MAXIMIZING ENVIRONMENTAL SUSTAINABILITY: STRATEGIES FOR REDUCING CARBON EMISSIONS AND POST-HARVEST LOSSES

WANG, Y.[1*] – AKPA, F. A.[2] – MATTHEW, O.[3] – AHSRAF, J.[4] – OGUNBIYI, T.[5] – OSABOHIEN, R.[6,7*]

[1]*School of Marxism, China University of Geosciences, Wuhan, 430074 Hubei, China*

[2]*Laboratoire d'Economie Publique, Faculté des sciences économiques et de gestion, Université d'Abomey-Calavi, Abomey-Calavi, Benin*

[3]*Department of Economics and Development Studies, Covenant University, Ota, Nigeria*

[4]*School ofComputer Information Engineering, Nanchang Institute of Technology, Jiangxi, China*

[5]*Public Administration, Johnson Shoyama School of Public Policy, University of Saskatchewan, Saskatoon, Canada*[6]*Institute of Energy Policy and Research (IEPRe), Universiti Tenaga Nasional (UNITEN), Kajang, Malaysia*

[7]*DEPECOS Institutions and Development Research Centre (DIaDeRC), Ota, Nigeria*

[*]*Corresponding authors*
e-mail: wangyuan20230912@163.com; romik247@gmail.com

(Received 13th Apr 2024; accepted 16th Jul 2024)

Abstract. This study examined the effects of environmental sustainability and carbon emissions on post-harvest losses. Data used were collected from several databases such as World Bank Development Indicators (WDI), Food and Agriculture Organization Statistics (FAOSTAT), World Bank Doing Business and country policy and institutional assessment (CPIA) over the period of 2004 to 2022. The study applied the Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS) and Granger causality tests for the data analysis. The results showed that environmental sustainability reduces post-harvest losses, while carbon emissions increase post-harvest losses. The results suggest that a focus on environmental sustainability practices can help reduce post-harvest losses, while higher carbon emissions are associated with increased post-harvest losses. This underscores the importance of adopting environmentally friendly practices to enhance food security and reduce waste in the agricultural supply chain.
Keywords: *agricultural supply chain management, food security, waste reduction, low carbon economy, sustainable development*
JEL Classifications: Q01, Q18, Q53

Introduction

In today's rapidly changing world, the agricultural sector faces significant challenges in meeting the growing demand for food (Food and Agricultural Organisation [FAO, 2019]) while also addressing environmental concerns (Godfray et al., 2010; Aina et al., 2024). One of the key issues that the industry grapples with is the need to maximize environmental sustainability by reducing carbon emissions and post-harvest losses (Akpa et al., 2023; Osabohien et al., 2023; Osabohien and Matthew, 2024). As the global population continues to increase, there is a pressing need to produce more food efficiently while minimizing the environmental impact of agricultural activities (FAO, 2019; Osabohien, 2024).

Environmental sustainability is the ability to maintain an ecological balance and conserve natural resources to support the wellbeing of current and future generations. In

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

recent times, the government of countries and international organizations have begun to pay an unprecedented attention to the environmental crisis due to the continuous decline of the global environmental quality (Degbedji et al., 2024). It is believed that a carbon emission is as a result of energy use which has a negative impact on the environment (Eregha and Mesagan, 2017; Saint-Akadiri et al., 2019; Li et al., 2024).

Anderson et al. (2008) stressed that since the industrial era, these emissions have grown significantly. The main issue with carbon emissions is that they cause climate change that could have a negative impact on the environment and on human and economic activity (Mohamed et al., 2024). Carbon emissions from human activities contribute to climate change, which poses significant risks to agriculture. Because, rising temperatures can cause heat stress in crops, leading to reduced yields and quality. Changes in precipitation patterns can result in droughts or floods, further impacting crop production. Warmer temperatures also create favourable conditions for pests and diseases, increasing crop losses and the need for pesticides. Water scarcity worsens with climate change, making irrigation more challenging and leading to crop failures. Additionally, climate change disrupts ecosystems, causing a loss of biodiversity that is essential for maintaining soil health and fertility (Jiang and Li, 2017; Matthew et al., 2018). The decline in agricultural output definitely affects the level of agricultural supply to the market, and once supply is adversely affected, demand will also be affected adversely (Matthew et al., 2023; Adediran et al., 2024; Osabohien et al., 2024).

Carbon emission often leads to change in rainfall patterns and increased temperature, which led to an increase in crops damage and reduced harvest for farmers. By 2050, crop yields in sub-Saharan African countries alone are projected to decrease by 5% to 17% (Osabohien, 2024). According to Akpa et al. (2023), for every one-degree increase in temperature, there is a corresponding 3%-point decrease in food output thereby leading to a 1.3% decline in growth. However, it is important to note that the issue of carbon emission goes beyond the experience of post-harvest losses and environmental sustainability as other attendant effects also occurs as a result of this. Also, the issue of climate change in the sub-Sahara Africa will further intensify the issue of food insecurity which would also weigh on child nutrition and educational attainment thereby leading to a major setback of the hard-earned sustainable development gains.

Post-harvest losses affect nutritional health and have negative financial impacts on both consumers and farmers. Post-harvest losses also deprive farmers of the opportunity to grow and strengthen their income generation activities (Kemeze, 2018; Gebreegziabher and van Kooten, 2020). Due to inadequate storage capacities and low-value chain development, small-scale farmers lose up to 40 percent of their seasonal harvest (Kasso and Bekele, 2018; Gebreegziabher and van Kooten, 2020). As a result, most small-scale farmers sell their produce immediately after harvest at a time when prices are low due to over-supply. The qualitative loss of food is estimated at 37% in sub-Saharan Africa (FAO, 2019). However, the World Bank (2011) estimates the value of post-harvest losses per year in sub-Sahara Africa (SSA) for all grains to be about $4 billion. The volume and value of these post-harvest losses estimate are alarming, highlighting the urgency to better understand and reduce post-harvest losses (World Bank, 2011).

In developing economies, post-harvest losses are complex and interlinked (Akpa et al., 2023; Osabohien, 2024). Indeed, the quest for environmental sustainability is necessary for the actualization of sustainable development goals of no poverty (SGD-1), food security (SGD-2), good health and wellbeing (SDG-3), clean water and sanitation (SDG-6), climate action (SGD-13), life below water (SDG-14) and life on land (SDG-15). On the other hand,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

post-harvest losses have become a major issue in Africa as a result of the adoption of unsustainable agricultural practices such as use of agro-allied chemicals (Osabohien, 2024) which has consequently led to the reduction of soil fertility, environmental pollution and loss of biodiversity (Degbedji et al., 2024).

Furthermore, it has been observed that household consumption is likely to decline rapidly as climate shock depresses agricultural production which affects overall growth and productivity and subsequently, overall economic welfare (Osabohien et al., 2023). Also, evidence from literature has revealed that post-harvest losses go beyond physical quantity loss but also includes observable loss in quality such as discolouration, mild growth, insect damage and odour s, all of which eventually affects the profitability of producers and the health of consumers. Despite the various strategies and policies that have been introduced in developing countries, post-harvest losses still remain a major challenge as these crises have threatened people’s well-being and slowed down the pace of the achievement of the sustainable development goals. Also, only 5% of agricultural research in sub-Saharan Africa is targeted at preventing post-harvest losses. This lack of awareness has posed as a significant loss to the key actors of the agricultural value chain, thereby reducing their profitability and threatened the long-term sustainability of the business (Ricker-Gilbert et al., 2022).

Thus, this study sets out to examine the link among environmental sustainability, carbon emissions and post-harvest losses in Africa. Therefore, the motivation for this study stems from the fact that when economic activity, including production, distribution and trade increases, it degrades the environment's quality because economic activity is accompanied by bio-diversity loss, deforestation for the construction of industries and manufacturing facilities, and carbon emissions from the usage of heavy energy, this will in turn affect agriculture resulting in post-harvest losses. If this is not promptly attended to, it will cause the African continent to be food insecure, which will further increase hunger, poverty and economic downturn. Also, several studies have examined the impact of carbon emission on agricultural output in selected countries and sub-regions of Africa, however, to the best of the researcher’s knowledge, only a few studies have focused on the entire African continent. In addition, previous studies did not bring in the environmental sustainability angle to the discourse, which this study is taking cognizance of.

The study focuses on investigating the relationship between environmental sustainability factors and post-harvest losses. The two main objectives are i) to explore the impact of environmental sustainability practices on post-harvest losses and ii) to analyze the relationship between carbon emissions and post-harvest losses. Environmental sustainability practices in agriculture, such as sustainable farming methods and eco-friendly packaging, are examined to understand their influence on reducing food waste and improving efficiency in the supply chain. Additionally, the study aims to assess how carbon emissions from agricultural activities contribute to post-harvest losses and explore strategies to reduce carbon footprints in the industry. By addressing these objectives, the research seeks to provide insights into the importance of adopting sustainable practices and reducing carbon footprints to enhance food security, environmental health, and economic sustainability in the agricultural sector.

This study consists of five sections viz; after this introductory section, section two presents a review of extant literature related to the study, section three discusses both the methodology and the data sources; section four deals with the analysis of the data employed in the study, the results and discussions; section five concludes the study with

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

recommendations for policies that will help improve on the environment given the carbon emissions and reduce post-harvest losses in Africa.

Literature Review and Theoretical Framework

Literature Review

Environmental sustainability provides both product and process advantages to the business. The process advantages include the gain in transactional efficiency, the transition of wastes into useful forms, a safer working environment, less production interruption, which entails more regular check-up and maintenance, more effective use of side products, reduction of cost of activities relating to the transportation and disposal of wastes and product improvement through process changes. The product advantages comprise a more standard product: better quality, safer products, more productive resource usage, lower packaging costs, reduction of customer's sell out, lower products, and increased product sales and scrap value (Ay-Karakuş et al., 2018). Environmental sustainability would help improve human welfare and social sustainability by safeguarding the sources of raw materials used for human needs and guaranteeing that human waste sinks are not exceeded to protect humans from harm. It demands to enable conditions that are not integral parts of environmental sustainability.

Amri et al. (2019) employed the Environmental Kuznets Curve (EKC) in estimating the relationship between carbon emissions and economic growth. They posited that income per capita positively affect carbons emissions in linear form, but it has a negative effect on carbon emissions in quadratic form, and they formalized EKC assumptions. Idowu and Awodele (2018) examined the environmental implications of the rapidly growing development and use of information and communication technology (ICT) as it pertains to sustainable development now and in the future. Using content analysis, the study concludes that ICT has provided means to help achieve the SDGs and communicate information globally and permeate all sectors of the economy.

Fern and Almod (2019) focused on the sustainable economic development of nations, specifically, development through the deployment of information and communication technologies (ICTs). The study used Eurostat data and applied the partial least-squares (PLS) method to address its objectives. This approach was used to analyse European Union countries from 2014 to 2017, using a fairly rigorous data. The most outstanding result was that ICT accounted for most of the explained variance in GDP per capita (GDPpp), and, specifically, the most representative indicator was "digital public services". Therefore, the study concluded that investing in ICT deployment supports European Union countries' sustainable development.

In another study, Lechenet et al. (2017) argued that herbicide, fungicide, insecticides among others is crucial in reducing pest while preserving crop productivity. The study engaged data from a network of 946 non-organic arable French demonstrations with a contrasting farm level of pesticide use. The study applied the regression analysis with the least absolute shrinkage and selection operator (LASSO). The result showed that reducing pests will increase productivity. The study by Amaefule et al. (2023) examined how climate change through carbon emissions have affected agricultural productivity in Nigeria using the Autoregressive Distributed Lag model (ARDL) and found that there is a long-run negative relationship between agricultural productivity and carbon emissions, and that carbon emission causes climate vulnerability which threatens agricultural productivity which eventually leads to the escalation of food insecurity and exposure to

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

poverty. Similarly, study by Matthew et al. (2020), employed the two-stage Least Squares (2SLS) econometric technique to examine the effects of carbon emission on agricultural output and life expectancy in West Africa from 2000 to 2018. The study found that for every 1% increase in carbon emission, agricultural output reduces by about 3.818% which showed that carbon emissions greatly affect agricultural output in the West African region.

From the literature, some studies have shown that reducing post-harvest losses in developing countries by 10% may lower fruit and vegetable prices by more than 13%, the population is at risk of hunger by 11%, and child under-nutrition by 4% by 2050 (Osabohien, 2024).

In the study by Raut et al. (2018), it was found that post-harvest losses in India are significant and cause an overall massive economic deficit. Therefore, reducing post-harvest losses can help achieve sustainability in balancing economic, social, and environmental dimension. In another study, Swai et al. (2019) found that post-harvest losses of maize are almost half of the produced grains in sub-Sahara Africa (SSA). Thus, creating a post-harvest losses resilient strategy to guide small-scale maize growing farmers in Africa is a prerequisite to creating a post-harvest losses resilient strategy. In this review, critical elements underlying post-harvest losses in Africa such as infestation by the bug–pests, microbes, rodents, poor transportation infrastructure, inadequate storage facilities, and poor value chain development should be considered. Abbas et al. (2019), using a conceptual approach, proved that food wastage and loss must be avoided to avoid food insecurity, especially in the face of unstable food prices and slow economic growth in Nigeria.

In another study, Kasso and Bekele (2018) employed the multistage random sampling method which was analysed with the use of descriptive statistics. The study found that amongst others, handling processes, storage and road networks and market conditions are the most significant causes of post-harvest losses. The study proved that tomato, mango and coffee were observed to have the highest proportion of post-harvest losses which stands at approximately 45%, 43% and 15%, respectively. In addition, the study shows that up to 50% losses are recorded from market to final consumers. This is confirmed by Elik et al. (2019) which proved that given the fact up to 50% of produce is lost, especially, among smallholder farmers, controlling post-harvest losses will improve welfare of small-scale farmers.

In rural Ethiopia, Minten et al. (2021), studied post-harvest losses in rural-urban value chains. The study engaged about 4000 commodities and found that across the value chains, close to 4% of commodities are lost. In Asosa, West Gojam and Hawasa regions of Ethiopia, Fufa et al. (2021) found that on average, approximately 32% of grains is destroyed along the value chain. This is validated in the study by Kamda-Silapeux et al. (2021) found that in Yaoundé, Cameroun, above 40% of harvest fruits gets destroyed along the value chain before getting to the final consumers.

Theoretical Framework

The theoretical basis for this study is based on the structural models of climate–economy interactions of Ramsey–Cass–Koopmans infinitely-lived agent framework (Sharma, 2011). They believed that the increase in the consumption of fossil fuel has been, to a large extent, has adversely affected the level of economic growth. This by extension has an adverse effect on agricultural produce via post-harvest loss of farm produce. Sharma (2011) opined that the Environmental Kuznets Curve (EKC) is involved

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

in describing the two-fold relationship existing between economic actions and pollutants of carbon emission substances that are emitted by carbon dioxide one hand, and among the level of economic activity and the use of natural resources on the other hand.

The EKC theory has it that dilapidation of the environment primarily hiked when a nation's income per capital is minimal over a period. Thus, as the economy experience growth, invariably dilapidation of the environment reduces. This reduction leads to an upturned "U-shaped" relationship between income per capital, natural resources use and emissions waste (Sharma, 2011).

Sharma (2011) reiterated that energy like crude oil, natural gas and coal, are highly essential as they are needful in satisfying both residential and industrial energy needs, useful in the transportation of human beings/goods and electricity generation. The combustion of fossil fuel is essential in all nations as it is required in producing goods and services. It is also a known fact that the combustion of fossil fuel releases a lot of carbon dioxide which contaminates the environment, which in turn has an adverse effect on the health of the individuals living in such an environment. Despite the fact that Sharma (2011) observed that a higher economic growth (as proxied by the gross domestic product) has an impact on the emissions of $C0_2$ at least in the short-run, the health of individuals is still adversely affected.

In addition, it has been established that since the 1900s, the activities of human beings cause carbon emissions which is at a dangerous state, and this has adversely affected the health of the individuals in the society (Ansuategi and Escapa, 2002). The resultant consequence of this increase in the rate of emissions, the concentration of carbon dioxide in the atmosphere has increased by 30%, since pre-industrial times (Ansuategi and Escapa, 2002). Examples of such anthropogenic activities include; trade, agriculture, deforestation (or forestry activities), fossil energy or fuel consumption and those other activities associated with economic growth.

Methodology

Model Specification

This research uses a balanced data panel from nine African countries (Benin, Burkina Faso, Cote d'Ivoire, Guinee Bissau, Mali, Niger, Nigeria, Senegal and Togo) to analyse the effect of environmental sustainability and carbon emissions on post-harvest losses. *Equation (1)* presents the initial model estimated in this research as follows:

$$lnY_{it} = \alpha_0 + \sum_{i=1}^{7} \alpha_i lnX_{it} + \varepsilon_{it} \quad \text{(Eq.1)}$$

where: Y is the post-harvest losses (kg/ha); t refers to the time dimension from 2004 to 2021; i is the individual dimension, that is, the African countries selected for the study. Similarly, X represents the vector of independent variables; and ε is the error term; α_0 and α_i are the constant term and the X vector variables parameters.

Based on the previous study by Akpa et al. (2023) which analyse the effect of financial inclusion on post-harvest losses and this of Bendinelli et al. (2020) that seeks to understand how macroeconomic conditions influence PHL crops such as rice, maize, soybeans and wheat grains, the empirical model chosen to analyse the effect of environmental sustainability and carbon emissions on post-harvest losses is in the following model:

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

$$lPHL_{it} = \alpha_o + \alpha_1 lCPIAESR_{it} + \beta_1 lEV_{it} + \alpha_2 lCO_{2it} + \alpha_3 lFD_{it} + \alpha_4 lELEC_{it} + \alpha_5 lSTORE_{it} + \alpha_6 lICT_{it} + \alpha_{it} lFI_{it} \quad \text{(Eq.2)}$$

where PHL_{it} is post-harvest losses in kg/ha in each country i at period t; $CPIAESR_{it}$ represents policy and institution for environmental sustainability, CO_{2it} refers to the CO_2 emission in each country i at period t; FD_{it} is the domestic credit to the private sector; $ELEC_{it}$ represents the population access to electricity; $STORE_{it}$ refers to the time required to build a warehouse (storage facility); ICT_{it} is the mobile cellular subscription; FI_{it} is the financial inclusion rate in each country i at period t; $\alpha_1, \dots, \alpha_7$ are the parameters to be estimated and μ_{it} refers to the error term or unobserved factors.

Estimation Technique

The long-run associations determination between environmental sustainability, carbon emissions, and post-harvest losses was carried out with the important steps described as follows. Firstly, the paper checked for the cross-section's dependence using the tests of Pesaran (2004). In the second stage, the second-generation unit root and co-integration tests was estimated. Specifically, Pesaran (2004), and Breitung (2001) tests were used to determine if the series have the same integration order.

Phillips and Hansen (1990) developed the FMOLS to manage an optimal co-integrating regression estimation. Though, the study used the Pedroni (2013) heterogeneous FMOLS estimator for the panel cointegration regression as it has the benefit of correcting endogeneity bias and serial correlation (Özcan, 2013; Khan et al., 2019). Giving to Merlin and Chen (2021), Khan et al. (2019) and Hamit-Haggar (2012), FMOLS is the most appropriate technique for the panel, which includes heterogeneous cointegration. The Dynamic OLS (DOLS) estimator had the same asymptotic allocation as that of the panel FMOLS estimation drawn by Pedroni (1996). Indeed, Stock and Watson (1993) are the first to develop a DOLS estimation. For Kao and Chiang (2000), DOLS give better results than FMOLS and eradicate correlation between regressors. In this study, both the DOLS and FMOLS estimations were performed as shown to verify the outcome consistency. In the third and last steps, the short- and the series long-run dynamics were checked using panel error correction models. The Granger causality test was performed within the Vector Error Correction Model (VECM) framework (Granger, 1988).

Data Sources

This study covers African countries from 2000 to 2022. The data used for the analysis was extracted from several sources notably the World Development Indicators (WDI), Food and Agricultural Organisation (FAO) and Country Policy and Institutional Assessment (CPIA). The dependent variable is post-harvest losses, measured by the lost quantity divided by the sum of production (imports and stock variation) of grains of country i in year t. This variable was sourced from the database of the Food and Agriculture Organisation. The choice of this variable is based on the studies of Gustavsson et al. (2013) and Bendinelli et al. (2020) and Akpa et al. (2023). The interest variables are CO_2 emission and Policy and institutions for environmental sustainability.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

CO_2 is measured as total greenhouse gas emission (CO_2 kt) while Policy and institutions for Environmental sustainability is measured on a scale of 0 – 6 (the higher the better) and are sourced from the world development indicators and country policy and institutional assessment, respectively. The variables are sourced from the studies of Amri et al. (2019), Matthew et al. (2018) and Saint-Akadiri et al. (2019). the expected sign for CO_2 emission is positive, meaning that the increase of CO_2 emissions increases post-harvest losses while the sign of Policy and institutions for Environmental sustainability is negative, meaning that Policy and institutions for Environmental sustainability reduce post-harvest losses.

Financial inclusion measured by the individual having a bank account (% of the total population) was sourced from the world development indicators. The use of this variable is supported by the studies conducted by Arshad (2022) and Akpa et al. (2023). The expected sign is negative, meaning that the financial inclusion decreases post-harvest losses. Financial development is measured as the domestic credit to private sector (% of GDP) and are sourced from the world development indicators. The variable choice is provided by Akisik and Gal (2022) and Villanthenkodath et al. (2023) and the expected sign is negative, meaning that financial development reduces post-harvest losses.

The mobile cellular telephone data are taken from World Development Indicators (WDI) and the variable expected sign is negative, meaning that the rise of mobile cellular telephones decreases post-harvest losses. The variable use draws insight from the study by Akpa (2023) and Akpa et al. (2023). Access to electricity is sourced from world development indicators and is measured by the percentage of the population with access to electricity provides by Candelise et al. (2021) and Akpa (2023) and the expected sign is negative. Storage provided by Akpa et al. (2023) and Debebe (2022) and the expected sign is negative. *Table 1* summarizes all the variables used in the estimation as well as their measurement and expected sign.

Table 1. *Variables and Measurement*

Identifier	Variable Name	Measurement	Sources
PHL	Post-harvest losses	$\%PHL = \frac{Losses}{Supply} = \frac{Losses}{Pr\,o\,duction + import + \Delta Stock}$	FAO
FI	Financial inclusion	individual having a bank account (% of total population)	WDI
STORE	Storage	Time required to build a warehouse (days)	Doing Business
ELEC	Infrastructure	measured by the percentage of population with access to electricity (% of total population	WDI
CPIAESR	Policy and institutions for Environmental sustainability	Scale of 0 – 6 (the higher the better)	CPIA
$C0_2$	Carbon footprints	Total greenhouse gas emission (CO_2 kt)	WDI
FD	Financial depth	Domestic credit to private sector (% of GDP)	WDI

Source: Authors' Compilation. Note: CPIA means country policy and institutional assessment

Results and Discussion

Summary Statistics of Variables and Correlation Analysis

Table 2 reports the descriptive statistics of the estimation variables, while *Table 3* presents the result for correlation analysis. The result for the summary statistics shows

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

that, in Africa post-harvest losses is on average estimated at 0,080 with a standard deviation of 0.043. African countries emit an average of 0.293 kiloton of CO_2 into their environment while the policy and institution for environmental sustainability average is about 3.252. The private sector received on average 17.484% of domestic credit. About 29.280% of the African population financially included. In some African countries, on average 61.743% of population have access to ICT through subscription to mobile cellular telephone while only 33.282% of African inhabitants have access to electricity. On average, it takes 235 days to build a warehouse, about 8 months.

Table 2. *Summary of Descriptive Statistics*

	PHL	CPIAESR	CO_2	FD	ELEC	SRORE	ICT	FI
Mean	0.080	3.252	0.293	17.484	33.282	234.534	61.743	29.280
Maximum	0.209	4.000	0.686	40.163	67.147	625.000	138.805	73.321
Minimum	0.017	2.500	0.052	2.335	4.700	88.000	3.414	0.861
Std. Dev.	0.043	0.504	0.174	7.620	18.184	132.369	33.839	18.989
Skewness	0.684	-0.272	0.601	0.548	0.336	1.569	0.211	0.595
Kurtosis	3.053	1.932	2.134	3.076	1.791	5.105	2.171	2.514
Jarque-Bera	8.058	6.164	9.419	5.188	8.212	61.300	3.714	7.090
Probability	0.017	0.045	0.009	0.074	0.016	0.000	0.156	0.028
Observations	103	103	103	103	103	103	103	103

Source: Authors' Computation

Table 3. *Correlation Results*

	PHL	CPIAESR	CO_2	FD	ELEC	STORE	ICT	FI
PHL	1.000							
CPIAESR	0.068	1.000						
CO_2	0.001	0.149	1.000					
FD	-0.130	0.346	0.394	1.000				
ELEC	-0.056	0.000	0.742	0.476	1.000			
STORE	0.203	-0.386	0.129	-0.158	0.488	1.000		
ICT	-0.133	0.302	0.442	0.520	0.563	-0.124	1.000	
FI	0.176	0.366	0.620	0.713	0.422	-0.167	0.397	1.000

Note: PHL means post-harvest losses, CPIAESR stand for Policy and institutions for Environmental sustainability, CO_2 means carbon emissions, FI means financial Inclusion, ELEC means electricity, STORE means Storage (time required to build a warehouse (days), ICT means Infrastructure measured by the percentage of population with access to electricity (% of total population). Source: Authors' Computation

The results of the correlation analysis are presented in *Table 2*. In fact, the purpose of correlation analysis is to avoid multicollinearity in model estimation. In the study, the correlation analysis was carried out to identify variables with a high correlation value, which was considered as a method for multicollinearity. Based on the results reported in *Table 3*, most variables have moderate correlation values (less than or equal to 0.5), except for CO_2 emission and access to electricity (0.742), CO_2 emission and financial inclusion (0.620), financial development and ICT (0.520), and finally access to electricity and ICT (0.563). As the CO_2 emission and environmental sustainability policies and institutions variables were weakly correlated with and among the other variables, they were included in the models simultaneously.

APPLIED ECOLOGY AND ENVIRONMENTAL RESEARCH 22(5):4913-4930.
http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

Cross-sectional Dependence and Panel Unit Root

Before determining the unit root properties of our data, the existence of cross-sectional dependence was established. The results of cross-sectional dependence and panel unit root are reported in *Table 4*. Based on previous works (Wang et al., 2021), Breusch-Pagan LM (Halugnga et al., 2017) and Pesaran (2004) CD tests were conducted in this paper to obtain reliable results. The null hypothesis of both tests is that there is no dependence among the variables. The results of the two tests show that our quantitative variables exhibit significant cross-country dependence. This implies that any shock in one African country may have spillover effects in other African countries.

Table 4. *Results of Cross-sectional Dependence Results*

Cross-sectional dependence test	**Pesaran (2004) CD test**		**Breusch-Pagan LM (1980) test**	
Variables	**CD-test**	**P-value**	**Statistic**	**P-value**
Post-harvest losses	22.369***	(0.000)	522.557***	(0.000)
Policy and institution for environmental sustainability	17.018***	(0.000)	387.337***	(0.000)
CO_2 emission	24.597***	(0.000)	768.897***	(0.000)
Financial development	27.331***	(0.000)	751.879***	(0.000)
Access to electricity	29.578***	(0.000)	876.207***	(0.000)
Storage	22.853***	(0.000)	549.546***	(0.000)
Mobile cellular subscription	22.787***	(0.000)	545.452***	(0.000)
Financial inclusion	27.597***	(0.000)	762.910***	(0.000)

Source: Authors' Computation. Note: *** means 1% level of significance. P-values are in parenthesis

Also, to check for panel unit root presence or not in the estimation variables, we refer to the CIPS and CDAF tests (*Table 5*). All series are assumed to be non-stationary in the null hypothesis of CADF. All variables in the CADF unit root test are stationary at first difference. Regarding CIPS, when the test statistics are greater than the critical values, we reject the null hypothesis and conclude that the panel series possess stationary properties. As can be seen, the results obtained for the CIPS (*Table 5*) indicate that the null hypothesis of non-stationarity can be rejected at levels of 1% significance at first difference. This implies that the variables used in this paper are integrated from 1(1).

Table 5. *Panel Unit Root Results*

Variables	**CIPS**		**CDAF**		**Decision**
	Level	**Difference**	**Level**	**Difference**	
Post-harvest losses	-2.766	-4.649***	0.760	-3.607***	I(1)
Policy and institution for environmental sustainability	-1.539	-6.725***	1.367	-4.787***	I(1)
CO_2 emission	-1.923	-4.345***	0.201	-2.670***	I(1)
Financial development	-1.076	-6.775***	0.503	-3.844***	I(1)
Access to electricity	-1.475	-3.532***	1.955	-3.588***	I(1)
Storage	-1.923	-6.117***	-0.450	-4.181***	I(1)
Mobile cellular subscription	-1.554	-3.900***	-0.361	-1.826**	I(1)
Financial inclusion	-2.596	-8.810***	0.621	-4.157***	I(1)

Source: Authors' Computation. Note: *** and ** means 1% and 5% levels of significance respectively

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

Panel FMOLS, DOLS and Granger Causality Result

The paper used the panel FMOLS approach, which is robust to the heterogeneity and endogeneity presence, to estimate the long-run parameters between environmental sustainability, carbon emissions and post-harvest losses in Africa. It should be noted that to ensure that the results are free from heteroscedasticity and endogeneity, the panel FMOLS approach uses heteroscedastic standard errors that fit a model with heteroscedastic residuals. Also, panel DOLS approach is used to check the panel FMOLS findings robustness. The estimate results are reported in *Table 6*.

Table 6. *Panel FMOLS and Panel DOLS Results*

	Dependent variable: Ln PHL			
Method	Panel FMOLS		Panel DOLS	
Policy and institution for environmental sustainability	-0.610^{***}	(0.121)	-0.632^{***}	(0.137)
CO_2 emission	0.430^{***}	(0.157)	0.616^{**}	(0.275)
Financial development	-0.397^{***}	(0.067)	-0.608^{***}	(0.175)
Access to electricity	-0.133^{*}	(0.067)	-0.621^{***}	(0.176)
Storage	0.258^{***}	(0.077)	0.120^{*}	(0.141)
Mobile cellular subscription	-0.228^{**}	(0.051)	-0.359^{**}	(0.165)
Financial inclusion	0.215^{***}	(0.086)	0.524^{***}	(0.100)
R-squared	0.901		0.921	

Source: Authors' Computation. Note: *, **, and *** means 10%, 5% and 1% levels of significance respectively. Values in parenthesis are standard errors

The effects of the interest variables (policy and institution for environmental sustainability and carbon emission) have a mixed effect on post-harvest losses. Indeed, the coefficient of policy and institution for environmental sustainability is negative and significantly correlated with post-harvest losses for both the panels FMOLS and DOLS models at 1% level. On the other hand, a rise of 1% in policy and institution for environmental sustainability leads to a decrease of 0.610% for the panel FMOLS model and 0.632% in panel DOLS model. The coefficient of CO_2 emission is positive and significantly correlated with post-harvest losses for both the panels FMOLS (at 1% level) and DOLS (at 5% level) models. On the other hand, a rise of 1% in CO_2 emission leads to an increase of 0.430% for the panel FMOLS model and 0.616% in panel DOLS model. So, reinforce actions to protect environment by lowering the carbon emission is very suitable to reduce post-harvest losses for African countries.

The coefficient of financial development is negative and significantly correlated with post-harvest losses for both the panels FMOLS and DOLS models at 1% level. On the other hand, a rise of 1% in financial development leads to a decrease of 0.397% for the panel FMOLS model and 0.608% in panel DOLS model. This result is consistent with the outcome of Arshad (2022) who found that an increase in financial development boosts dietary energy supply, indicating a decrease in post-harvest losses. The coefficient of access to electricity is negative and significantly correlated with post-harvest losses for both the panels FMOLS (at 10% level) and DOLS (at 1% level) models. On the other hand, a rise of 1% in access to electricity leads to a decrease of 0.133% for the panel FMOLS model and 0.621% in panel DOLS model. The outcome is supported by

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

Candelise et al. (2021) who found in a panel of 54 developing countries over the period 2000–2014 that access to electricity reduces the percentage of individuals suffering from under-nourishment by 0.12 points, indicating a decrease in post-harvest losses.

The coefficient of storage is positive and significantly correlated with post-harvest losses for both the panels FMOLS (at 1% level) and DOLS (at 10% level) models. On the other hand, a rise of 1% in storage leads to an increase of 0.258% for the panel FMOLS model and 0.120% in panel DOLS model. This result is the same as the outcome of Akpa et al. (2023) in WAEMU countries. The authors justified their outcome by insufficient/lack of warehouses to store agricultural products after harvest. Also, in the sample of these studies, about 8 months are required to build a warehouse. The coefficient of mobile cellular subscription is negative and significantly correlated with post-harvest losses for both the panels FMOLS and DOLS models at 5% level.

Furthermore, the result shows that a rise of 1% in mobile cellular subscription leads to a decrease of 0.228% for the panel FMOLS model and 0.359% in panel DOLS model. This result is consistent with the outcome of Kc et al. (2016), Ejemeyovwi et al. (2021) and Akpa et al. (2023). The coefficient of financial inclusion is positive and significantly correlated with post-harvest losses for both the panels FMOLS and DOLS models at 1% level. On the other hand, a rise of 1% in financial inclusion leads to an increase of 0.215% for the panel FMOLS model and 0.524% in panel DOLS model. This result is on contrary with the outcome of Akpa et al. (2023) who found that an increase in financial inclusion decreases post-harvest losses. The plausible explanation of this finding is that the rate of financial inclusion in African countries is low. In fact, among the countries in the sample, only 17.484% of their population have bank account. So, raise the rate of financial inclusion is crucial to decrease post-harvest losses.

It can be assumed that storage means extra costs for producers or distributors due to transportation, building infrastructure, material handling, etc. However, the prices can be much higher out of the harvest season because of the reduction of the supply and increase in demand. Storage does come with additional costs for producers and distributors, including expenses related to transportation, building infrastructure, material handling, and maintenance. These costs can add up and impact the overall profitability of agricultural operations. However, the benefits of storage in terms of reducing post-harvest losses and taking advantage of market fluctuations can outweigh these initial costs. During the harvest season, when there is an abundance of fresh produce in the market, prices tend to be lower due to the high supply and competition among producers. At this time, storing excess produce allows farmers and distributors to avoid selling their crops at low prices and instead wait for market conditions to improve. By storing their crops until demand increases or supply decreases, producers can sell their products at higher prices, maximizing their profits.

Out of the harvest season, when fresh produce is less readily available, prices typically rise due to the reduced supply and increased demand. This is where stored crops become particularly valuable, as they can help meet consumer demand when fresh produce is scarce. Producers and distributors who have invested in storage facilities can capitalize on this price increase by releasing their stored crops into the market at a time when prices are more favourable. In this way, storage acts as a strategic tool for producers and distributors to manage market fluctuations and optimize their returns on investment. While there are costs associated with storage, the potential for higher prices during periods of low supply can offset these expenses and lead to increased profitability. By

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

carefully planning and managing their storage practices, agricultural stakeholders can leverage market dynamics to their advantage and enhance their economic sustainability.

The findings of the panel Granger causality test are reported in *Table 7*. Using the Dumitrescu and Hurlin (D-H) panel causality test, this paper further investigates the direction of causality. The D-H causality test deals with cross-sectional dependence in panel data series, as proposed by Dumitrescu and Hurlin (2012). It relies on the individual Granger-causality Wald statistic, averaged across cross-sections. The outcomes from *Table 7* show that LNCPIAESR cause the post-harvest losses. However, the causality between PHL and each of these CO_2, NFD, ELC, STORE, ICT, FI are bi-directional.

Table 7. *Panel Granger Causality Test*

Causality direction	F-Statistic
CPIAESR → PHL	52.190***
PHL → CPIAESR	0.151
CO_2 → PHL	3.316**
PHL → CO_2	48.859***
FD → PHL	31.950***
PHL → FD	14.393***
ELEC → PHL	9.2473***
PHL → ELEC	25.607***
STORE → PHL	9.875***
PHL → STORE	21.523***
ICT → PHL	5.304***
PHL → ICT	34.106***
FI → PHL	10.969***
PHL → FI	11.795***

Source: Authors' Computation. Note: *, **, and *** means significant at 10%, 5% and 1% levels respectively. PHL means post-harvest losses, CPIAESR stand for Policy and institutions for Environmental sustainability, CO_2 means carbon emissions, FI means financial Inclusion, ELEC means electricity, STORE means Storage time required to build a warehouse (days), ICT means Infrastructure measured by the percentage of population with access to electricity (% of total population)

Conclusion and Recommendations

This study examined the effects of environmental sustainability and carbon emissions on post-harvest losses in West Africa. Environmental sustainability is concerned with how environmental resources will be protected and maintained for future generations. Human activities like industrialization, over-exploitation of natural resources and pollution have led the environment to be used exhaustively. Post-harvest losses affect nutritional health and have negative financial impacts on both consumers and farmers. Post-harvest losses also deprive farmers of the opportunity to grow and strengthen their income generation activities. Due to inadequate storage capacities and low-value chain development, small-scale farmers lose up to 40 percent of their seasonal harvest. The study posits that environmental sustainability and carbon emissions have effects on post-harvest losses in West Africa.

The study, therefore, recommends the following; first, the governments of the West African countries should provide financial aids to the farmers in order to safeguard the farmers from experiencing post-harvest losses. Second, the farmers should provide

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

storage facilities, so that they can store their agricultural produce in order to reduce post-harvest losses. Third, in order for the countries to be environmentally sustainable, the governments need to prevent environmental pollution, over-exploitation of resources and environmental degradation, these would help reduce post-harvest losses of the agricultural produce of the farmers.

Some of the potential factors influencing the success of agricultural goods storage include temperature and humidity control, ventilation, pest control, suitable storage containers, proper handling practices, monitoring, and management. Therefore, maintaining optimal conditions such as temperature and humidity levels, adequate airflow, and effective pest control is crucial to prevent spoilage and losses. Regular monitoring for signs of spoilage, implementing modern infrastructure and technology, and following best practices in handling and loading can improve the quality and shelf life of stored crops. By considering these factors and implementing appropriate strategies, farmers can reduce post-harvest losses and ensure a sustainable supply of high-quality agricultural products.

Furthermore, various technologies are used to protect harvested products during storage can be adopted. These include fumigation which involves using chemical agents to kill pests, while Controlled Atmosphere Storage and Modified Atmosphere Packaging modify the storage atmosphere to inhibit pest growth can also be applied. Similarly, insect-proof storage structures and biocontrol agents can prevent infestations in stored products can be used. On other hand, UV light treatment disinfects surfaces, and temperature/humidity control can prevent mold growth. Electronic monitoring systems will help tracks environmental conditions. Implementing these technologies and best practices can safeguard agricultural products against pests, diseases, and deterioration, ensuring quality and safety for consumers

Funding. This study received no external funding.

Competing Interests. Authors declare no competing interest.

REFERENCES

[1] Abbas, A. M., Abbas, I. I., Agada, I. G. (2018): Reducing post-harvest losses in Nigeria's agricultural sector: Pathway to sustainable agriculture. – International Journal of Sciences 5(2): 16-21.

[2] Adediran, O., Osabuohien, E., Silberberger, M., Osabohien, R., Adebayo, W. G. (2024): Agricultural value chain and households' livelihood in Africa: The case of Nigeria. – Heliyon 10(7): e28655.

[3] Aina, O. E., Mugivhisa, L. L., Olowoyo, J. O., Obi, C. L. (2023): Nutritional Quality Assessment and Safety Evaluation of Food Crops. – Applied Ecology & Environmental Research 21(6):5415-5432. http://dx.doi.org/10.15666/aeer/2106_54155432.

[4] Akisik, O., Gal, G. (2022): IFRS, financial development and income inequality: An empirical study using mediation analysis. – Economic Systems 47(2): 101069. https://doi.org/10.1016/j.ecosys.2022.101069.

[5] Akpa, A. F. (2023): Effect of Natural Resources Rents on Income Inequality in Sub-Saharan Africa: Exploring the Direct and Indirect Transmission Mechanisms. – International Journal of Development Issues 22(2): 167-181. https://doi.org/10.1108/IJDI-11-2022-0244.

[6] Akpa, A. F., Osabohien, R., Ashraf, J., Al-Faryan, M. A. S. (2023): Financial inclusion and post-harvest losses in West African economic and Monetary Union. – Agricultural Finance Review 83(2): 320-332.

[7] Amaefule, C., Shoaga, A., Ebelebe, L. O., Adeola, A. S. (2023): Carbon emissions, climate change, and Nigeria's agricultural productivity. – European Journal of Sustainable Development Research 7(1): em0206.

[8] Amri, F., Zaied, Y. B., Lahouel, B. B. (2019): ICT, total factor productivity, and carbon dioxide emissions in Tunisia. – Technological Forecasting and Social Change 146: 212-217.

[9] Anderson, J., Fergusson, M., Valsecchi, C. (2008): An overview of Global Greenhouse Gas Emissions and emissions reduction scenarios for the future. – Retrieved from: www. ieep. eu/assets/428/overview_gge. pdf (Accessed at: 13/12/12). Brussels: IEEP.

[10] Ansuategi, A., Escapa, M. (2002): Economic growth and greenhouse gas emissions. – Ecological Economics 40(1): 23-37.

[11] Arshad, A. (2022): Impact of financial inclusion on food security: evidence from developing countries. – International Journal of Social Economics 49(3): 336-355. doi: 10.1108/IJSE-08-2021-0462.

[12] Ay-Karakuş, B., Talo, M., Hallaç, İ. R., Aydin, G. (2018): Evaluating deep learning models for sentiment classification. – Concurrency and Computation: Practice and Experience 30(21): e4783.

[13] Bendinelli, W. E., Su, C. T., Pera, T. G., Caixeta Filho, J. V. (2020): What are the main factors that determine post-harvest losses of grains? – Sustainable Production and Consumption 21: 228-238. doi: 10.1016/j.spc.2019.09.002.

[14] Breitung, J. (2001): The local power of some unit root tests for panel data. – In: Nonstationary panels, panel cointegration, and dynamic panel. Emerald Group Publishing Limited, pp. 161-177.

[15] Candelise, C., Saccone, D., Vallino, E. (2021): An empirical assessment of the effects of electricity access on food security. – World Development 141: 105390.

[16] Debebe, S. (2022): Post-harvest losses of crops and its determinants in Ethiopia: Tobit model analysis. – Agriculture and Food Security 11(1): 1-8. doi: 10.1186/s40066-022-00357-6.

[17] Degbedji, D. F., Akpa, A. F., Chabossou, A. F., Osabohien, R. (2024): Institutional quality and green economic growth in West African economic and monetary union. – Innovation and Green Development 3(1): 100108.

[18] Ejemeyovwi, J. O., Osabohien, R., Adeleye, B. N., De Alwis, T. (2021): Household ICT utilization and food security nexus in Nigeria. – International Journal of Food Science. doi: 10.1155/2021/5551363.

[19] Elik, A., Yanik, D. K., Istanbullu, Y., Guzelsoy, N. A., Yavuz, A., Gogus, F. (2019): Strategies to reduce post-harvest losses for fruits and vegetables. – Strategies 5(3): 29-39.

[20] Eregha, P. B., Mesagan, E. P. (2019): Political economy of oil resources management in Nigeria: Lessons from other countries. – No. WP/19/065, AGDI Working Paper.

[21] FAO. (2019): The State of Food and Agriculture 2019: Moving forward on food loss and waste reduction. – Food and Agriculture Organization of the United Nations.

[22] Fern, A., Almod, M. (2019): Is sustainable economic development possible thanks to the deployment of ICT? – Sustainability 11: 6307. doi:10.3390/su11226307.

[23] Fufa, N., Zeleke, T., Melese, D., Daba, T. (2021): Assessing storage insect pests and post-harvest loss of maize in major producing areas of Ethiopia. – International Journal of Agricultural Science and Food Technology 7(1): 193-198.

[24] Gebreegziabher, Z., van Kooten, G. C. (2019): Commodity storage, post-harvest losses, and food security: panel data evidence from Ethiopia. – Journal of Agricultural & Food Industrial Organization 18(1): 20190058.

[25] Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., Toulmin, C. (2010): Food security: The challenge of feeding 9 billion people. – Science 327(5967): 812-818.
[26] Granger, C. (1988): Some recent development in a concept of causality. – J. Econ. 39: 199-211.
[27] Gustavsson, J., Cederberg, C., Sonesson, U., Emanuelsson, A. (2013): The methodology of the FAO study: Global Food Losses and Food Waste - extent, causes and prevention. – SIK Report No. 857, SIK Report (857), p. 70, available at: https://www.diva-portal.org/smash/get/diva2:944159/FULLTEXT01.pdf.
[28] Halunga, A. G., Orme, C. D., Yamagata, T. (2017): A heteroskedasticity robust Breusch–Pagan test for Contemporaneous correlation in dynamic panel data models. – Journal of Econometrics 198(2): 209-230.
[29] Hamit-Haggar, M. (2012): Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. – Energy Econ. 34: 358-364.
[30] Idowu, S. A., Awodele, O. (2018): Information and communication technology (ICT) revolution: its environmental impact and sustainable development. – International Journal on Computer Science and Engineering 2(1): 30-35.
[31] Jiang, X. T., Li, R. (2017): Decoupling and decomposition analysis of carbon emissions from electric output in the United States. – Sustainability 9(6): 1-13.
[32] Kamda-Silapeux, A., Ponka, R., Frazzoli, C., Fokou, E. (2021): Waste of fresh fruits in Yaoundé, Cameroon: Challenges for retailers and impacts on consumer health. – Agriculture 11(2): 89.
[33] Kao, C., Chiang, M. H. (2000): On the estimation and inference of a cointegrated regression in panel data. – Adv Econom 15: 179e222. https://doi.org/10.1016/S0731-9053(00)15007-8.
[34] Kasso, M., Bekele, A. (2018): Post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia. – Journal of the Saudi Society of Agricultural Sciences 17(1): 88-96.
[35] Kc, K. B., Haque, I., Legwegoh, A. F., Fraser, E. D. G. (2016): Strategies to reduce food loss in the global south. – Sustainability (Switzerland) 8(7): 1-13. doi: 10.3390/su8070595.
[36] Kemeze, F. H. (2018): The impact of agricultural insurance on the demand for supplemental irrigation: A randomized controlled trial experimental evidence in Northern Ghana. – In: Building a Resilient and Sustainable Agriculture in Sub-Saharan Africa, pp. 181-206.
[37] Khan, M. W. A., Panigrahi, S. K., Almuniri, K. S. N., Soomro, M. I., Mirjat, N. H., Alqaydi, E. S. (2019): Investigating the Dynamic Impact of CO_2 Emissions and Economic Growth on Renewable Energy Production: Evidence from FMOLS and DOLS Tests. – Processes 7: 496. doi:10.3390/pr7080496.
[38] Lechenet, M., Lechenet, M., Dessaint, F., Py, G., Makowski, D., Munier-Jolain, N. (2017): Reducing pesticide use while preserving crop productivity and profitability on arable farms. – Nature Plants 3(3): 1-6.
[39] Li, N., Agene, D., Gu, L., Osabohien, R., Jaaffar, A. H. (2024): Promoting clean energy adoption for enhanced food security in Africa. – Frontiers in Sustainable Food Systems 8: 1269160.
[40] Matthew, O. A., Osabohien, R., Fagbeminiyi, F., Fasina, A. (2018): Greenhouse gas emissions and health outcomes in Nigeria: Empirical insight from auto-regressive distribution lag technique. – International Journal of Energy Economics and Policy 8(3): 43-50.
[41] Matthew, O. A., Owolabi, O. A., Osabohien, R., Urhie, E., Ogunbiyi, T., Olawande, T. I., Edafe, O. D., Daramola, P. J. (2020): Carbon emissions, agricultural output and life expectancy in West Africa. – International Journal of Energy Economics and Policy 10(3): 489-496. DOI: https://doi.org/10.32479/ijeep.9177.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

[42] Matthew, O. A., Osabohien, R., Omosehin, O. O., Jawaid, N., Aderemi, T., Olanrewaju, O., Evans-Osabuohien, P. N. (2023): Information and Communication Technology deployment and agricultural value chain nexus in Nigeria. – Heliyon 9(9): e19043.
[43] Merlin, M. L., Chen, Y. (2021): Analysis of the factors affecting electricity consumption in DR Congo using fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS) and canonical cointegrating regression (CCR) estimation approach. – Energy 232: 121025. https://doi.org/10.1016/j.energy.2021.121025.
[44] Minten, B., Tamru, S., Reardon, T. (2021): Post-harvest losses in rural-urban value chains: Evidence from Ethiopia. – Food Policy 98: 101860.
[45] Mohamed, E. F., Abdullah, A., Jaaffar, A. H., Osabohien, R. (2024): Reinvestigating the EKC hypothesis: Does renewable energy in power generation reduce carbon emissions and ecological footprint? – Energy Strategy Reviews 53: 101387.
[46] Osabohien, R., Karakara, A. A. W., Ashraf, J., Al-Faryan, M. A. S. (2023): Green environment-social protection interaction and food security in Africa. – Environmental Management 71(4): 835-846.
[47] Osabohien, R. (2024): Soil technology and post-harvest losses in Nigeria. – Journal of Agribusiness in Developing and Emerging Economies, (ahead-of-print).
[48] Osabohien, R., Matthew, O. (2024): Nutrition and sustainable development goal 5: gender equality. – Frontiers in Nutrition 11: 1384066. https://doi.org/10.1108/JADEE-08-2022-0181.
[49] Osabohien, R. A., Jaaffar, A. H., Ibrahim, J., Usman, O., Igharo, A. E., Oyekanmi, A. A. (2024): Socioeconomic shocks, social protection and household food security amidst COVID-19 pandemic in Africa’s largest economy. – Plos One 19(1): e0293563.
[50] Özcan, B. (2013): The nexus between carbon emissions, energy consumption and economic growth in Middle East countries: A panel data analysis. – Energy Policy 62: 1138-1147.
[51] Pedroni, P. (1996): Fully Modified OLS for Heterogeneous Cointegrated Panels and the Case of Purchasing Power Parity. – Department of Economics, Indiana University: Bloomington, IN, USA.
[52] Pedroni, P. (2001): Fully modified OLS for heterogeneous cointegrated panels. – In Nonstationary Panels, Panel Cointegration, and Dynamic Panels; Emerald Group Publishing Limited: Bingley, UK, pp. 93-130.
[53] Pesaran, M. H., Schuermann, T., Weiner, S. M. (2004): Modeling regional interdependencies using a global error-correcting macroeconometric model. – Journal of Business & Economic Statistics 22(2): 129-162.
[54] Phillips, P. C. B., Hansen, B. E. (1990): Statistical Inference in Instrumental Variables Regression with I(1) Processes. – Rev. Econ. Stud. 57: 99.
[55] Raut, R. D., Gardas, B. B., Kharat, M., Narkhede, B. (2018): Modeling the drivers of post-harvest losses-MCDM Approach. – Computers and Electronics in Agriculture 154: 426-433.
[56] Ricker-Gilbert, J., Omotilewa, O., Kadjo, D. (2022): The economics of post-harvest loss and loss-preventing technologies in developing countries. – Annual Review of Resource Economics 14: 243-265.
[57] Saint-Akadiri, S., Bekun, F. V., Sarkodie, S. A. (2019): Contemporaneous interaction between energy consumption, economic growth and environmental sustainability in South Africa: what drives what? – Science of the Total Environment 686: 468-475.
[58] Sharma, S. S. (2011): Determinants of carbon dioxide emissions: Empirical evidence from 69 countries. – Applied Energy 88: 376-382.
[59] Stock, J. H., Watson, M. W. (1993): A simple estimator of cointegrating vectors in higher order integrated systems. – Econometrica 61(4): 783e820. https://doi.org/10.2307/2951763.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930

[60] Swai, J., Mbega, E. R., Mushongi, A., Ndakidemi, P. A. (2019): Post-harvest losses in maize store-time and marketing model perspectives in sub-Saharan Africa. – Journal of Stored Products and Postharvest Research 10(1): 1-12.
[61] Villanthenkodath, M. A., Pal, S., Mahalik, M. K. (2023): Income Inequality in Globalization Context: Evidence from Global Data. – Journal of the Knowledge Economy 15: 3872-3902. https://doi.org/10.1007/s13132-023-01342-5.
[62] Wang, J., Dong, X., Dong, K. (2021): How renewable energy reduces CO_2 emissions? Decoupling and decomposition analysis for 25 countries along the Belt and Road. – Applied Economics 53(40): 4597-4613.
[63] World Bank (2011): Missing Food: The Case of Postharvest Grain Losses in Sub-Saharan Africa. – Economic And Sector Work 60371 Washington, D.C.: World Bank http://go.worldbank.org/0J2CTQTYP0.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2205_49134930