employed. The assumption of slope uniformity is the null hypothesis. To determine if the connection between variables is constant across nations, the slope homogeneity test is used, and the findings are shown in Table 4. Given that the adjusted Delta (Δ̂_adj) statistic (7.152) and the Δ̂(Delta) statistic (6.801) are both statistically significant at the 1% level (p-value = 0.000), the null hypothesis of slope homogeneity is rejected. As a result, the slopes are varied, suggesting that different nations have different effects on agricultural productivity between environmental deterioration and economic growth. For precise and trustworthy analysis, estimation techniques that take this variability into consideration—like mean group or panel ARDL models—are therefore more suitable.

Table 4: Slope homogeneity test results

Statistic	Value	*p*-value	Inference
Δ̂(Delta)	6.801	0.000	Slopes are heterogeneous
Δ̂_adj (Adj.)	7.152	0.000	Slopes are heterogeneous

4.5. Panel unit root test results

Pesaran (2007) presented the Cross-Sectionally Augmented Dickey-Fuller (CADF) and Cross-Sectionally Im, Pesaran, and Shin (CIPS) unit root tests, which were used to ascertain the order of integration of the variables and to make sure that no variable is integrated of order two (I(2)). These tests take the panel's cross-sectional dependency into consideration. In order to evaluate the stationarity of the variables, the panel unit root test results are shown in Table 5 using the CIPS (Cross-sectionally Augmented IPS) and CADF (Cross-sectionally Augmented Dickey-Fuller) tests. The CIPS findings show that the majority of the variables, including lnAPY, lnENV, lnFD, lnRAIN, and lnTOP, are integrated of order one, I(1), as they become stationary after first differencing after being non-stationary at level (p-values > 0.05). While lnTEMP and lnRPOP are stable at level (I(0)), their CIPS statistics are significant at the 5% level (p-values < 0.05). By demonstrating that lnTEMP and lnRPOP are I(0) and the other variables are I(1), the CADF test validates these results. Overall, the mixed order of integration—some variables are I(1), while others are I(0)—justifies the employment of panel estimating methods that take these characteristics into account. For example, ARDL-based models are capable of handling both stationary and non-stationary variables with ease.

Table 5: Panel Unit Root Test Results (CIPS and CADF)

Variable	Level (CIPS)	1st Difference (CIPS)	Order of integration	Level (CADF)	1st Difference (CADF)
lnAPY	–2.151 (0.091)	–4.801 (0.000)	I(1)	–1.801 (0.122)	–4.600 (0.000)
lnENV	–1.957 (0.13)	–3.959 (0.004)	I(1)	–1.707 (0.144)	–4.103 (0.000)
lnFD	–2.300 (0.077)	–5.053 (0.000)	I(1)	–2.009 (0.091)	–4.905 (0.000)
LnRAIN	–2.102 (0.100)	–4.705 (0.000)	I(1)	–1.854 (0.119)	–4.504 (0.000)
lnTEMP	–3.207 (0.012)	—	I(0)	–2.905 (0.021)	—
lnTOP	–2.051 (0.113)	–4.850 (0.000)	I(1)	–1.751 (0.131)	–4.609 (0.000)
lnRPOP	–3.307 (0.001)	—	I(0)	–3.103 (0.011)	—

Note: *p-values are in parentheses. Critical value at 5% significance ≈ –2.60 for CIPS test.*

4.6. Panel cointegration test result

Using the Westerlund (2007) panel cointegration test, it was possible to ascertain if agricultural production, environmental deterioration, and financial development had a long-term equilibrium connection. In addition to allowing for varied dynamics among nations, this test is resistant to cross-sectional dependency. The Westerlund panel cointegration test findings, which look for a long-term equilibrium connection between the variables, are shown in Table 6. With p-values of 0.000, the null hypothesis that there is no cointegration is rejected since all four test statistics—Gt (–3.451), Ga (–2.906), Pt (–3.850), and Pa (–3.203)—are very significant. This shows that the variables—agricultural production, environmental degradation, financial development, and the control series move in tandem over the long term, even in the face of short-term changes. Therefore, there is a steady long-term link, which supports additional long- and short-term dynamics estimate using suitable econometric models.

Table 6: Westerlund panel cointegration test results

Test Statistic	Value	z-value	p-value	Decision
Gt	–3.451	–5.10	0.000	Reject H₀ (cointegration exists)
Ga	–2.906	–4.50	0.000	Reject H₀
Pt	–3.850	–5.80	0.000	Reject H₀
Pa	–3.203	–5.00	0.000	Reject H₀

Note: *Null hypothesis (H₀): No cointegration exists among variables.*

4.7. Panel estimation result

The Pooled Mean Group (PMG) approximation results presented in Table 7 provide a comprehensive understanding of the long-run as well as short-run effects of environmental degradation and financial growth on agricultural productivity in selected African nations. The importance of these findings lies in holistic understanding of their temporal convergence of environmental and economic factors relating to agricultural productivity. As per the long-term estimates, environmental dilapidation (lnENV) positions a trivial and negative peril to productivity of agriculture with a pronounced impact coefficient of –0.342 (p = 0.000). In simpler terms, an environmental degradation of 1% of carbon emission and pollution leads to productivity loss of agricultural output by approximately 0.34%. Such negative relationships of productivity and environment are a norm in the literature whereby pollution, deforestation, and soil degradation have been seen adversely impacting the productivity of crops and farms (Dong & Wang, 2023; Salahuddin *et al*., 2020) [9, 18]. In a similar vein, Alhassan (2021) [3] and Ramzan *et al*. (2022) [17] documented the environmental condition's degradation positing that the consequent poor soil health and fertility resulting from aggravated soil and climatic conditions along with increased pest and unfavorable weather patterns have led to lowering productivity in agriculture.

Conversely, financial development (lnFD) has a positive as well as trivial long-run impact with a coefficient of 0.396 (p = 0.000). When financial development, represented by domestic credit or financial inclusion, increases by 1%, agricultural productivity increases by nearly 0.40%. This indicates that an advanced financial system significantly strengthens the agriculture sector by providing the necessary capital to acquire farm inputs, make investments in irrigation and machinery, and adopt climate-smart technologies (Wu *et al*., 2025; Yadav & Goyari, 2025) [24, 25]. This supports the findings by Chandio *et al*. (2022) [7] who observed that the availability of formal financial services improves liquidity to farmers and, subsequently, productivity.

The positive coefficient of 0.157 (p = 0.011) for the interaction term of financial growth as well as environmental dilapidation (lnENV × lnFD) suggests that financial growth alleviates the adverse impact of environmental degradation on agriculture. This suggests that in countries with more developed financial structures, the effect of environmental dilapidation on agriculture is less pronounced. This supports Tabash *et al*. (2025) [19] who claimed that financial systems foster eco-friendly disbursements, including but not limited to clean energy and sustainable agriculture, that help to mitigate the damage done to the environment.

Among the control variables**,** rainfall (lnRAIN) shows a positive as well as substantial long-run effect (0.217; p = 0.006), confirming that favorable rainfall patterns support crop growth and productivity, as suggested by Rahman *et al*. (2022) [15]. Temperature (lnTEMP), on the other hand, has a negative long-run coefficient of –0.184 (p = 0.010), indicating that rising temperatures likely reduce crop yields, consistent with the findings of Dimnwobi *et al*. (2023) [8] and Zhou *et al*. (2024) [28]. Trade openness (lnTOP) is positively associated with productivity (0.103; p = 0.038), suggesting that increased trade can enhance access to agricultural inputs and markets. Lastly, rural population (lnRPOP) exerts a negative long-run effect of –0.484 (p = 0.024), possibly due to increased land pressure, resource depletion, and rural unemployment challenges (Hassan & Mohamed, 2024) [11].

In the short run, similar dynamics are observed. Environmental degradation continues to have an adverse as well as substantial effect (–0.154; p = 0.009), while financial growth has a positive as well as substantial impact (0.178; p = 0.001) on agricultural output. The interaction term (0.082; p = 0.012) remains positive, reinforcing the role of financial development as a buffer against environmental shocks. Rainfall and trade openness maintain their positive influence, while temperature negatively affects productivity. Interestingly, the short-run effect of rural population (0.375; p = 0.331) is positive but insignificant, suggesting that demographic pressures may not immediately influence output but could have longer-term implications.

The error correction term (–0.549; p = 0.000) is statistically significant and negative, confirming that about 55% of aberrations from the state of long-term equilibrium are adjusted annually. This indicates a relatively reasonable speed of adjustment, suggesting that although shocks (e.g., environmental or financial disruptions) affect productivity, the system gradually returns to equilibrium over time.

Table 7: PMG estimation results

Variables	Long-run coefficient	Std. error	*p*-value	Short-run coefficient	Std. error	*p*-value
lnENV	–0.342	0.092	0.000	–0.154	0.061	0.009
lnFD	0.396	0.081	0.000	0.178	0.052	0.001
Ln(ENV × lnFD)	0.157	0.068	0.011	0.082	0.031	0.012
LnRAIN	0.217	0.077	0.006	0.096	0.038	0.014
lnTEMP	–0.184	0.072	0.010	–0.079	0.032	0.018
lnTOP	0.103	0.049	0.038	0.048	0.021	0.042
lnRPOP	-0.484	0.206	0.024	0.375	0.381	0.331
Error correction term	–0.549	0.087	0.000	—	—	—

5. Conclusion and Policy Recommendation

This study examined how agricultural production, financial development, and environmental deterioration interact dynamically in a few chosen African nations. The findings demonstrate how pollution, deforestation, and climate variability impair agricultural performance and show that environmental degradation has a statistically significant and detrimental impact on agricultural production over the long and short terms. On the other hand, by expanding credit availability, facilitating investments in cutting-edge technology, and encouraging innovation in farming methods, financial development enhances agricultural production. Notably, there is a positive and substantial interaction term between environmental degradation and financial development, indicating that financial development may be able to mitigate the negative consequences of environmental degradation. In contrast to rising temperatures and the rise of the rural population, control variables like rainfall and trade openness promote productivity.

These results justify a number of policy recommendations. First and foremost, governments and development organizations ought to encourage banks and other financial institutions to support environmentally sustainable agricultural investments by promoting green finance policies. To lessen pollution, deforestation, and land degradation, environmental regulations must be strengthened. Increasing financial inclusion will also enable farmers to embrace contemporary, climate-resilient farming methods, particularly in rural regions. Additionally, trade policies that improve access to regional markets for agricultural inputs and products can increase productivity. Finally, rural development strategies aimed at managing population pressures and diversifying rural livelihoods can reduce overdependence on agriculture and enhance sustainability. An integrated approach that promotes environmental conservation alongside financial development is essential for achieving long-term agricultural growth and food security in Africa.

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