Evaluating Food Production Shocks and Their Effects on Population Growth and Hunger in Africa

Abiodun Funso Okunlola[1]* and Adewale Rafiu Aregbeshola[1]

[1] College of Economic and Management Sciences, Department of Business Management, University of South Africa, South Africa
* Abiodun Funso Okunlola, corresponding author. Email: okunlaf@unisa.ac.za
Submitted: 12 January 2024. Accepted: 14 May 2024. Published: 16 August 2024
Volume 33, 2025. pp. 336–360. http://doi.org/10.25133/JPSSv332025.018

Abstract

This study evaluates the impact of a one-standard deviation shock on food production and its subsequent effects on hunger and population growth in Africa. Using a forty-one-year dataset sourced from the Regional Strategic Analysis and Knowledge Support System (ReSAKSS), the African Development Bank (AfDB), the United Nations Department of Economic and Social Affairs (UN DESA), and the World Bank Development Indicators, the study employs three estimation methods: long-run significance, vector autoregression, and impulse response function (IRF). The findings indicate no long run correlation between the variables. However, the IRF suggests that shocks to food production negatively impact hunger and population growth. The study underscores the need for urgent mass food production and the use of advanced agricultural production techniques to mitigate the exacerbating hunger crisis in Africa, given the rising population, conflicts, and climate change challenges.

Keywords

Food production; hunger; impulse response function; index; population growth

Introduction

Food serves as one of the most vital life sustenance. Governments worldwide often ensure that their population is constantly served good, quality, and nutritious baskets full of their products. As such, there is frequently a deliberate action (also with private partnership) to ensure that food is produced in proportion to population growth needs. Inversely, any shortfall or inadequate production will lead to hunger (Akinbode et al., 2022; Brown et al., 2020; El-Rasoul & Ali, 2020; Fagbemi et al., 2023; Goli et al., 2022; Mustapha & Enilolobo, 2019; Osinubi & Apanisile, 2021).

Food production (FP) is referred to as all foods (crops and livestock), edible and of immense nutritional value for human consumption, excluding fodder crops, coffee, and tea (Food and Agriculture Organization [FAO] et al., 2020, 2022; Ogunniyi et al., 2022; Okunlola et al., 2019a, 2019b; Regional Strategic Analysis and Knowledge Support System [ReSAKSS], 2023; von Braun, Afsana, Fresco, Hassan, 2021; von Braun, Afsana, Fresco, Hassan, & Torero, 2021). How well a nation can produce food adequate for its population is determined by the food production index (FPI) (FAO et al., 2020). In order words, FPI details all food production (aggregate) originating from each country based on 2004 to 2006 = 100 basket measurements (FAO et al., 2023a). The FPI is based on the price-weighted sum of aggregate production minus quantities used as seed and feed in the same period and calculated based on the Laspeyres formula (FAO et al., 2020). Thus, the closer a country is to or above 100, the better ranked the country and vice versa. In Africa, the Food and Agriculture Organization (FAO) (2023a) and Regional Strategic Analysis and Knowledge Support System (ReSAKSS) (2023) indicate that Burundi ranks highest at 158.72, while Cabo Verde ranksd least at 80.42. Also, Africa-wide food production aggregates stand at 110.

On the other hand, a nation lacking sufficient/adequate nutritional food/diet is said to be hungry (Ogunniyi et al., 2022; Pawlak & Kolodziejczak, 2020). Thus, like insufficient food production, hunger connotes a condition in which a person or group of persons cannot eat sufficient food to meet basic nutritional needs for a sustained period (FAO et al., 2022; Pawlak & Kolodziejczak, 2020; ReSAKSS, 2023; von Braun, Afsana, Fresco, Hassan, & Torero, 2021). Similarly, a country's hunger level is judged based on the Global Hunger Index (GHI) 100-point scale (Goli et al., 2022; Ogunniyi et al., 2022; von Grebmer et al., 2022). Specifically, GHI measures four divisions of hunger classification (undernourished, stunting, wasting, and mortality) with a scale of 0 to 9.9, indicating low hunger; 10 to 19.9 indicating moderate; 20 to 34.9 indicating serious; 35 to 49.9 means alarming; while value equal to or above 50 means hunger is extremely alarming (FAO et al., 2023a; World Food Programme [WFP], 2020; von Grebmer et al., 2022).

On record, in terms of population, Africa leads after South Asia in the 2023 ranking of the region with the hungriest people in the world (Akinbode et al., 2022; Fauziyyah & Duasa, 2021; von Grebmer et al., 2022). The World Bank (2023) and Ogunniyi et al. (2022) stated that up to 828 million of the world's population are undernourished, and 193 million more are at an acute level. Africa has more presence in all categories of hunger severity except extremely alarming (Ogunniyi et al., 2022; von Grebmer et al., 2022). For instance, 18.4 million people in Ethiopia, Kenya, and Somalia are in acute hunger. Also, hunger reports in the Central African Republic, Chad, Madagascar, and the Congo Democratic Republic are alarming (von Grebmer et al., 2022). Only Algeria, Tunisia, and Morocco have a hunger rate of < 9.9. Egypt, South Africa, Namibia, Eswatini, Ghana, Cote d'Ivoire, Gabon, Gambia, and Senegal fall within the moderate bracket, while the rest share serious and alarming points (von Grebmer et al., 2022). On aggregate, Africa's share of the world's hunger stands at 21.6 index, an indication that the continent faces a severe hunger situation (Akinbode et al., 2022; Doku et al., 2020; El-Rasoul & Ali, 2020; Grace et al., 2023; Mustapha & Enilolobo, 2019; ReSAKSS, 2023; WFP, 2020).

Interestingly, juxtaposing the two scenarios of a 110-point scale of food production and a hunger scale of 20.0–34.9 level for the continent requires a gauge of assessment, especially with the aspiration of the 2025 and 2030 Africa shared prosperity agenda, more importantly, as the continent battles with drought, climate change, conflict, insecurity, poverty, unrest, flood and the aftermath of the COVID-19 pandemic (Adeleye et al., 2020; Corral et al., 2020; Fagbemi et al., 2023; Goli et al., 2022; Ogunniyi et al., 2022; Tacoli, 2017; Ulimwengu et al., 2021; von Braun et al., 2023; World Bank, 2020).

To say the least, while studies such as Adeleye et al. (2020), Akinbode et al. (2022), Fauziyyah and Duasa (2021), Goli et al. (2022), Tacoli (2017), and Ulimwengu et al. (2021) are of the views that Africa's food production is commendable, this study seeks to validate and or invalidates the assumption in the event of current reality. It asks how long the food production rate/pattern/process or system will sustain Africa to avert, reduce, and avoid hunger. Similarly, in the event of plausible global shocks, as in the case of the COVID-19 pandemic, intense adverse climate conditions, and sudden conflicts like the ongoing Ukraine/Russia war, how will food production impact the population? These queries form the centerpiece of the study.

Literature review

Food production connotes all the processes involved in transforming food items (seedlings/crop/stocks) into edible use (Harris et al., 2020; Reardon et al., 2019; Ulimwengu & Blumenthal, 2023; von Braun, Afsana, Fresco, & Hassan, 2021). The use, often, is for commercial purposes measured in baskets. However, not all foods are classified as edible and nutritious to humans. Thereby, the Food and Agriculture Organization (FAO) et al. (2023a) and Regional Strategic Analysis and Knowledge Support System (ReSAKSS) (2023) describe food production as all food crops and livestock considered edible and that contain nutrients, excluding coffee and tea. In order words, a country's food production is measured through the food production index. Ab initio, the index measures a country's food basket (items included in the basket) against the base year, 2004 to 2006 = 100.

Contradictorily, despite 219.9 million hectares of arable land in Sub-Saharan and North Africa, Harris et al. (2020), Shukla et al. (2021), Ulimwengu and Blumenthal (2023), Ulimwengu et al. (2021), and the Higher Level Panel for Expert Help (HLPE) (2014) still observe that the food production system is entangled by an array of factors aforementioned, including the ongoing Ukraine-Iran crisis, putting more population at risk of food shortage, especially in Africa (Akinbode et al., 2022; Arndt et al., 2023; Doku et al., 2020). This is in addition to a hike in food prices. Already, a five-year record indicates that one out of every four African lacks sufficient nutritious food intake, thereby exacerbating the continent's hunger level (Akinbode et al., 2022; FAO et al., 2023a; Ogunniyi et al., 2022; Ulimwengu & Blumenthal, 2023). Moreover, an average of 278 million people is hungry—an indicator of the threat to reaching the 2030 Comprehensive Africa Agriculture Development Programme (CAADP) policy and Goal 2 of the United Nations's Sustainable Development Goals (SDGs).

Table 1: Africa List of Foods

	West Africa	East Africa	Central Africa	Northern Africa	Southern Africa
1	cassava	beef	cassava	barley	banana
2	camel	cassava	common beans	cereal	Castrol oil
3	cattle	cashew nut	cooking banana	citrus fruits	cereal
4	cashew	cloves	corn	cork	chicory roots
5	cocoa	coconuts	cotton	cotton	citrus
6	cotton	dairy	coffee	figs	coffee
7	coffee	legumes	cucumber	fruits	fiber crops
8	donkey	maize	eggplant	grapes	grapefruits
9	goats	millet	millet	dates	green maize
10	groundnuts	fruits & vegetables	peanuts	legumes	maize
11	livestock	oil-crops	pepper	maize	pears
12	horses	pyrethrum	sweet potato	olive	potatoes
13	palm oil	pulses	tobacco	rice	pulses
14	peanut	sorghum	yam	vegetable	sisal
15	pig	sisal		wheat	sugarcane
16	poultry	sugarcane			sunflower
17	rice	tea			tea
18	sorghum	tobacco			fodder
19	sheep	wheat			tobacco
20	millet, maize				vegetables
21	wheat				wheat
22	yam				other tubers
23	beans				
24	sorghum				

Note: Africa Development Bank (2022)

Table 1 lists varying types of food produced across the West, East, Central, North, and Southern African regions. A glimpse shows some common foods across one or two regions, while others indicate that certain foods are peculiar to an area.

Table 2: Africa Major Food Import Dependency Ratio

Food Type	WA	EA	SA	NA	CA	AfW
Meat	13	2	16	8	34	12
Starchy Roots	0	0	5	4	0	0
Vegetable Oil	60	86	74	78	44	71
Vegetables	5	4	11	1	5	3
Milk	9	2	10	14	9	9
Eggs	3	3	1	0	40	2
Oil Crops	1	2	14	29	0	7
Fruits	2	2	15	4	1	3
Cereals	24	19	32	54	34	33
Pulses	1	5	42	52	5	8

Note: WA = West Africa, EA = East Africa, SA = Southern Africa, NA = North Africa, CAC = Central Africa, AfW = Africa wide (FAO et al., 2020)

Despite the foods in Table 1, Table 2 shows that Africa still depends on imported food to meet deficits along the food chain. The import dependency indicates the ratio at which each food class is sourced across the regions. For instance, the meat dependency rate is high in West, South, and Central Africa. Similarly, vegetable oil dependency is also high across all the regions. There is also evidence of high dependence on oil crops in South and North Africa. The need for milk is also high across Africa except for East Africa, which recorded a ratio of 2. Fruits, cereal, and pulses also show high dependence across the region.

Table 3: Arable Land Across the Globe

Region	**Year (millions of hectares)**			**Ranking by Recent Measure**
	1961	**1991**	**2007**	
Baltic states and CIS	235.4	224.4	198.5	3
Eastern Europe	48.7	45	39.7	7
Developing Asia	404.4	452.5	466.4	1
Latin America and the Caribbean	88.7	133.6	148.8	5
North Africa	20.4	23	23.1	8
North America	221.5	231.3	215.5	2
Oceania	33.4	48.5	45.6	6
Sub-Saharan Africa	133.8	161.3	196.1	4

Note: Statista (2009)

Based on the measures of the region with the most arable land, as shown in Table 3, developing Asia comes first in the 2007 ranking. Next on the list is North America. This is followed by the Baltic and the Commonwealth of Independent States (CIS). After that, Sub-Saharan Africa has the most arable land. Latin America and the Caribbean come after. Oceania is next, and Eastern Europe and North Africa are in that order. Since land is a leading factor in food production, the volume of arable land available per region should indicate how much food can be produced. Whether this does so or not remains a matter needing further inquiry.

Population growth

Population refers to the number of individuals or groups living in a geographical location in time and space. The United Nations Department of Economic and Social Affairs (UN DESA) (2022, 2023) defines population as all inhabitants of a given country or area considered together. The World Health Organization (WHO) (2023) considers population to be 'all inhabitants of a country, territory, or geographical area, total or for a given sex and/or age group, at a specific time.'

On the other hand, population growth relates to the rate at which individuals increase over time. Historically, the world's population has doubled compared to the earlier centuries. The world's population is about 8 billion compared with 2.5 billion in the 1960s. Out of this, Africa leads after Asia with approximately 1.4 billion in population and is still counting (Akinbode et al., 2022; United Nations Department of Economic and Social Affairs [UN DESA], 2022). Asia has a total population of 4.7 billion people. The population of the Americas is approximately 1 billion, while the population of Europe is approximately 742 million (UN DESA, 2022, 2023).

Table 4: World's Population Comparison

Continent	Area Space	Population	World Population Projections		
Africa	30.37m km2	1.4 billion	2022	2030	2050
Europe	10.53m km2	746.4 million	7.942 billion	8.512 billion	9.687 billion
Asia	44.58m km2	4.7 billion			
Americas	42.55m km2	1.0 billion			

Note: FAO et al. (2023b), UN DESA (2023)

Table 4 presents the volume of area square kilometers and population that each continent occupies. Asia remains the continent with the most area space, followed by the Americas, Africa, and Europe. However, in terms of population, Asia and Africa top the lead in that order, followed by the Americas and Europe, respectively. The world's population was estimated at over 7.9 billion in 2022, and it is expected to reach nearly 9.7 billion by the year 2050 (UN DESA, 2023).

Hunger index

Hunger refers to lack, inadequate, or deprivation of access to nutritious three-square meals. Von Grebmer et al. (2022) and ReSAKSS (2023) describe hunger as a condition in which a person cannot eat sufficiently nutritious food sustainably. To understand hunger severity, von Grebmer et al. (2022) classify hunger into four categories. These categories are then indexed on a 100-scale point, representing a tool of measurement by which hunger level is determined globally. They are identified as below:

a. **Undernourishment** categorizes the proportion of a country's undernourished population: those with inadequate calorie intake during meals.
b. **Stunting in children** is another category of hunger measurement. Here, stunting is evidence of low height compared to age, which occurs in children under five. This condition is classified as chronic undernutrition.
c. **Wasting in children** means low weight compared to height for children under five. This condition is referred to as acute undernutrition.
d. **Mortality in children** simply refers to death in children. It is used to measure the rate of children that die between 0 to 5 years of age.

Based on this classification, a measurement scale point (0–100) is ascribed to describe further how low or high hunger is in each scenario. Thus, there are low, moderate, severe, alarming, and extremely alarming hunger levels. Where hunger hovers between 0 and 9.9, it is described as low. A 10 to 19.9 point is ascribed to a moderate hunger level. Between 20 to 34.9 means hunger is serious. A scale of 35–49.9 means hunger is alarming, while 50–100 means hunger is extremely alarming.

Cumulatively, Africa has consistently maintained a mix of severe and alarming records, with moderate outcomes in fewer South/North African countries (FAO et al., 2023a). A five-year record indicates that one out of every four Africans lacks sufficient nutritious food intake (FAO et al., 2023a; Ogunniyi et al., 2022; Ulimwengu & Blumenthal, 2023). Presently, the total is said to be 278 million people in one form of hunger or the other, an indication of a threat to reaching Africa's 2030 goal of eradicating hunger and poverty in the continent as contained in its CAADP 2004 policy, as well as the UN's SDGs Goal 2 (Kamenya et al. 2022; Neal et al.

2023). This situation is further exacerbated by the pandemic and the ongoing Ukraine/Iran war.

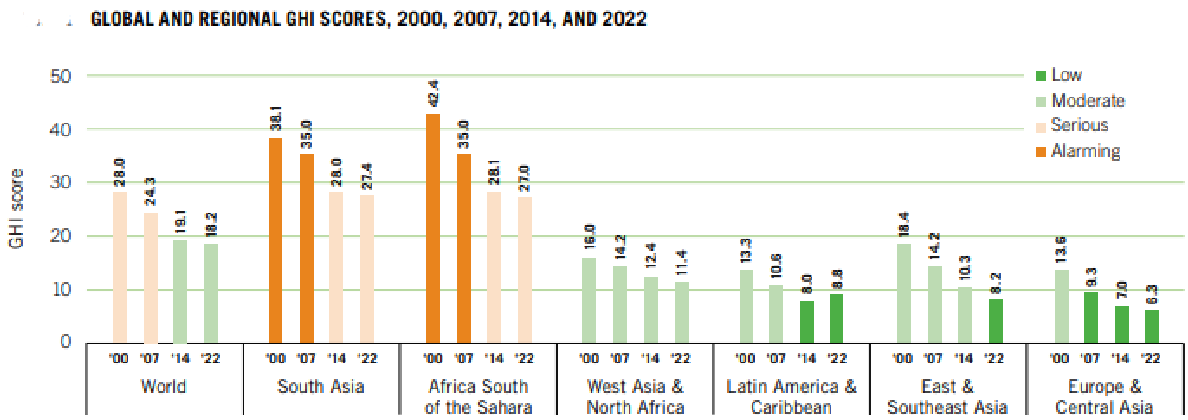
Table 5: Africa Hunger Index Classification by Region

Region	Composite Index (1997–20 21)	Average (1997–2021)	Remark	Ranking
WAC	828.4	34.5	Serious	3
SAC	790	32	Serious	2
NAC	348.5	14.5	Moderate	1
EAC	958.4	39.9	Alarming	5
CAC	929.6	38.7	Alarming	4
	2022 index			
Africa	21.6		Serious	

Note: WAC = West Africa, SAC = Southern Africa, NAC = North Africa, EAC = East Africa, CAC = Central Africa. Scores are based on the Author's Compilation of data from ReSAKSS (2023) and von Grebmer et al. (2022)

In Table 5, the regional hunger index is presented. First is the composite index for the period between 1997 to 2021. The second column represents the average of the same period. Based on the average, North Africa is the least hungry region, with a score of 14.5; as such, hunger is moderate. Next to this is Southern African countries (SAC), with a hunger level score of 32. This means hunger is serious in the region, followed by countries in West Africa (WAC). The report shows that WAC has an index of 34.5, meaning that hunger is also serious. Hunger is alarming in the Central African Republic (CAC) and East African countries (EAC) at an index of 39.9 and 38.7, respectively.

Figure 1: Global and Regional Global Hunger Index Scores From 2000, 2007, 2014, & 2022

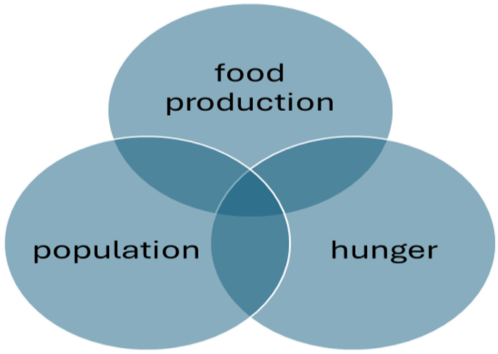


Note: Adopted from von Grebmer et al. (2022)

The conceptual linkages

The illustrated diagram below represents the conceptual linkages between the dependent and independent variables of the study. With the linkages, it is believed that food production, population growth, and hunger are intertwined, which represents how the lack/low production of the former influences the quality of the other two concepts.

Figure 2: Study Conceptual Link



Note: Authors conceptualization

Theoretical review

Tracking food production, population growth, and hunger nexus is linked to Malthus's (1998/1798) theorization in 1766. Although recent theories, such as Marxists and Demographic transition, have criticized Malthus's basic assumptions, rational consensus submission still admits the potency of Malthus' theorization to date (Adeleye et al., 2020; Akinbode et al., 2022; Goli et al., 2022; Malthus, 1998/1798). Inherent in Malthus's postulation rests on the fact that population growth is inevitable worldwide, especially as the two sexes become attracted to each other. By implication, as the population grows, a need to increase food production is vital because food production cum population growth is *sine-qua-non*. Authorities must identify this to move beyond the static subsistence food production system. Malthus's postulation is primarily anchored on the need to increase food production as the population grows to avoid hunger. The basic assumptions are:

i. **Population growth cum subsistence**: Malthus observed that the global population will continue to double while available land remains constant. Practically, the static land will not be sufficient to cater for increased food production, thereby leading to hunger and death.

ii. **Population growth limitation**: Population is necessarily limited by subsistence. In other words, for a population to grow, subsistence food production must grow or give way to increased food production.

iii. **Presence of checks**: Malthus provided two check scenarios for population growth and food production, which could lead to positive and negative hunger. The former is described as famine (hunger), diseases or war, pestilence, and vicious customs of women. These items are potential elements that could hinder increased food production to serve the growing population. Also, the latter includes birth control checks. Accordingly, it is observed that if population growth is not put in check, hunger will be unavoidable through the inability of food production to keep up with the growing population (FAO et al., 2023a; Harris et al., 2020; Reardon et al., 2019; World Bank, 2023). As such, it is said that the food supply grows in arithmetic progression while the population grows in geometric progression.

Although Malthus's (1998/1798) assumptions provide an impressive foundational approach to understanding food production, population growth, and hunger today, they are not without criticism. Amidst Malthus's criticisms are Marxists and Demographic Transition theories, whose criticism and postulation are well thought through. However, owing to the global relevance of Malthus's assumptions, the postulations are still much well echoed. Hence, Malthus's theorization underpins the study's theoretical thought.

Furthermore, as the world grapples with Malthus's basic assumptions, hunger remains a global phenomenon despite technological leverage in food production. This is particularly the case with Africa, whose population has more than doubled over the past decades, lacks technological advantage in leveraging increased food production, and records high levels of hunger arising from deprivation, drought, conflicts/wars, poverty, land crises, climate change, pestilence and the aftermath of the COVID-19 pandemic (Adeleye et al., 2020; Fagbemi et al., 2023; FAO et al., 2022, 2023a; Goli et al., 2022; Mazzucato et al., 2020; Ogunniyi et al., 2022; von Braun et al., 2023; World Bank, 2020, 2021, 2023).

Table 6: Summary of Empirical Literature

Author	Year	Research Area	Variable/Measure	Methodology	Finding	Summation
Adeleye et al.	2020	Sub-Saharan Africa, Latin America, and the Caribbean	Poverty, inequality, and Gross Domestic Product (GDP)	Comparative analysis of pooled OLS, Fixed effects, and GMM	Increased inequality impacts poverty and vice versa	The mixed outcome of how the trilemma impacts one another across countries
Akinbode et al.	2022	Sub-Saharan Africa	Inequality, population, and hunger	System GMM	Inequality and population positively increase hunger level while food production reduces hunger level	There is a need to ensure food production keeps pace with the population and hunger needs.
Brown et al.	2020	United States of America	Hunger, including stunting, wasting, and underweight	Theoretical–structured literature	The review shows a significant relationship among the variables checked with a limitation on the relationship subsisting between violence and wasting	Children's malnutrition required predictable analysis that could yield better results
Doku et al.	2022	Sub-Saharan Africa	Food availability, food accessibility, food stability, and food utilization	System GMM	The German bilateral trade improves Food stability and security, but government expenditure is insignificant.	Africa's government spending is insufficient to enhance food security.
El-Rasoul and Ali	2020	Africa	Food production index, calories per daily intake, real food prices index, real GDP per capita	Time series analysis- cointegration, Granger causality, and Impulse Response Function,	The mixed outcome of the variables	Food production needs to be encouraged to ensure food security and nutritional meals.
Fagbemi et al.	2023	Sub-Saharan Africa	Food production and climate change	Fixed effect and two-step system GMM	Climate change significantly impacts food production in	Food shortages as a result of adverse weather will increase hunger and reduce the availability of nutritious food among the population

Fauziyyah and Duasa	2021	Southeast Asia	Food production, agriculture employment, land, real gross domestic product, consumer price index, carbon emission, and gross fixed capital formation.	Panel data estimation	Food production is positive and significant. Agriculture employment, consumer price index, and real gross domestic product are positively substantial, while carbon emission gross fixed capita is negatively significant, except land and foreign direct investment	Mixed outcomes indicate only a few are positive and significant
Goli et al.	2022	Multi-country assessment (Africa, Europe, Asia)	Conflicts and Child Health	Multivariate regression Analysis	Insufficient food nutrition because of conflicts impacts a child's health negatively	Good nutritious food is negatively correlated with conflicts.
Grace et al.	2022	Africa	Conflict, climate change, and acute malnutrition	Cross-sectional	A mixed outcome with climate and conflict impacts Kenya and Nigeria (weight for height), while in Uganda, it is household and individual level.	It guides policymakers, especially humanitarian aid, on how best to respond to this study.
Harris et al.	2020	Asia and Vietnam	Food supply, food prices, food expenditure, diet, and nutrition	Conceptual food system framework	Theoretical summation of the interactions of the variables	Improvement in nutritional foods for the people of Vietnam
Mustapha and Enilolobo	2019	Sub-Saharan Africa	Agricultural expenditure and agricultural output	System GMM	Existence of a weak relationship between agricultural expenditure and output	There is insufficient spending that will spur agricultural output to feed the population, and this calls for concern.
Neal et al.	2023	Europe and the United Kingdom	Hunger and Food cues	Emotional Blink Attention (EBA), Bayesian analytics	There is no evidence of hunger when a cue is present	It is a quasi-experimental summation that found no link between hunger and cues for food.
Ogunniyi et al.	2021	Africa	Agricultural exports, imports trade, hunger, and	Panel Data of pooled OLS, Fixed Effect, Random	A poor and negative link exists between exports and	There is an indication of insufficient food production to meet the

			gross domestic product per capita	Effect, and Hausman test	hunger and GDP per capita but not with imports.	population's needs, hence the need to import.
Okunlola et al.	2019b	West Africa and Nigeria	Real gross domestic product (RGDP), finance provision to oil palm, cocoa, groundnuts, fishery, poultry, cattle & roots, and tubers	Philip Perron, Autoregressive distributed lag (ARDL), Wald test	None of the variables is significant in explaining growth in the study	Insignificant impact of agriculture on growth
Okunlola et al.	2019a	West Africa and Nigeria	Gross domestic product, credit to oil palm, cocoa, groundnuts, fishery, poultry, cattle, roots, and tubers	t-statistics, stepwise regression analysis	Roots and tubers, cocoa, and poultry have the most contributory impact on growth in that order, respectively	The outcome shows agriculture consisting of food with the most contributory impact on growth
Osinubi and Apanisile	2021	Sub-Saharan Africa	Agric investment, human capital, ethics, external conflict, gross domestic product, agricultural production index, poverty, internal conflict, government stability, inflation, religious tension, socioeconomic conditions, and poverty	Two-step system GMM	These variables are significant in explaining food production	Investment in agriculture/institutional quality promotes food production
Pawlak and Kolodziejczak	2020	Developing countries	Food security and hunger; undernourishment scale.	Comparative analysis method	Food production and security are primarily due to country-specific characteristics	Theoretical conclusion of the importance of scaling up food security
Tacoli	2021	Developing Economies with Low- and Middle-income countries	Food production, food affordability, and hunger	Theoretical description	It attempted to unveil the link between urban poor and access to nutritional food.	As the urban population rises, so does food insecurity, and the need for more nutritious food is also threatened.
von Braun, Afsana, Fresco, Hassan, & Torero	2021		Food systems, including food security and hunger	Theoretical	Provided how authority should leverage technology to increase food production	There is a need to increase nutritional food production and end hunger by leveraging science and technology

Brief CADDP and the 2030 United Nations Sustainable Development Goals (SDGs)

While the Comprehensive Africa Agriculture Development Programme (CAADP) and Sustainable Development Goals (SDGs) of the United Nations are in tandem, it suffices to say that both aim to end poverty and hunger globally by the year 2030. Specifically, CAADP objectives highlight the following:

i. Land management and water control to increase food production
ii. Improve agriculture with food production and allied infrastructure
iii. Increase food production supply to reduce hunger
iv. Deployment of technology agricultural production research to increase food production

Likewise, the United Nations Sustainable Development Goals has seventeen (17) goals. These are no poverty, zero hunger, well-being and good health, quality education, equality of gender, clean water and sanitation, affordable and green energy, decent work and economic growth, industry innovation and infrastructure, reduction of inequality, sustainable cities and communities, responsible consumption and production, climate action, water, land, peace/justice/strong institutions, and partnership for the goals. Of all, poverty, zero hunger, and well-being/good health well suit the purpose of the study.

Methodology

Three paths to achieving the aim of this study are used in this methodology. First, the study identifies the existence or otherwise of a long-run relationship between the explained and the explanatory variables. In order words, both Trace and Max-Eigen Johansen cointegration test is examined. Johansen (1991), Phillips and Ouliaris (1988), and Sims et al. (1990) opined that the cointegration technique can be used when a relationship between several non-stationary time series exists among variables. Secondly, the affirmation of the inter-relationship influence that runs through and from the endogenous and exogenous variables and the explicit conversion of the univariate stochastic model into a multivariate vector autoregressive (VAR) estimation is also checked. With this, the forecasting vector is ascertained across each variable in time. Lastly, the forecast response to an n^{th} shock of both endogenous and exogenous variables is then examined using the impulse response function process (IRF) to determine probable shock response outcomes of the variables. However, a pre-estimation test using Augmented Dickey-Fuller (ADF) is carried out before these paths. In addition, the variable is diagnosed with normality distribution status. Similarly, a stylized trend projecting the variable movement in time is also presented for visualization. Data sourced is from the Regional Strategic Analysis and Knowledge Support System (ReSAKSS), Africa Development Bank (AfDB), World Bank Development Indicators, and United Nations Department of Economic and Social Affairs (UN DESA) for 41 years (1981–2022).

Table 7: Description of Variables

Variable	Meaning	Description	Expected sign
FPI	Food Production Index: These crops are considered edible and nutritious for human consumption.	The index describes price changes over time of food commodities in the basket	+ Sig

Variable	Meaning	Description	Expected sign
		weight (2004–2006 = 100). It is derived by dividing the yearly aggregate by the average aggregate to its base year using the Laspeyres index formula. $li = \left(\frac{\Sigma Cij Qir}{\Sigma Cir Qir}\right) x\ 100$ Where: li = Laspeyres Index Cir = price of commodity l at r Qir = represents the quantity of commodity l at time r. Cij = price at time j.	
Popgr	Population growth: This is the annual population growth per country in Africa. Population growth used is Africa-wide.	The population growth rate is the rate of annual growth (%). This represents the annual rate of increase across Africa.	+Sig
HI	Hunger Index: Hunger is a state of distress occasioned by lack of food, undernourishment/malnutrition, or deprivation. The index is the scale that determines the hunger level per country, region, and globally.	A global hunger measurement tool used to track and rank hunger. It is determined on a scale of 100, where 0 indicates no hunger, and 100 signifies the worst.	+ Sig

Estimation path - specification of the model

The following estimation path underpins the study. First, a pre-estimation test was conducted, and the study identified the fitness of the variables by first checking the normality distribution status through skewness, kurtosis, and Jaque-Bera information. Thus, the skewness - where $\S k = \frac{\Sigma f(\chi - \mu)\ 3}{\sigma 3}$ is derived such that $\S k$ = represents skewness; χ…, is the mean of the distribution, µ… is the parameter, and **σ**... is the standard deviation. Such that zero outcome means the variables are symmetrical, +/- outcome means the variables are skewed to the right or left, respectively.

For kurtosis, $k = \frac{\Sigma f(\chi - \mu)4}{\sigma 4}$ is the derivative of kurtosis wherein k>3 is the peak, k<3 is flat, and k=3 is mesokurtic are all possible outcomes. Also, the Jaque-Bera is given as $JB = n\ [\frac{(Nb1)2}{6} + \frac{(b2-3)2}{24}]$ where $b1$.. is sample skewness coefficient, $b2$.. is k coefficients which simply affirms the fitness of the variables and identify whether both $\S k$ and k matches a normal distribution.

Secondly, the empirical model is specified as follows:

$$FPI = f\ (Popgr, HI) \qquad (1)$$

Where: *FP* = food production index and is the dependent variable; *Popgr* = population growth and *HI* = hunger index, independent variables.

When Equation 1 is transformed into its vector autoregressive (VAR) form, in our case, a three-variable VAR form, it becomes:

$$FPI_t = \acute{\alpha} + \sum_{i=1}^{k} \beta_i (FPI)_{t-j} + \sum_{k=1}^{l} \beta_j (Popgr)_{t-j} + \sum_{n=1}^{m} \beta_k (HI)_{t-j} + \varepsilon_{1t} (2)$$

$$Popgr_t = \Phi + \sum_{i=1}^{k} \beta_i (Popgr)_{t-j} + \sum_{k=1}^{l} \beta_j (FPI)_{t-j} + \sum_{n=1}^{m} \beta_k (HI)_{t-j} + \varepsilon_{2t} \ (3)$$

$$HI_t = \delta + \sum_{i=1}^{k} \beta_i (HI)_{t-j} + \sum_{k=1}^{l} \beta_j (Popgr)_{t-j} + \sum_{n=1}^{m} \beta_k (FPI)_{t-j} + \varepsilon_{3t} \ (4)$$

Where: FP_t, *Popgr*, and *HI* are as defined above; *t-j* = lag period of associated series; *t* = time parameter of the estimate; $\varepsilon_{t1..3}$ = stochastic error.

Given Equations 2–4, a pass-through can be explained wherein significant causality can be assessed based on how outcome influences itself (i.e., unidirectional), influences others (bidirectional), and or independently, upon the introduction of one standard deviation shock to one of the innovations as follows:

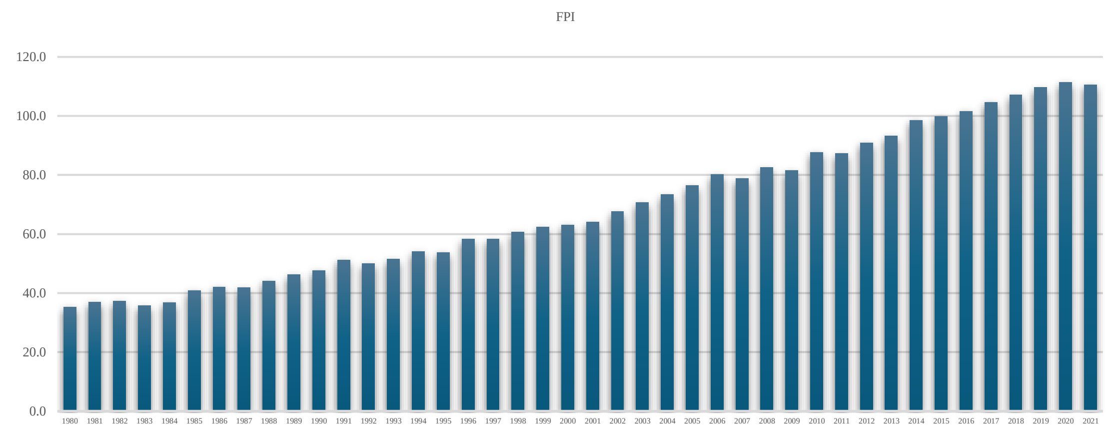
$\sum_{b=1}^{a} \beta_m \neq 0; = \sum_{i=1}^{k} \beta_i ; \sum_{k=1}^{l} \beta_j ; \sum_{n=1}^{m} \beta_k ; = 0$,... wherein, *Popgr* and *HI* cause an increase in the prediction of *FPI*. Also, where $\sum_{b=1}^{a} \beta_m = 0;\ and;\ \sum_{i=1}^{k} \beta_i ;\ \sum_{k=1}^{l} \beta_j ; \sum_{n=1}^{m} \beta_k ; \neq 0,\ \ldots,$ increase *FPI* as a function of increased utility in *Popgr* and *HI*; and, lastly, $\sum_{b=1}^{a} \beta_m \neq 0;\ and;\ \sum_{i=1}^{k} \beta_i ;\ \sum_{k=1}^{l} \beta_j ; \sum_{n=1}^{m} \beta_k ; \sum_{o=1}^{n} \beta_l ; \neq 0$,.. where both endogenous and exogenous influence each other.

Result and analysis

The study started its analysis by first presenting the visual plot of the variables. This enables us to visualize the trend in the movement of these variables for the period in review. These are given hereunder.

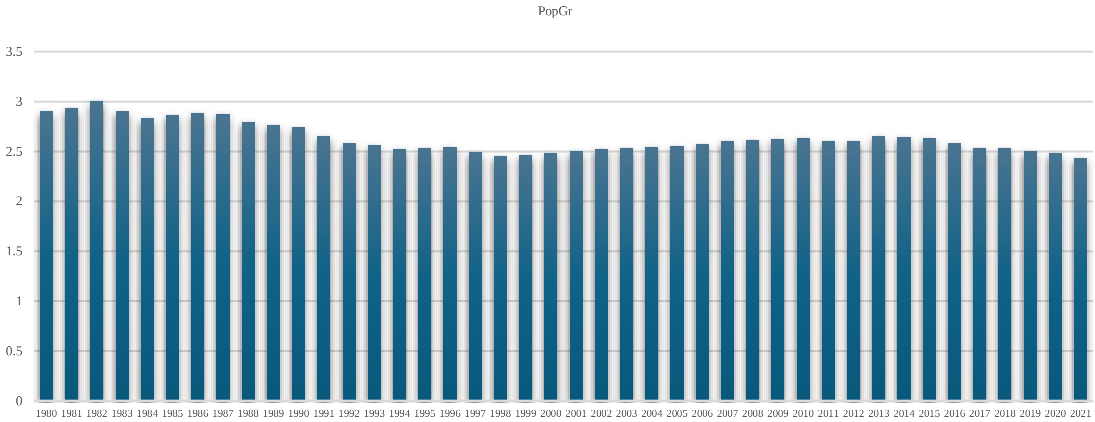
Descriptive Analysis

Figure 3: Food Production Index (FPI)



In Figure 3, the food production index Africa-wide trend shows a step-like movement, trending from low to high. The former occurred at the early period under review and rose steadily toward the end of the review period.

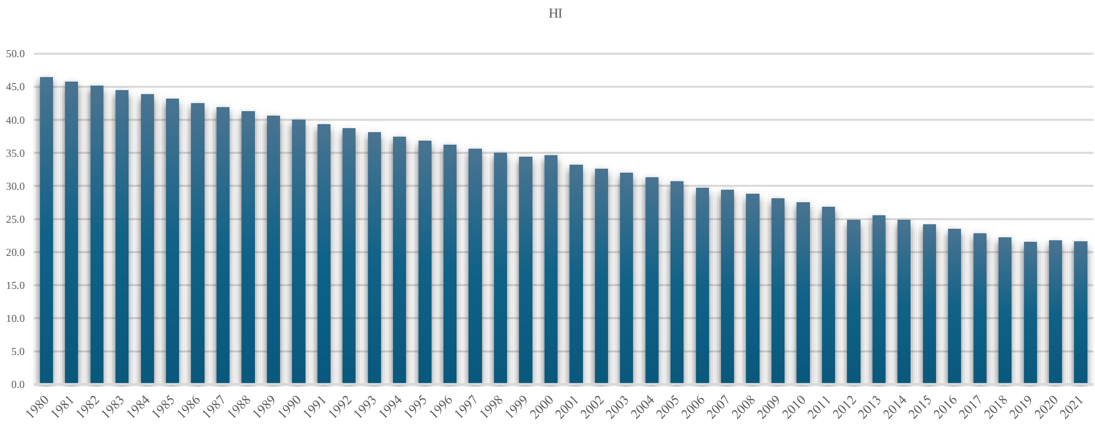
Figure 4: Population Growth (PopGr)



Note: ReSAKSS (2023)

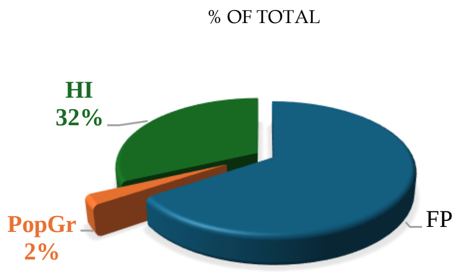
Figure 4 presents the rate of population growth. The trend shows that the population growth rate in Africa slightly oscillates throughout the period. However, this trend indicates little or no significant difference in movement over the period. This depicts an indication of a balanced but steady growth rate in the period in review.

Figure 5: Hunger Index (HI)



Similarly, Figure 5 presents the Africa-wide hunger index level. The visuals indicate a downward step-like slope movement from 1980 through 2021. This trend connotes a visual decline in hunger levels on the continent, suggesting a possible reduced hunger rate.

Figure 6: Percent of Variables Contribution



Note: ReSAKSS (2023)

Lastly, in Figure 6, the combined illustrations for the study variables, food production, population growth, and hunger, are visualized. Again, food production occupies the larger percentage of the other variables. A hunger level of 32% follows this, while population growth stands at 2% for the period in review.

Table 8: Normality Distribution Output

Parameter	Variables		
	FPI	**Popgr**	**HI**
Skewness	0.2956	0.8856	0.0080
Kurtosis	1.8123	2.6065	1.7735
Jarque Bera	3.0801	5.7609	2.6328
Probability	0.2143	0.0561	0.2680

The variables' normality distribution is checked to ascertain their conformity to normal distribution assumptions. The result is presented in Table 8. Three parameters are identified. First, the skewness determines how long or short, positively or negatively skewed the variables are. The results show that all variables are positively skewed and symmetrical. Furthermore, the kurtosis result indicates that FPI and HI are platykurtic while Popgr is slightly mesokurtic. Also, Jacque Bera's outcome demonstrates that all variables are normally distributed judging by the respective probability.

Table 9: Augmented Dickey-Fuller Test Result

Parameter		***t*-statistic**	**Prob.***	**Variable**	**Order**
ADF		-9.6330	0.000	D(FP)	I(1)
Critical Val	1%	-4.2050			
	5%	-3.5266			
	10%	-3.1946			
				D(Popgr)	I(1)
ADF		-4.5908	0.0037		
Critical Val	1%	-4.2050			
	5%	-3.5266			
	10%	-3.1946			
				D(HI)	I(1)
ADF		-8.9171	0.000		
Critical Val	1%	-4.2050			
	5%	-3.5266			
	10%	-3.1946			

The study further checked the stationarity status of the variables. This is to ascertain their level of integration and ascertain further estimation paths. The results presented in Table 9 show that all variables undergone a differencing check. Specifically, D(FPI) became stationary after it was differenced. This makes it an order one variable. Likewise, D(Popgr) did not become stationary at the level until after undergoing the first difference treatment test; thus, it is equally an order one variable. Lastly, D(HI) also became stationary after the first difference treatment was executed. In this way, it is integrated at order one. As a result, the study proceeds to ascertain their level of long-run cointegration relationship using the Johansen cointegration test.

Table 10: Cointegration Result

Unrestricted Cointegration Rank Test (Trace)					
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 CV	Prob.**	Remark
None	0.39689	25.8979	29.7970	0.1318	> 0.05 NC
At most 1	0.09562	5.67141	15.4947	0.7340	> 0.05 NC
At most 2	0.04043	1.65086	3.84146	0.1988	> 0.05 NC
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)					
Hypothesized No. of CE(s)					
None	0.396894	20.22651	21.13162	0.0665	> 0.05 NC
At most 1	0.095628	4.020595	14.26460	0.8572	> 0.05 NC
At most 2	0.040432	1.650866	3.841466	0.1988	> 0.05 NC

*Note: Trace & Max-Eigenvalue test indicates no cointegration at .05 level; **Denotes hypothesis rejection; NC = No cointegration*

Again, the study proceeds to ascertain whether there is a long-run cointegrating relationship between food production, population growth, and hunger in Africa using the Johansen cointegration estimation technique. This was borne out of the outcome of the level of integration of the variables displayed after having undergone stationarity examination. Presented in Table 10 is the outcome of both the Trace and Max-Eigenvalue outcomes. Conventionally, both tests are premised on the assumption that there is no cointegration in any given model on a .05 significant level (Mackinnon et al., 1999). As such, any p value > .05 negates the rejection of the null hypothesis; otherwise, a $p < .05$ means there is cointegration in the model. Thus, for both Trace statistic and Max-Eigenvalue outcome at 'none,' 'at most 1', and 'at most 2', with the corresponding probability (Prob.**), the result indicates that it is > .05. Since the prob. is > .05, the study concludes that a cointegration relation is absent among the variables. By implication, it is said that there is no long-run cointegrating relationship between food production and population growth and hunger in Africa.

To further ascertain the run-through impact of whether food production necessitates population and hunger, whether population influences food production and hunger, or whether hunger relates to population growth and level of food production as derived in Equations 2–4, the study proceeds to determine the impulsive response that runs through them should a one standard deviation shock be introduced in the model, in the long run, using the vector autoregression environment presented below.

Table 11: Lag Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-192.7115	NA	3.567893	9.785575	9.912241	9.831374
1	-13.25444	323.0227	0.000711	1.262722	1.769386*	1.445916
2	-1.050557	20.13641*	0.000611*	1.102528*	1.989190	1.423117*

*Note: *Indicates lag order selected by the criterion; LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion*

The study proceeded to ascertain the lag criterion. This is generated automatically using the system's automatic selection, as presented in Table 11. Clearly, of the available criteria—sequential modified LR test, final prediction error (FPE), Akaike information criterion (AIC), Schwartz information criterion (SIC), and Hannan-Quinn (HQ)—lag(-2) is common to the outcome, as denoted by the symbol. In other words, LR = 20.13641, FPE = 0.000611*, AIC = 1.102528, and HQ = 1.423117 are common selections.

Table 12: VAR Result

	FPI	Popogr	HI
FPI(-1)	0.236467	0.000261	0.051548
	(0.15440)	(0.00386)	(0.04002)
	[1.53153]	[0.06750]	[1.28793]
FPI(-2)	0.300949	-0.001700	-0.017899
	(0.14812)	(0.00371)	(0.03840)
	[2.03173]	[-0.45883]	[-0.46614]
Popgr(-1)	4.142633	1.242562	0.018019
	(6.37594)	(0.15950)	(1.65281)
	[0.64973]	[7.79014]	[0.01090]
Popgr(-2)	3.301276	-0.313311	-0.718771
	(6.54238)	(0.16367)	(1.69595)
	[0.50460]	[-1.91431]	[-0.42441]
HI(-1)	-0.653290	-0.024169	0.666888
	(0.63496)	(0.01588)	(0.439697)
	[-1.36624]	[1.14426]	[2.40955]
C	69.01238	0.394060	-4.920828
	(16.7044)	(0.41789)	(4.33020)
	[4.13139]	[0.94298]	[-1.13640]

The outcome in Table 12 indicates the result derived from the vector autoregression estimation. Recall that var structure allows a linear function estimation of each variable (endogenous and exogenous) as the past lag of self (endogenous) and other variables (exogenous). Data in parentheses (( )) denotes the standard error, ([ ]) denotes *t*-statistics, and C represents the coefficient. A coefficient may be negative (-) or positive (+), indicating a negative or positive signed outcome. A *t*-statistic value of less than 2 (< 2) or greater than 2 (> 2) means an insignificant or significant outcome, respectively. Thus, the coefficients are positively signed but statistically insignificant for FPI(-1) through FPI, Popgr, and HI.

Similarly, the outcomes shown by Popgr(-1) through FP, Popgr, and HI are all positively signed. However, the relationship between Popgr and FPI is insignificant, judging by the t-statistics. That of Popgr and Popgr at 7.7901 indicates that it is significant. This is evidence of increased population growth in Africa. Lastly, Popgr and HI are also insignificant, judging by the value of the t-statistics. This outcome affirms the presence of hunger in the continent.

Overall, HI(-1) results across FPI, Popgr, and HI indicate that both FP and Popgr are negatively signed to HI(-1), while HI is positive. Similarly, the t-statistic between HI(-1) and FP is also negatively signed and statistically insignificant. This affirms the insignificant outcome recorded against Popgr and HI in the earlier paragraph. In addition, HI(-1) and Popgr are also statistically insignificant. However, HI and HI show that they are significant at a slightly moderate level.

Table 13: Serial Correlation

Null hypothesis: No serial correlation at lag h & at lags 1 to h						
Lag	**LRE* stat**	**Df**	**Prob.**	**Rao F-stat**	**df**	**Prob.**
1	13.75806	9	0.1312	1.602823	(9, 68.3)	0.1319
2	10.88447	9	0.2837	1.242212	(9, 68.3)	0.2847

*Note: *Edgeworth expansion corrected likelihood ratio statistic*

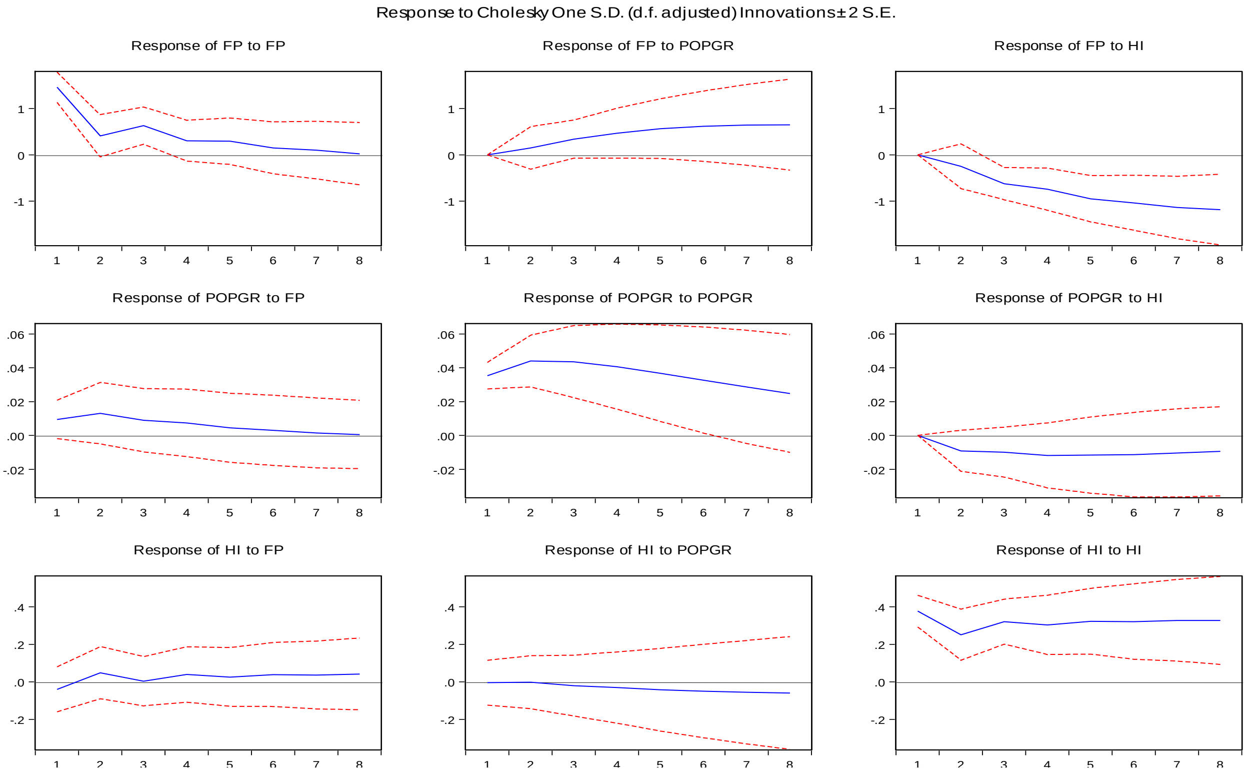
To ensure that serial correlation is not present in the model and to avoid estimation bias, the study performed the serial correlation estimation check. Serial or autocorrelation is used to ascertain whether error terms correlate over time. The null proposition is often that no serial correlation is checked against the .05 significant level. With the outcome in Table 13 and corresponding probabilities of LRE* stat and Rao F-stat, the study concludes that there is no serial correlation; thus, the model has no estimation bias.

Table 14: Homoscedastic Outcome

Joint test:		
Chi-sq	**df**	**Prob.**
82.67785	72	0.1829

Again, the study also checked whether the model is homoscedastic. This is done by ascertaining the residual and the error term variance for consistency to fulfill the assumption of a basic regression model. Based on the result in Table 14, the model is homoscedastic because the null hypothesis is not rejected. Thus, it is concluded that the residuals are distributed with equal variance.

Figure 7: Impulse Response Function of All Variables



Presented in Figure 7 is the impulse response function of the var extension of the model. Here, the aim is to ascertain how responsive each variable is to one standard deviation shock to one another. In order words, nine figures from food production through population growth and hunger are presented. Again, each figure has two red lines described as the confidence interval at 95% level, the blue line indicates the impulse response function (IRF), and the numbering 1 to 8 indicates the time in period (i.e., years).

Thus, from the right-hand side of the figure to the left, the FP to FP index maintained a sharp decline from Periods 1 to 2. There was a minor increase in Period 3 after that, but this soon declined in Period 4 and later dipped again in Period 5, maintaining a gradual decline till Period 8. Further, the FP index to Popgr maintained a relatively stable state mid-way through Periods 1 to 2. After that, there was a minor increase in Period 3, and it gained another minor increase in Periods 4 to 5 and 6 and maintained this state throughout the period. Going forward, the FP index and HI demonstrate a negative and steady decline state throughout the period. Although a minor decline was recorded in Period 1, it dipped further throughout the period, climaxing at a -1.

Furthermore, Popgr to FP index shows some level of stability in Periods 1 to 2. After that, it declined till it reached the baseline in Period 8. Also, Popgr to Pogr gradually increased in Periods 1 to 2. It maintained stability after that until Period 3 but dipped into a step-like form from Period 3 to Period 8. Similarly, Popgr to HI is negatively signed throughout the period. Although a minor negative decline was recorded in Period 1, this further dipped in Period 2 through to Period 8.

Similarly, the HI to FP index declined in Period 1 through mid-way. However, it rose above the baseline in Period 2, declining back to the base in Period 3 before it peaked again in Period 4. It maintained an oscillatory trend not above its previous peak till Period 8. Furthermore, the HI and Popgr trend maintains a negative trend throughout the period, except for a slightly below baseline trend recorded in Period 1. Finally, HI and HI sharply declined from Period 1 to 2. There is a minor increase later but above the Period 1 threshold. After that, a steady state trend is recorded for the rest of the period.

Conclusion and recommendation

The conclusion reached from the result of the study further invalidates earlier assumptions of commendable food production in Africa. It shows that Africa's aspiration to meet the required food needs is far from reality, judging by the absence of a long-run cointegrating relationship between food production, population growth, and hunger. Likewise, the result also demonstrates the continent's inability to withstand plausible food shock.

Further, the non-existence of a long-run relationship occasioned by both the Trace and Max-Eigenvalue estimation outcome, which led to the use of a vector autoregression estimation, also led to the conclusion that the dynamic relationship expected between food production, population growth, and hunger does not exist, if at all it does exist, it is low. In order words, there is a weak interaction between these variables. Also, this conclusion places urgent responsibilities on the government to aid planning and forecasting purposes, especially as shown by the rising population outcome.

Lastly, the probable impact of the shock on the FP on Popgr and HI is checked using the impulse response function technique. The result further intensifies our conclusion of a critical situation between food production, population growth, and hunger in Africa. By implication, it means any one probable shock to food production will exacerbate the hunger situation that needs attention in Africa and slow down the likelihood of attaining the 2030 goal.

To gauge the already established level of hunger and to avoid an increase in the number of populations already impacted, urgent action is required. Moreso, the continent battles with all forms of unfavorable human and natural challenges: drought, famine, unrest, insecurity, poverty, insurgency, climate change, floods, diseases, and land issues, among others. In order words, a mass campaign for mass food production is urgently required. Also, consideration of amendments to constraints, such as laws (i.e., land, etc.), that hinder mass food production is urgently needed. It is also imperative that alternative food production techniques be considered (i.e., mechanized, technology, etc.). Similarly, food production peculiarity is vital, such that regions tend to specialize in production with which it has an advantage and can exchange with one another for the ultimate merits inherent in economies of scale. Most importantly, African synergy is imperative at this time to achieve this feat.

Acknowledgments

The authors hold our anonymous referees for open-access papers in high esteem. We also acknowledge the editor in principle. This article APC is made possible with support from the management of the University of South Africa research fund, and the authors thank the institution.

References

Adeleye, B. N., Gershon, O., Ogundipe, A., Owolabi, O., Ogunrinola, I., & Adediran, O. (2020). Comparative investigation of the growth-poverty-inequality trilemma in Sub-Saharan Africa and Latin America and Caribbean countries. *Heliyon, 6*, Article e05631. https://doi.org/10.1016/j.heliyon.2020.e05631

African Development Bank (AfDB). (2022, January). *AfDB Statistics Pocketbook 2022* (Vol. 22). https://www.afdb.org/en/documents/afdb-statistics-pocketbook-2022

Akinbode, S. O., Okuneye, P. A., & Onyeukwu, C. O. (2022). Inequality, population growth, and hunger in Sub-Saharan Africa. *SN Social Sciences, 2*(250), 1–23. https://doi.org/10.1007/s43545-022-00554-x

Arndt, C., Diao, X., Dorosh, P., Pauw, K., & Thurlow, J. (2023). The Ukraine war and rising commodity prices: Implications for developing countries. *Global Food Security, 36*, Article 100680. https://doi.org/10.1016/j.gfs.2023.100680

Brown, M. E., Backer, D., Billing, T., White, P., Grace, K., Doocy, S., & Huth, P. (2020). Empirical studies of factors associated with child malnutrition: Highlighting the evidence about climate and conflict shocks. *Food Security, 12*, 1241–1252. https://doi.org/10.1007/s12571-020-01033-7

Corral, P., Irwin, A., Krishnan, N., Gerszon, D. M., & Vishwanath, T. (2020). *Fragility and conflict: On the front lines of the fight against poverty*. World Bank. https://doi.org/10.1596/978-1-4648-1540-9

Doku, I., Richardson, T. E., & Essah, N. K. (2022). Bilateral climate finance and food security in developing countries: A look at German donations to Sub-Saharan Africa. *Food and Energy Security, 11*, 1–15. https://doi.org/10.1002/fes3.304

El-Rasoul, A. A., & Ali, A. M. (2020). The causality relationship between nutrition and economic growth in Egypt. *Middle East Journal of Applied Sciences, 10*(01), 138–145. https://doi.org/10.36632/mejas/2020.10.1.16

Fagbemi, F., Oke, D. F., & Fajingbesi, A. (2023). Climate-resilient development: An approach to sustainable food production in Sub-Saharan Africa. *Future Foods, 7*, Article 100216. https://doi.org/10.1016/j.fufo.2023.100216

Fauziyyah, N. E., & Duasa, J. (2021). Analysis of food security in Southeast Asia countries. *Earth and Environmental Science, 756*, Article 012020. https://doi.org/10.1088/1755-1315/756/1/012020

Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP), & World Health Organization (WHO). (2020, July). *The state of food security and nutrition in the world: Transforming food systems for affordable healthy diets*. FAO. https://doi.org/10.4060/ca9692en

Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP), & World Health Organization (WHO). (2022, July). *The state of food security and nutrition in the world 2022: Repurposing food and agricultural policies to make healthy diets more affordable*. FAO. https://doi.org/10.4060/cc0639en

Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP), & World Health Organization (WHO). (2023a, July). *The state of food security and nutrition in the world 2022: Urbanization, agrifood system transformation and healthy diet across the rural-urban continuum*. FAO. https://doi.org/10.4060/cc3017en

Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP), & World Health Organization (WHO). (2023b, June). *The state of food security and nutrition in the world 2023: Urbanization, agrifood systems transformation and healthy diets across the rural-urban continuum*. Rome, FAO. https://doi.org/10.4060/cc3017en

Goli, S., Mavisakalyan, A., Rammohan, A., & Vu, L. (2022). Exposure to conflict and child health outcomes: Evidence from a large multi-country study. *Conflict and Health, 16*, Article 52. https://doi.org/10.1186/s13031-022-00483-9

Grace, K., Verdin, A., Brown, A., Bakhatsiyarava, M., Backer, D., & Billing, T. (2022). Conflict and climate factors and the risk of child acute malnutrition among children aged 24–59 months: A comparative analysis of Kenya, Nigeria, and Uganda. *Spatial Demography, 10*, 329–358. https://doi.org/10.1007/s40980-021-00102-w

Harris, J., Nguyen, P. H., Tran, L. M., & Huynh, P. N. (2020). Nutrition transition in Vietnam: Changing food supply, food prices, household expenditure, diet, and nutrition outcomes. *Food Security, 12*, 1141–1155. https://doi.org/10.1007/s12571-020-01096-x

High Level Panel of Experts on Food Security and Nutrition [HLPE]. (2014). *Food losses and waste in the context of sustainable food systems*. Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i3901e/i3901e.pdf

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregression models. *Econometrica, 59*(6), 1551–1580. https://doi.org/10.2307/2938278

Kamenya, M. A., Hendricks, S. L., Gandidzanwa, C., Ulimwengu, J. M., & Odjo, S. (2022). Public agriculture investment and food security in ECOWAS. *Food Policy, 113*, Article 102349. https://doi.org/10.1016/j.foodpol.2022.102349

Mackinnon, J. G., Haug, A. A., & Michelis, L. (1999). Numerical distribution functions of likelihood ratio tests for cointegration. *Journal of Applied Econometrics, 14*(5), 563–577. http://www.jstor.org/stable/223206

Malthus, T. R. (1998). *An essay on the principle of population, as it affects the future improvement of society*. (Original work published 1798). Electronic Scholarly Publishing Project. http://www.esp.org/books/malthus/population/malthus.pdf

Mazzucato, M., Semieniuk, G., & Watson, D. (2020). Climate change and the tasks of the state. *World Development, 132*, Article 104992. https://doi.org/10.1016/j.worlddev.2020.104992

Mustapha, S. A., & Enilolobo, O. S. (2019). Role of public agriculture spending on performance in Sub-Saharan Africa: A channel-based analysis. *Canadian Social Science, 15*(8), 59–73. http://dx.doi.org/10.3968/11227

Neal, C., Pepper, G. V., Allen, C., & Nettle, D. (2023). No effect of hunger on attentional capture by food cues: Two replication studies. *Appetite, 191*, Article 107065. https://doi.org/10.1016/j.appet.2023.107065

Ogunniyi, O. R., Okunlola, F. A., & Alatise, M. A. (2021). Intra-Africa agricultural trade and hunger reduction: Africa economic analysis. *Ilorin Journal of Economics Policy (IJEP), 8*(3), 36–52.

Okunlola, F. A., Osuma, G. O., & Omankhanlen, E. A. (2019a). Agricultural finance and economic growth: Evidence from Nigeria. *Business: Theory and Practice, 20*, 467–475. https://doi.org/10.3846/btp.2019.43

Okunlola, F. A., Osuma, G. O., & Omankhanlen, A. E. (2019b). Has Nigerian agricultural output spurred economic growth: The financing gap model using stepwise regression. *Investment Management and Financial Innovations, 16*(3), 157–166. https://doi.org/10.21511/imfi.16(3).2019.15

Osinubi, T. T., & Apanisile, O. T. (2021). Effect of agricultural investment on food security in Sub-Saharan Africa: What role does institution play? *International Journal of Food and Agricultural Economics, 9*(2), 125–141. https://www.foodandagriculturejournal.com/vol9.no2.pp125.pdf

Pawlak, K., & Kolodziejczak, M. (2020). The role of agriculture in ensuring food security in developing countries: Consideration in the context of the problem of sustainable food production. *Sustainability, 13*, Article 5488. https://doi.org/10.3390/su12135488

Phillips, P. C. B., & Ouliaris, S. (1988). Testing for cointegration using principal components methods. *Journal of Economic Dynamics and Control, 12*(2–3), 205–230. https://doi.org/10.1016/0165-1889(88)90040-1

Reardon, T., Echeverria, R., Berdegue, J., Minten, B., Liverpool-Tasie, S., Tschirley, D., & Zilberman, D. (2019). Rapid transformation of food systems in developing regions: Highlighting the role of agricultural research & innovations. *Agricultural Systems, 172*, 47–59. https://doi.org/10.1016/j.agsy.2018.01.022

Regional Strategic Analysis and Knowledge Support System [ReSAKSS]. (2023, July). *Data sets for tracking the implementation of the Comprehensive Africa Agriculture Development Programme (CAADP)*. Retrieved from https://www.resakss.org/

Shukla, P. R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D. C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M., & Malley, J. (Eds.). (2021, August). *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes* *in terrestrial ecosystems*. Intergovernmental Panel on Climate Change (IPCC). https://www.ipcc.ch/srccl/

Sims, C. A., Stock, J. H., & Watson, M. W. (1990). Inference in linear time series models with some unit roots. *Econometrica, 58*(1), 113–144. https://doi.org/10.2307/2938337

Statista. (2009, June). *Areas of arable land in selected world regions 1961, 1991, 2007 (in millions of hectares)*. https://www.statista.com/statistics/269235/arable-land-worldwide-by-region/

Tacoli, C. (2017). Food (in)security in rapidly urbanizing, low-income contexts. *International Journal of Environmental Research and Public Health, 14*(12), Article 1554. https://doi.org/10.3390/ijerph14121554

Ulimwengu, J. M., & Blumenthal, N. (2023). Assessing structural failure of African food systems. In S. Maina (Ed.), *Empowering Africa's food systems for the future* (Issue 11, pp. 27–51). AGRA. https://agra.org/wp-content/uploads/2023/09/AASR-2023.pdf

Ulimwengu, J. M., Domgho, L. M., & Collins, J. (2021). Assessing the vulnerability of West and Central Africa countries to COVID-19. In J. M. Ulimwengu, M. A. Constas, & E. Ubalijoro (Eds.), *2021 Annual trend and outlook report: Building resilient African food systems after COVID-19* (Chapter 5, pp. 66–80). International Food Policy Research Institute (IFPRI). https://ebrary.ifpri.org/digital/collection/p15738coll2/id/134755

United Nations Department of Economic and Social Affairs (UN DESA). (2022). *World population prospects 2022: Summary of results* (UN DESA/POP/2022/TR/N0.3). United Nations. https://www.un.org/development/desa/pd/content/World-Population-Prospects-2022

United Nations Department of Economic and Social Affairs (UN DESA). (2023, January). *World social report 2023: Leaving no one behind in an ageing world* (ST/ESA/379). United Nations. https://www.un.org/development/desa/pd/content/world-social-report-2023

von Braun, J., Afsana, K., Fresco, L., & Hassan, M. (2021). Food systems: Seven priorities to end hunger and protect the planet. *Nature, 597*, 28–30. https://doi.org/10.1038/d41586-021-02331-x

von Braun, J., Afsana, K., Fresco, L. O., Hassan, M., & Torero, M. (2021). Food system concepts and definitions for science and political action. *Nature Food, 2*(12), 748–750. https://doi.org/10.1038/s43016-021-00361-2

von Braun, J., Ulimwengu, J. M., Nwafor, A., & Nhlengethwa, S. (2023). Overview chapter. In S. Maina (Ed.), *Empowering Africa's food systems for the future* (Issue 11, pp. 14–26). AGRA. https://agra.org/wp-content/uploads/2023/09/AASR-2023.pdf

von Grebmer, K., Bernstein, J., Wiemers, M., Reiner, L., Bachmeier, M., Hanano, A., Towey, O., Ní Chéilleachair, R., Foley, C., Gitter, S., Larocque, G., & Fritschel, H. (2022, October). *2022 Global Hunger Index: Food systems transformation and local governance*. Welthungerhilfe. https://www.globalhungerindex.org/pdf/en/2022.pdf

World Food Programme (WFP). (2020, April 15). *Global hunger crisis*. https://www.wfp.org/global-hunger-crisis

World Bank. (2020, October 7). *Poverty and shared prosperity 2020: Reversals of fortune—Frequently asked questions*. https://www.worldbank.org/en/research/brief/poverty-and-shared-prosperity-2020-reversals-of-fortune-frequently-asked-questions

World Bank. (2021). *The Human Capital Index 2020 update: Human capital in the time of COVID-19*. https://doi.org/10.1596/978-1-4648-1552-2

World Bank. (2023, July 27). *Food security update*. https://www.worldbank.org/en/topic/agriculture/brief/food-security-update