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Green Environment-Social Protection Interaction and Food Security in Africa

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Abstract

Expanding food production to commensurate with population growth has often come at a cost resulting from environmental problems. Industries generate pollutants that destroy the environment and negatively affect the level of food security. These trends threaten the sustainability of food systems and undermine the capacity to meet food security needs. Against this backdrop, this study examines how the green environment influences food security in Africa. To further articulate the novelty and contributions of the research to the extant literature, the study also examines the interaction effect of the green environment and social protection on food security. The study engaged panel data consisting of 37 African countries listed in the International Development Association (IDA) of the World Bank. The data was sourced from Food and Agricultural Organisation (FAO), Country Policy and Institutional Assessment (CPIA) and the World Development Indicators (WDI) for the period 2005 to 2019 and applied the system Generalised Method of Moments (SGMM). The result shows that a green environment and social protection are statistically significant and positively determine the level of food security in Africa. In addition, the result shows that a green environment and social protection interaction positively and significantly influence food security. The implication is that a 1% increase in the drive for a green environment may improve the level of food security by 0.8%. Also, increases in the level of social protection intervention may increase food security by 1.2%. The interaction between social protection and food security can increase food security by 0.96%. In summary, it is found that African countries under study have moderate social protection coverage and policy for environmental management and sustainability required to drive food security. The discussions of the findings and policy implications of the study are underscored in the paper.

Keywords Environmental management · Food security · Green growth · Social protection

JEL Codes F64 · Q18 · Q56

Introduction

Expanding food production to commensurate with population growth has often come at a cost resulting from environmental problems (Adeleye et al. 2021). Industries generate pollutants that destroy the environment, negatively affecting the level of food security. These trends threaten the sustainability of food systems and undermine the capacity to meet food security needs. This study argues that by reducing environmental issues and with social protection intervention, the level of security will improve. This is crucial because tackling problems relating to food insecurity in Africa is important to the sustainability of food security.

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Despite the progress made in ameliorating poverty, the proportion of severely food-insecure households remains a problem of global concern (FAO, 2022). FAO (2022) estimated that the proportion of undernourishment keeps showing upward trends across the globe. It implies that the prevalence of severe food insecurity rose to 23.4% in 2021 in Africa (FAO, 2022). At 23.4%, the prevalence of severe food insecurity is higher in Africa than in other developing regions, and it doubles the world average of 11.7% (FAO, 2022).

Mkonda and He (2018) found that despite the efforts of different agricultural stakeholders, Africa is yet to attain food security. This condition negatively affects the welfare and livelihoods of a large proportion of households. To prevent this, issues related to shocks faced by farming households and the environment should be mitigated. This study argues that environmental problems and lack of sufficient social protection intervention to mitigate the impact of shocks faced by farmers are some of the significant factors that hamper the drive for food security in Africa.

This study defines the green environment as 'the conservation of the environment that aims to enhance the well-being of the total environment'. The concept of a green environment calls for a low-carbon environment that seeks to achieve low energy consumption and efficiency, and less pollution and emissions (Jin, 2012). This is crucial for agriculture sustainability towards achieving food security. The rationale for this is that environmental problems negatively affect the efficiency of farmers (Gwambene et al. 2022). Therefore, in many countries, green growth strategies and carbon emissions reduction policies (Meybeck et al. 2012) that are essential to achieve food security sustainability should be implemented.

Several countries in Africa have started to pursue the principle of green growth. Some joint declarations made by African leaders on green growth recognised the need to take advantage of the opportunities that green growth presents to economic growth and development. One example is the Bamako Declaration on the Environment for Sustainable Development which was adopted by African ministers of the environment (United Nations Environment Programme UNEP, 2010). Another example is the Seventh African Development Forum held in Ethiopia in October 2010 which admonished African governments to "*prioritize and promote a green economy as a vehicle for addressing the challenges of climate change impacts on ecosystem sustainability and harnessing the opportunities provided by its vast and diverse ecosystems and natural resources*" (UNECA, 2010). This strategy aims to protect the total environment and achieve food security.

Food security has been defined by various international organisations. For example, the FAO (1996) defined food security as a situation "*when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life*". Also, the United Nations Development Programme (UNDP, 1994) defines food security as "*a situation that exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life*". With this definition, food security includes four dimensions (FAO, 2008), notably- availability, accessibility, utilisation, and stability.

Though all four dimensions of food security are important, this study conceptualised food security by building its argument on the availability component. The study proxied food availability by per capita food production. It argues that to a large extent, food availability depends on the level of production. Availability implies that a sufficient quantity of food should be available, and every member of the household should have access to food (FAO, 2022). According to the United Nations (2015), this dimension implies the availability of food to sustain a healthy life by having enough nutrients.

Studies have been conducted concerning green environment principles and food security, and most of these studies link the green environment principles to other important sectors of the environment. Also, empirical studies have mainly focused on the green economy, agriculture performance and poverty (Adeleke & Josue, 2019; Adeleye et al. 2021; Gwambene et al. 2022); inequality and food security (Mkonda & He, 2018; Pybus et al. 2021), green economy, employment, welfare and livelihood (Jacob et al. 2015). These studies have neglected the interaction between the green environment and social protection to achieve food security in Africa. This study contributes to the extant literature by examining the impact of social protection and the green environment on food security. In addition, to further articulate the novelty and contributions of the study to the extant literature, it also examines the interaction effect of the green environment and social protection on food security, which is relatively sparse in the literature, to the best of the knowledge of the authors. This study is structured into five sections. Following this introduction is a review of the literature. The methodology is embedded in section three. Results are presented and discussed in section four, while the study concludes in section five.

Literature Review

Empirical and Thematic Review

Green environment and food security in the world

Some scholars opined that the food crisis is accustomed to population growth and human health. Some such scholars are Hopfenberg and Pimentel (2001), Lunn and Theobald, (2006) and Iseki (1994) who have argued that increased food demand is due to growth in world population and attempts to intensify production leads to more increases in population. Thus, studies on food security have been documented in the literature. However, the argument of how green agriculture drives food security is scanty and almost non-existent.

Barbier (2016) sought to answer the research question, is green growth relevant for poor economies? The study identified two broad structural features that need to be concentrated on achieving green growth. Barbier (2016) asserted that developing countries are resource-dependent where a large share of their export consists of primary products, making them highly reliant on commercial primary products. Also, many developing countries have a substantial share of their rural population located in less favoured agricultural areas and remote locations. The study concluded that for green growth to be a catalyst for economy-wide transformation and poverty alleviation, then it must be accompanied by policies aimed directly at overcoming these two structural features.

Again, Marsh et al. (2001) focused on the impact that food losses along the global food supply chains have on food security and concluded that food losses are consistent for the vast majority of traded agricultural commodities. These studies have legitimated the strand of literature devoted to exploring how food losses increase food insecurity in developing countries, the most dependent on trade and in need of innovations. Thus, a green economy that emphasizes food utilization would be a sin qua none to averting these food losses across the globe. Also, Eikenberry and Smith (2005) pointed out that food recovery and donation programmes may help reduce the amount of wasted food and thus contribute to improving the status of food insecurity in most developed countries. Thus, the food utilization aspect of food security is key to achieving food security.

Green environment, food and food security in Africa

Gwambene et al. (2022) pointed out that environmental factors such as climate, and carbon emissions undermine the effort of small-scale farmers in Ethiopia. International Food Policy Research Institute IFPRI (2011) studied to establish a link between agricultural productivity and the food crisis in Africa and noted that declining public investments in agriculture is one of the root causes of the food crisis. In addition, Adeleye et al. (2021) noted that environmental degradation has a negative effect on agricultural productivity in Nigeria. A thematic review of the literature shows mixed results. In one strand of the literature, scholars studied food security cum agriculture productivity and the impact of climate and environmental issues. For instance, Smith and Haddad (2000), Benson (2004) and Bouis and Hunt (1999) all summarized that food crises are mostly caused by declining agricultural and food production which is caused by bad climate conditions and environmental issues like droughts and floods.

Some studies on agricultural productivity in the realm of the green revolution are done qualitative and report on issues relating to the green environment. For instance, Jiren et al. (2020) focused on the interrelated challenges of food security and biodiversity conservation and using a participatory scenario planning exercise with 35 stakeholder organisations in a workshop in South-eastern Ethiopia they found that agro-ecological development pathways stand a good chance of generating synergies between food security and biodiversity conservation. The study further indicated that pathways prioritizing agriculture efficiency are more likely to degrade natural capital and cause social inequity.

Again, Musvoto et al. (2014) indicated that for agriculture to take its position in a green environment, it has to be productive, contribute to economic growth, and promote the environment and social and cultural systems. In another development, Kinda and Akol (2016) indicated that the implementation of the principles of the inclusive green environment (IGE)/inclusive green growth (IGG) could become an opportunity to improve food security in Africa through its four dimensions, which are food availability, food accessibility, stability of food access, and satisfactory utilisation. Thus, the green environment pursuit is intertwined with agriculture which subsequently affects food security.

Kinda (2021) contributes to the current debate on the effect of the green economy on development through an empirical investigation of the effect of the green economy on food security in 35 SSA countries from 2001–2015. Using the two-step GMM system estimator, the author showed the controversial effects of green economy indicators on food security (food availability and the proportion of undernourished people). The results provide evidence that biofuels contribute to increased food insecurity in SSA countries, whereas renewable energy reduces food security. Finally, carbon dioxide emission reduction has no effect. These results are robust to alternative robustness checks.

Resnick et al. (2012) studied three SSA countries as case studies on implementations of green growth in Malawi, Mozambique and South Africa and concluded that the implementation of green growth in those countries comes with trade-offs. The green growth strategies are essentially carbon emissions reduction policies and in the short term, the green growth agenda may be extremely costly because countries can deviate from their traditional development trajectories. The authors concluded that the poor may lose as a result of shifting to a green growth strategy. By increasing poverty, green growth strategies may reduce households' access to food in SSA countries.

Conceptual Framework

Drawing from the literature, the study conceptualised the issue of green environment-food security as outlined in Fig. 1. The study argues that agriculture practices affect biodiversity and biodiversity affects agriculture in agriculture in a complex way. This reciprocity of impact could be two-edged positive and negative depending on the farming system and the kind of biodiversity under consideration. Agriculture can positively affect biodiversity by preserving important aspects of the agroecological landscape. Also, agriculture can negatively impact biodiversity through expansion of the agricultural land base (for example, deforestation), via intensification (e.g. excessive input use leading to species loss). Thus, the green environment principles could help mediate the negative impact agriculture could have on biodiversity.

In Fig. 1, as nation's governments and their agencies make efforts to achieve growth and development through policies and programmes, they could achieve it by green environment principles. Such a drive for development would lead to food security. The tenets of a green environment (particularly green agriculture) could drive the achievement of food security. A green environment dwells on the sustainability of the environment and hence such would lead to a reduction in biodiversity loss which makes agriculture sustainable.

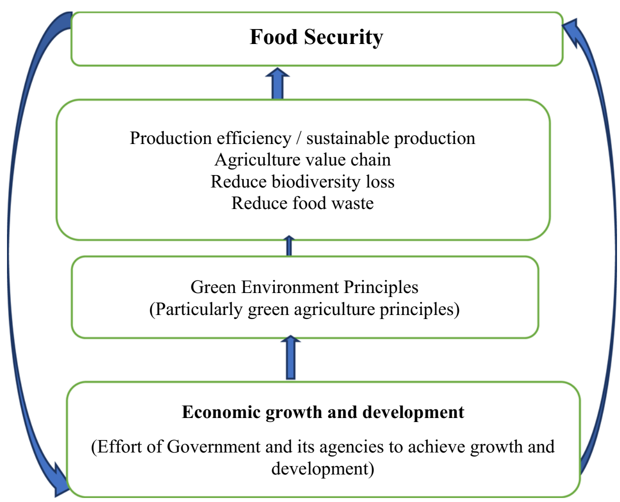


Fig. 1 Food security-green environment (green agriculture) interactions. Source: Authors' compilation

Green agriculture entails agriculture that is capable of maintaining its productivity (sustainable production) and usefulness to society indefinitely (Ikerd, 1993). Thus, promoting a green environment (green agriculture) that is from conventional farming to organic farming (OECD Organisation for Economic Co-operation and Development, 2011) could lead to the achievement of sustainable agriculture and subsequently, food security would be enhanced.

Still in Fig. 1, to achieve food security, food wastage should be minimised. The issue of food waste is a clear example of where the application of green agriculture principles can bring some benefits. Innovations that lead to a reduction in food waste are central to green agriculture. This reduction in food waste helps free up resources and ensure food for the future (food security). Estimates have it that about 30% of all food produced particularly in developed countries is discarded (Gooch et al. 2010, Lundqvist, 2009). Thus, in the figure, as green agriculture principles are implemented, it leads to a reduction in food wastage and subsequently food security is achieved. Similarly, green agriculture would make the agriculture value efficient and effective to reduce postharvest loss and food waste leading to enhance food security.

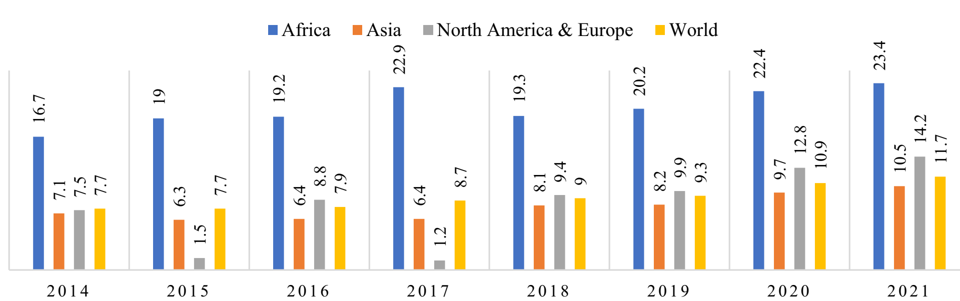
Efforts to achieve food security are backed by the state's growth and development policies and food security intends to drive development. In the Figure, growth and development drive food security and this intention drive development by making the country's food sufficient. Food sufficiency drives human welfare and development.

Stylised Facts

State of food security in the world

Figure 2 captures the state of food insecurity around the globe. Globally, the proportion of persons who are severely food insecure continues to rise from 7.7% in 2014 to 11.7% in 2021. The global prevalence of severe food insecurity

Fig. 2 Severe food insecurity around the world (% of the total population). Source: Authors based on FAO (2022) data



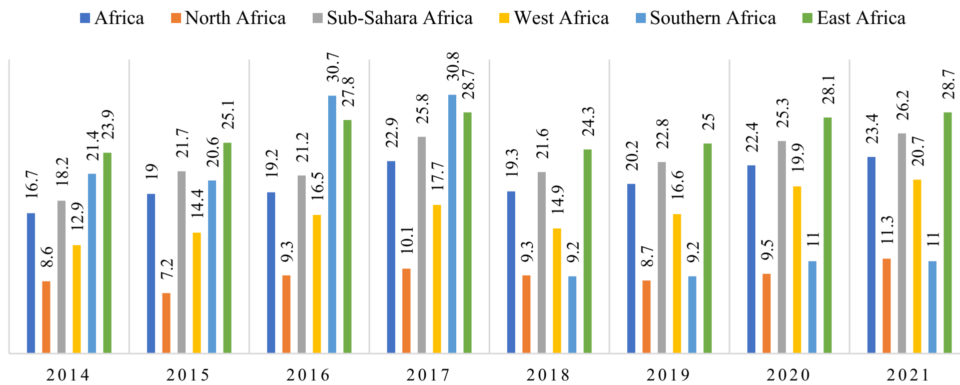


Fig. 3 Severe food insecurity across Africa (% of the total population). Source: Authors based on FAO (2022) data

rose from 9.3 to 10.9% between 2019 and 2020, and 11.7% in 2021. This food insecurity at severe levels indicates that such people had run out of food and, at worst, gone a day without eating. It is estimated that about 923.7 million people faced severe food insecurity in 2021, which is 73.6 million more than in the 2020 figure and 207 million more people compared to the 2019 figure (FAO, IFAD, UNICEF, WFP & WHO. 2022).

The figure further revealed that Africa has a greater percentage of severe food insecure persons compared to Asia and North America and Europe. The FAO, IFAD, UNICEF, WFP and WHO (2022) indicated that about 322 million Africans were facing severe food insecurity in 2021, which is 58 million more than in 2019 before the COVID-19 pandemic. Globally, more than one-third of the total number of people facing severe food insecurity in 2021 live in Africa affecting nearly one in every four people.

The FAO, IFAD, UNICEF, WFP and WHO (2022) noted that food security also continued to worsen in Latin America and the Caribbean, as there was a rise of 1.1% point of the number of people facing moderate or severe food insecurity in 2021 reaching 40.6%. While severe food insecurity rose by 1.4% points to reach 14.2% representing nearly 10 million more people in one year.

State of food security in Africa

The prevalence of food insecurity in Northern Africa is roughly half that of sub-Saharan Africa; however, the food security situation appeared to worsen more in Northern Africa from 2020 to 2021. Within sub-Saharan Africa, East Africa is the sub-region facing the highest levels of food insecurity and is also where the largest increases occurred from 2020 to 2021. However, Southern Africa recorded the highest severe food insecurity in the years 2016 and 2017 Fig. 3.

Consistently over the years 2014 to 2021, West Africa and Northern Africa have recorded severe food insecurity below the continental average. This shows that the contribution of these sub-regions (North and West Africa) to severe food insecurity in Africa is mild compared to other sub-regions in Africa. On the other way around, East Africa has consistently recorded severe food insecurity above the African average over the same period.

Study Methodology

Data Sources and Description of Variables

This study engaged panel data consisting 37 of African countries.[1]The reason for these 37 countries is that they are listed in the International Development Association of the World Bank. The data for the study was sourced from the Food and Agriculture Organisation (FAO), Country Policy and Institutional Assessment (CPIA) and the World Development Indications (WDI) for the period 2005-2019. The variables used in the study, measurement and source are discussed herein, while the summary is presented in Table 1.

Food security

Food security is the dependent variable, which is measured by food production per capita. This study acknowledges the four dimensions of food security - availability, access, utilisation and stability. Though all four dimensions of food security are important, however, this study conceptualised food security by focusing on the availability component. The study proxied availability by per capita food production. This variable was sourced from the FAO database.

[1] Angola, Benin, Burkina Faso, Burundi, Cape Verde, Cameroun, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Congo, Côte d'Ivoire, Djibouti, Ethiopia, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe

Table 1 Variables, Measurement and Sources

Symbol	Variable Name	Measurement	Source	Expectations
FS	Food security	Gross per capita food production	FAO	
GRE	Green Environment	Policy and institutions for environmental sustainability (scale of 1=low to 6=high).	CPIA	Positive
SOP	Social Protection	policies for social coverage (scale: 1=low to 6=high)	CPIA	Positive
ARL	Arable Land	Arable in hectares	WDI	Positive
AC	Agricultural Credit	Total credit to agriculture (US$, 2015 prices)	FAO	Positive
IT	Information and Technology	Individuals using the internet (% of the total population)	WDI	Positive
EA	Agricultural employment	Employment in agriculture (% of total employment)	WDI	Positive
	Interaction	The multiplication of the green environment and social protection	X	Positive

CPIA country policy and institutional assessment, *X* computed by the authors, *FAO* Food and Agricultural Organisation and *WDI* World Development Indicators

Source: Authors' Compilations

Green environment

The green environment is defined as the 'preservation of the environment that aims to enhance total well-being'. The concept of the green environment calls for a low-carbon environment that seeks to achieve low energy consumption and efficiency, and less pollution and emissions (Jin, 2012). This variable is captured by policies and institutional support for environmental sustainability. It was sourced from the country policy and institutional assessment (CPIA).

The green environment variable is on a scale of 1 to 6. A score of 1 to 2 means that there is low support for environmental sustainability, and a score of 3 to 4 means that there is a moderate drive for environmental sustainability. Similarly, a score of 5 to 6 means that there is a sufficient policy for environmental sustainability. This variable is an important factor when estimating the determents of food security. Because according to Gwambene et al. (2022) found that climate change and vulnerability significantly influence the production and food security of small-holder farmers. In addition, according to Adeleye et al. (2021) environmental degradation negatively affects agricultural production.

Social protection

Social protection is also included in the model and it is measured as overall social protection coverage. The rationale for including social protection is based, as agriculture is faced with a series of shocks (Osabohien et al. 2022), social protection is required to build resilience among the most vulnerable households for shock mitigation. Social protection was sourced from the CPIA. Similar to the green environment, the social protection variable is ranked on a scale of 1 to 6. A score of 1 to 2 means that there is a low social protection coverage, a score of 3 to 4 means that there is moderate social protection coverage, and a score of 5 to 6 means that there is sufficient social protection intervention.

Arable land

Another variable included in the model is arable land. This study considers arable land important because, it argues that the availability of land to farmers, may enhance production. Arable land is measured in hectares

Agriculture credit

Agricultural credit is another variable included in the model. This is measured by credit to agriculture, in US$.

Information technology

information and communication technology is measured by people with access to the internet as a percentage of the total population. This is also curial drawing insights from Anser et al. (2021) that found that ICT is one of the significant drivers of food security in Africa.

Employment in agriculture

Employment in agriculture employment is measured as the percentage of total employment. The *'a priori'* expectation is that a green environment, social protection, arable land, credit to agriculture, information technology and employment in agriculture should be positively and significantly related to food security. The summary of the variables and their measurements is captured in Table 1.

Table 2 Summary Statistics of Variables

Variable	Mean	Min	Max	SD	VIF
Food security	90.77138	138.7800	46.2200	16.9925	
Credit to agriculture	259.4299	2559.826	0.0293	433.9795	2.84
Arable land	6484710	37000000	48000	7598382	2.85
Social protection	3.3595	4.30000	2.2000	0.4376	1.47
Green environment	3.2749	4.00	2.0000	0.4570	1.53
Employment in agriculture	57.0345	89.1100	15.2700	17.2488	1.64
Information technology	8.7836	43.8399	0.2197	9.0684	1.73

Min means minimum value, Max maximum value, *SD* standard deviation, *VIF* variance inflation factor

Source: Authors' compilation

Method Specification and Method of Analysis

Drawing insight from the study by Nhamo et al. (2020) and Osabohien et al. (2022), this study specifies an empirical model given in Eq. (1). The mode specifies that food security is a function of the green environment, social protection and other variables that may influence food security, given in Eq. (1)

$$lnFS_{it} = \varphi + \vartheta lnGrE_{it} + \gamma lnSOP_{it} + \psi lnX'_{it} + e \tag{1}$$

where FS_{it} is food security (food production per capita) of country i at time t, GrE_{it} is the green economy, SOP_{it} social protection and X'_{it} is a set vector of control variables. Similarly, $i(i\ =, \ldots,\ N)$ and $t(t\ =\ 1, \ldots,\ T)$ represent countries under investigation and the period of study, respectively. In the model, ln represents the natural log of the variable. The control variables used in this study are arable land, credit to agriculture, information technology and employment in agriculture. To further expand the contribution of the study to the literature, the study interacted green environment with social protection, as given in Eq. (2)

$$\begin{aligned} lnFS_{it} = \varphi + \vartheta lnGrE_{it} + \gamma lnSOP_{it} \\ + \alpha ln(GrE_{it} * \gamma SOP_{it}) + \psi lnX'_{it} + e. \end{aligned} \tag{2}$$

The study applied the system Generalised Method of Moments (SGMM) as a result of the issues of endogeneity that may be present in Pooled OLS and Fixed effect. The system GMM model is given in Eq. (3)

$$\begin{aligned} lnFS_{it} = \varphi + \omega lnFS_{it-1} + \vartheta lnGrE_{it} + \gamma lnSOP_{it} \\ + \rho ln(GrE_{it} * \gamma SOP_{it}) + \psi lnX'_{it} + e \end{aligned} \tag{3}$$

While variables are as defined above, $lnFS_{it-1}$ captures the natural logarithm of the lag of food security in country i at time t. As a result of the issue of endogeneity, that may be present in Polled OLS and fixed effect result, the study engaged the SGMM. The GMM is regarded as a more efficient technique of estimation when analysing panel data with endogeneity problems (Arellano & Bond, 1991; Arellano & Bover,1995; Nickell, 1981). The presence of the lagged dependent variable as part of the independent variable forms the rationale for using this technique for this study.

As a way of robustness, the study engaged the D-H panel causality analysis. Dumitrescu and Hurlin (2012) provide an extension designed to detect causality in panel data. Following Dumitrscu and Hurlin (2012), Lopez and Weber (2017), the model is given below

$$\begin{aligned} y_{i,t} = \alpha_i + \sum_{k=1}^{k} \gamma_{ik} y_{i,t-k} + y_{i,t} + \sum_{k=1}^{k} \beta_{ik} x_{i,t-k} + \varepsilon_{i,t} i \\ = 1, \ldots, N \, and \, t = 1, \ldots, T \end{aligned} \tag{4}$$

where $x_{i,t}$ and $y_{i,t}$ capture the observations of the two stationary variables for entity i at time t. In this regard, the coefficients are permitted to vary across entities; however, the coefficents are expected to be time-invariant (Dumitrscu & Hurlin, 2012; Lopez & Weber, 2017). The lag of order k is assumed to be similar for all entities. The DH test assumes that there can be causality for some entities but not for all. Accroding to Granger (1969), the process for predicting the presence of causality is by checking for the significant influence of previous figures of the independent variable, x on the current value of the dependent variable, y. Therefore, the null hypothesis is explained as

$$H_0 : \beta_{i1} = \ldots\ = \beta_{ik} = 0 \,\forall\, i = 1, \ldots, N \tag{5}$$

This null hypothesis agrees with the absence of causality for all entities in the model. Unlike Granger (1969), according to the Dumitrscu & Hurlin (2012) test, there can be the causality for some entities but not necessarily for all. Therefore, the alternate hypothesis is given as

$$\begin{aligned} & H_1 : \beta_{i1} = \ldots\ = \beta_{ik} = 0 \,\forall\, i = 1, \ldots, N_1 \\ & \beta_{i1} \neq 0 \, or \ldots or \, \beta_{ik} \neq 0 \,\forall\, i = N_1 + 1, \ldots N \end{aligned}$$

Table 3 Pooled OLS, Fixed Effect and System GMM Result

Dependent Variable: Food Security				
Variables	Pooled OLS	Fixed Effect	2SLS	System GMM
FS(-1)	–	–	–	0.4655* (0.000)
Credit to agriculture	−0.0079 (0.419)	0.0292** (0.021)	0.0229* (0.000)	0.0527* (0.001)
Arable land	−0.0086 (0.631)	0.6425* (0.000)	−0.0072 (0.458)	0.0380** (0.014)
Social protection	0.0114 (0.942)	0.1548 (0.381)	0.0499*** (0.063)	1.1722* (0.005)
Green environment	−0.0409 (0.777)	0.1657 (0.278)	−0.0534 (0.663)	0.8145** (0.021)
Agricultural employment	0.0652 (0.232)	−0.0858 (0.360)	0.1225* (0.000)	0.3280* (0.003)
Information technology	0.1406* (0.000)	0.0857* (0.000)	0.1385* (0.000)	0.1069* (0.000)
Interaction term	0.0684 (0.879)	−0.5612 (0.253)	0.0579*** (0.087)	0.9632* (0.009)
Constant	4.1019* (0.000)	−4.7697 (0.000)	3.8495* (0.000)	1.0278* (0.005)
Model Statistics				
R-squared	0.50	0.54	0.52	–
Groups/Observation	37/289	37/289	37/289	37/289
No. of Instrument	–	–	–	30
Wald test/F-test	336.00* (0.000)		348.84* (0.000)	368.67* (0.000)
AR (1)				−2.82* (0.005)
AR (2)				1.59 (0.111)
Hansen test				2.10 (0.553)

The *p*-values are in the parentis (·), * and **, which means that the coefficient is significant at 1%, and 5%, respectively

Source: Authors' compilation

From the model, where $N_1 \in[0, N-1]$ is not known. Assuming that $N_1 0$, it implies that causality exists for all entities. Similarly, N_1 should be strictly lower than N; otherwise, it means that causality does not exist for all entities and H_1 diminishes to H_0 (Dumitrscu & Hurlin, 2012; Lopez & Weber, 2017).

Presentation and Discussion of Results

Summary Statistics of Variables

The summary statistics of the variables and the VIF (variance inflation factor) are provided in Table 2. From Table 2, the summary statistics show that food production per capita in Africa is about 91. Employment in agriculture (% of the total employment) has a mean value of 57.03. This implies that on average, the agricultural sector in Africa constitutes about 57% to total employment. Similarly, regarding information technology, data description shows that on average, approximately 9% of the total population in Africa has access to mobile internet services. This proportion shows that the rate of internet access in Africa is low. Similarly, the data also proves that regarding agricultural credit, the average total credit of \$259.43 m is allocated to the agricultural sector. On the other hand, African countries under study have arable land of 6484710 hectares.

Green environment and social protection were measured on a scale of 1 (lowest) to 6 (highest). A score that is 1 to 2 is ranked as the lowest, which reflects a situation of individuals in a country having very low access to social protection benefits and low quality of environmental management and low level of social protection intervention. A score range of 3 to 4 is ranked moderate, meaning there exist moderate social benefits and environmental protection policies in a country. This reflects a situation of individuals having moderate access to social benefits and the existence of moderate policies to promote environmental management and sustainability, and a score range of 5 to 6 is ranked highest, meaning that social protection and policy for environmental management and sustainability are effective. On the other hand, policy and institutions for environmental sustainability (a measure for a green environment) assesses the extent to which environmental policies foster the protection and sustainable use of natural resources and the management of pollution.

The summary statistics as presented in Table 2, show African countries under investigation are operating at a scale of 3.36 for social protection and 3.27 for green environment. This implies that African countries under study have moderate social protection coverage and policy for environmental sustainability. Therefore, scaling-up social protection and driving toward a green environment are necessary for African countries to drive food security in the coming decades. The result of the VIF was used to check for the level of multicollinearity in the model is also presented in Table 2. On a general note, VIF =1 means that there is no correlation among the variables, VIF between 1 and 5, means that the variables are moderately related, while VIF of above 5 means that there is a high level of multicollinearity in the model. The VIF result, as presented in Table 2, it shows that there is no incidence of a high level of multicollinearity. This is based on the fact that the values are less than 5.

Econometric Results

The results obtained from the Pooled OLS, fixed effect, two-stage least squares (2SLS), and the system GMM are presented in Table 3. The study engaged the Pooled OLS and Fixed Effects as baseline analysis, while the main analysis is the system GMM. In this study, the problem of endogeneity is controlled with system GMM. This is based on the rationale that, system GMM estimators are well-known to treat endogeneity in which the independent variables are not strictly exogenous. In such circumstances, the Pooled OLS and Fixed Effect methods may produce a biased estimate (Arellano & Bond, 1991; Arellano & Bover, 1995). Given the weakness of Pooled OLS and Fixed effects regression, the results from the SGMM are interpreted and inferences are drawn from it. The prerequisite rule for system GMM is a significant autocorrelation of the first-order autoregressive AR (1) process and an insignificant autocorrelation at the second-order autoregressive AR (2) process. The Sargan test in this study is insignificant, reflecting the fact that the instruments are not correlated with the residuals, and thus are valid.

The result shows that the level of last year's food security affects the state of the current year's food security by 0.47%. The study finds that a green environment is statistically significant and a positive determinant of food security. The coefficient of a green environment is 0.8145, which means a 1% increase in efforts in making policies and institutions for environmental management and sustainability effective, will lead to an increase in food security by 0.81%. On a similar note, social protection is also found to have a significant and positive impact on food security in Africa. This means that broadening the social protection intervention may result in an improvement in the level of food security by 1.17%. The result shows social protection and green environmental interact positively to influence food security by 0.96%. It shows that when a green environment and social protection have interacted, there is a significant improvement in the level of food security.

Driving towards a green environment is important because unwanted use of land such as poor farming methods causes environmental degradation. In greening the environment, social spheres, economic activities and technological factors play a vital role. Factors such as deforestation are a major cause of environmental degradation that affects green environment drive (Karakara & Osabuohien, 2020). The effective management of the environment may improve the level of food. This aligns with previous findings which indicated that a lack of good environmental management results in challenges such as floods, landslides, drought, hailstorms, and water scarcity in Uganda. Similarly, it follows the findings by Gwambene et al. (2022) which prove that climate change and other environmental hazards negatively affect the food security of small-holder farmers.

Given the fact that the green environment positively affects food security, there is a need to enhance policy for a sustainable environment. Mkonda and He (2018) found that production (ton/ha) exhibits a negative movement. This trend can be attributed to an environmental problem that could affect productivity. Anghinoni et al. (2021), found that sustainability of agricultural production is critical to meet the growing demand for food, therefore, reducing environmental hazards is crucial to enhancing productivity. Similar findings were obtained by Monroy-Torres et al. (2021), showing that the rumen microbiome is also responsible for the production of one of the most potent greenhouse gases. It is recommended that conventional methods to lower methane production by ruminants have proved successful but to a limited and often temporary extent. In line with the findings by Pyrchenkova et al. (2021), improvement in soil fertility via the reduction of environmental hazards is essential in enhancing agricultural efficiency.

The study finds that social protection and its interaction with the green environment is crucial to improve the level

Table 4 D-H Panel Causality Analysis

	Food Security	Credit	Arable land	Social protection	Green environment	Agric employment	Information Technology	Interaction term
Food Security		4.2525** (0.040)	16.4361* (0.000)	2.2864 (0.1311)	4.0737** (0.044)	0.6034 (0.4376)	11.7906* (0.000)	3.3056*** (0.069)
Credit	0.1639*** (0.068)		1.4109 (0.235)	0.2736 (0.601)	0.56467 (0.4530)	0.3488 (0.555)	1.3580** (0.024)	0.4106 (0.522)
Arable land	0.2878 (0.591)	10.4382* (0.001)		1.31014 (0.2530)	2.18792 (0.1398)	0.00050 (0.9821)	0.55683 (0.4559)	1.2721 (0.260)
Social protection	0.3260*** (0.056)	0.0913 (0.762)	0.00053 (0.9816)		16.995* (0.000)	33.8105* (0.000)	6.7047* (0.009)	15.6649* (0.000)
Green environment	0.6685 (0.414)	0.08565 (0.7700)	0.05635 (0.8125)	1.4748 (0.225)		21.3884* (0.000)	5.5695** (0.018)	15.1793* (0.000)
Agric employment	1.0900** (0.029)	1.9916** (0.015)	2.2185** (0.013)	0.00298 (0.9565)	0.0804 (0.776)		3.0225*** (0.083)	0.0214 (0.8837)
Information technology	11.6564* (0.000)	0.1165 (0.733)	3.3907* (0.006)	2.0219 (0.1558)	4.3727** (0.037)	0.8054 (0.3700)		3.0937*** (0.079)
Interaction	0.5185 (0.471)	0.0793 (0.778)	0.0592 (0.807)	1.2734 (0.2597)	17.3000* (0.000)	25.693* (0.000)	6.5855** (0.010)	

The *p*-values are in the parentis (·), * and **, means that the coefficient is significant at 1%, and 5%, respectively

Source: Authors' Computation, 2021

of food security. This is crucial because, as agriculture is faced with shocks, access to social protection is essential to mitigate the impact of such shocks. This follows the findings of Osabohien et al. (2022), proving that social protection has a significant and positive impact on food security. Other variables included in the model significantly explain food security. The result shows that widening social protection coverage and deployment of technology leads to an increase in food security. This is similar to the findings of Anser et al. (2021). In addition, these findings support the work by Bahrulolum et al. (2021) who noted that the emission of nanoparticles by physical and chemical methods produces hazardous materials, which damage the environment and cause harm to the food system.

As a robustness check, the study engaged the Dumitrescu and Hurlin (DH) panel causality. Understanding the causal link between variables in a study is a critical step in economic research and policymaking. The Dumitrescu and Hurlin (2012) test determine the nature of the causal link between related variables. This test is useful for addressing the issue of heterogeneity. Table 4 depicts the D-H panel's causality analysis. The findings indicate that there is a two-way causal link between food security, credit to agriculture, and information technology in African countries under study. However, unilateral causation extends from food security to arable land, social protection, a green environment, and agricultural employment.

This study examines how the green environment and social protection affect food security in Africa. To further articulate the novelty and contributions of the research to the extant literature, the study also examines the interaction effect of the environment and social protection on food security. The study aims to contribute to policy dialogue for actualising the sustainable development goal of no poverty (SDG-1), food and nutrition security (SDG-2), good health and wellbeing (SDG-3), clean water and sanitation (SDG-6), sustainable cities and communities (SDG-11), sustainable consumption and production (SDG-12), combat climate action (SD-13), life below water (SDG-14) and life on land (SGD-15), respectively.

To achieve its objectives, the study engaged the system GMM on a panel consisting of 37 African countries listed in the International Development Association (IDA) of the World Bank for the period 2005 -2019. The study finds that the green environment has a significant and positive impact on food security. The result shows that an improvement in environmental management may improve the level of food security by 0.81%. In addition, an improvement in social protection interventions is capable of enhancing the level of food security by 1.17%. The interaction of a green environment and social protection has a positive and significant on food security. It implies that if social protection and a green economy interact, the level of food security is improved by 0.96%.

The result from the study calls for the need to build a climate-resilient green environment that primarily seeks agricultural intensification to attain food security. In addition, it calls for the need to expand social protection interventions to mitigate risk ad shocks experienced by farmers. Because, the reduction of risk and shocks, will enhance the productivity of farmers, and thus, food security. The study concludes by recommending that policies to improve environmental sustainability such as pollution controls, afforestation, and reduction in deforestation among others should be implemented to drive the safety of the total environment. In addition, it recommended that social protection interventions should be expanded to build resilience among farmers against risk and shocks. However, this study is not without limitations. One of the limitations is that among the four dimensions of food security – availability, access, stability and utilisation, this study only focused on one dimension which is availability. As a recommendation for further studies, given data availability, when examining the impact of a green environment and social protection on food security, other dimensions of food security should be considered.

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