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Benjamin Darkwa[1], Kwabena Danso[2]

FORECASTING PROTEIN FOOD PRODUCTION IN AFRICA: TRENDS, CHALLENGES, AND POLICY INTERVENTIONS FOR SUSTAINABLE FOOD SECURITY

Abstract: Food security remains a critical challenge in Africa, particularly as the demand for protein-rich foods rises. Despite possessing vast agricultural potential, the continent struggles with optimizing protein food production due to limited access to modern farming technologies, inadequate storage facilities, and inefficient distribution networks. This study models and forecasts protein food production in Africa from 2020 to 2030 using a forest-based forecasting approach. The analysis focuses on key protein sources, including milk, livestock, eggs, and beans, utilizing data from the Food Production Index. The study employs ArcGIS Pro 2.8.2 to assess production trends and spatial variations across African regions. Findings reveal significant trends, with milk production peaking in 2022, livestock production increasing in 2028, egg production reaching its highest level in 2027, and bean production recording its peak in 2030. The results highlight the need for policy interventions to enhance protein production, particularly in low-performing regions such as Western Sahara, Chad, and Burkina Faso. It is recommended that African governments, stakeholders (such as the African Union) and NGOs should bring strategic investments in infrastructure, technological advancements, and policy frameworks to boost protein food security and support sustainable agricultural development in Africa.

Keywords: Food Security, Protein Food Production, Fores-Based Forecasting, Sustainable Agriculture, Africa

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[1] University of Education Winneba, Faculty of Social Sciences Education, Department of Geography Eduation, Winneba, Ghana, ORCID ID: https://orcid.org/0009-0005-9336-7358, email: darkwabenjamin45@gmail.com

[2] University of Education Winneba, Faculty of Social Sciences Education, Department of Geography Eduation, Winneba, Ghana, ORCID ID: https://orcid.org/0009-0000-5865-8102, email: danso.kwabena@outlook.com

Introduction

Food security remains a critical global challenge, particularly as the world population continues to grow and resources become increasingly strained. The demand for protein-rich foods, essential components of human nutrition and development, has risen significantly in recent decades (Food and Agriculture Organization, 2022). Global protein food production, encompassing animal and plant-based sources, faces numerous challenges including climate change, resource constraints, and technological limitations (Nirmal et al., 2024). These challenges are particularly pronounced in developing regions, where protein deficiency is a significant nutritional concern affecting millions.

Africa, home to approximately 1.4 billion people, faces unique challenges in protein food production and accessibility. The continent's protein consumption per capita remains significantly lower than global averages. According to recent estimates, the average daily protein intake in Sub-Saharan Africa is approximately 56 grams per person, compared to the global average of about 83 grams per person per day (FAO, 2022). This disparity underscores the urgent need for interventions aimed at improving protein availability and accessibility across the continent, with many regions consuming less than half the recommended daily protein intake (Sans & Combris, 2015). Despite possessing vast agricultural potential, including approximately 60% of the world's uncultivated arable land, Africa struggles to optimize its protein food production systems. This is particularly concerning given that the recommended daily protein intake for a healthy adult is about 50 to 60 grams, depending on age, sex, and level of physical activity. Traditional protein sources such as livestock, fish, and legumes face production constraints due to limited access to modern farming technologies, inadequate storage facilities, and inefficient distribution networks (Adeyeye, 2017).

The situation is further complicated by rapid population growth, urbanization, and changing dietary patterns across the continent. By 2050, Africa's population is projected to double, placing unprecedented pressure on existing food production systems (Serraj et al., 2019). This demographic shift, coupled with rising income levels in some regions, has led to increased demand for protein-rich foods, creating a widening gap between production and consumption. Despite numerous agricultural initiatives and policies aimed at boosting food production, there remains a significant knowledge gap regarding the trajectory of protein food production in Africa. Current production models often fail to account for the complex interplay of factors affecting protein food systems across the continent's diverse ecological and socioeconomic landscapes. Understanding these patterns and developing accurate forecasting models is crucial for informed policy-making and strategic planning.

This study addresses this knowledge gap by modelling and forecasting protein foods production in Africa from 2020 to 2030. Specifically, the research seeks to identify key factors influencing food production and develop robust forecasting models to project future production scenarios. The study provides valuable insights for policymakers, agricultural stakeholders, and food security initiatives working to enhance protein food production across Africa.

Materials and methods

Study area: Africa is the world's second-largest continent and has the second-highest population after Asia, covering approximately 30.3 million km^2 (11.7 million square miles), which constitutes about 20% of the Earth's total land area (Nzabarinda et al., 2021). As of 2024, Africa's population was estimated at 1.48 billion, representing nearly 18.8% of the global population (You et al., 2014). Geographically, the continent is bordered by the Mediterranean Sea to the north, the Isthmus of Suez and the Red Sea to the northeast, the Indian Ocean to the southeast, and the Atlantic Ocean to the west. It includes 54 fully recognized sovereign countries, eight territories, and two de facto independent entities. Algeria is the largest country by land area, Seychelles the smallest, and Nigeria is the most populous.

Economically, Africa is rich in natural resources and has a diverse range of economic activities, including mining, oil and gas production, tourism, manufacturing, and services. However, agriculture remains the backbone of most African economies. It employs approximately 60% of the continent's labor force, making it the largest employer, especially in rural areas. The sector comprises both food crop and animal production, which are vital for food security and livelihoods. Despite its potential, agricultural productivity remains relatively low due to factors such as limited access to technology, climate variability, poor infrastructure, and underinvestment.

Given that food crop and animal production are primary sources of dietary protein for most African populations, improving agricultural systems is central to addressing protein deficiencies and ensuring food security. This makes the study of protein food production across Africa relevant and urgent in the context of rising population pressures and nutritional needs.

Research design approach: This study adopted the quantitative research approach, informed by a descriptive research design. Descriptive research design is the type of research design that aims to obtain information to systematically describe phenomena, situations or populations (Kim et al., 2017). It was simpler for the researchers to explain a specific phenomenon at one particular time to make quantifiable conclusions. In demonstrating the suitability of the adopted descriptive research design and approach, it has been determined that it is appropriate for providing numerical descriptions of trends, attitudes, or opinions of the targeted population in Africa.

Data sources and processing: The study employed the Food Production Index, which was acquired from the World Bank (https://bit.ly/2mNpi9T). Beans, milk, livestock, and eggs were chosen as food variables from the Food Production Index due to the scarcity of research studies and their relevance to human growth (Table 1).

The selection was based on the Gross Per Capita Production. Table 1 depicts the variables for the food production index used in this study. Microsoft Excel was used to process and filter the food production index. The sorting considered the variables and year gap for the research. Afterwards, the datasets were joined to the African State shapefile, using ArcGIS Pro 2.8.2. The African country's layers had their geographic coordinates as the EPSG:4326, which is then projected to WGS 1984 World Mercator

projected geographic coordinate. This was done using ArcGIS Pro 2.8.2. The shapefile was acquired from ICPAC GEOPORTAL and available at https://bit.ly/3E1R33S.

Table 1. The primary dataset variables

Variable (Item)	Variable (Item) Code
Beans (dry)	176
Livestock	2044
Egg (hen in shell)	1062
Milk (total)	1780

Source: World Bank, 2024

Data analysis: The study employed a forest-based forecast approach to predict food production trends in African countries over the next ten years. This method was chosen due to its capacity to handle complex temporal and spatial patterns in food production. Specifically, the food production index variables including beans, livestock, eggs, and milk were analyzed using the forest-based forecast model because of their nonlinear and dynamic trends. The analysis was conducted using ArcGIS Pro 2.8.2, which integrates geospatial and statistical tools to generate predictive models.

The forest-based forecast tool in ArcGIS Pro utilizes decision trees and machine learning techniques to identify patterns and trends in time-series data. It applies forest-based regression to forecast the future time slice of a space-time cube. This spatiotemporal data structure captures variations in food production across both space and time (Environmental Systems Research Institute [ESRI], 2022). The model aggregates historical production data and accounts for multiple influencing factors, such as climatic conditions, land use changes, and socio-economic variables. By leveraging multiple decision trees, the model minimizes prediction errors and enhances accuracy in forecasting.

The forecasting process involved training the model on historical food production data and validating its predictive capabilities by assessing key statistical parameters, including mean, standard deviation, minimum and maximum values, skewness, and kurtosis. These statistical measures provided insights into production fluctuations and distribution patterns across different African regions. Additionally, the study assessed spatial variations by mapping the predicted production levels across the continent to identify regions of high and low food output.

The results from the forest-based forecast analysis offered critical insights into the stability and potential growth of the food production sector in Africa. By capturing regional disparities and production trends, this approach contributes to informed decision-making for policymakers and stakeholders in the agricultural sector. The predictive analysis is essential for strategic planning, ensuring food security, and implementing sustainable agricultural practices across the continent.

However, one limitation of the forest-based forecasting approach is its reliance on the availability and consistency of historical data. Incomplete or sparse data can affect the accuracy

of predictions. To address this, the study ensured thorough data preprocessing and validation to minimize errors and enhance the reliability of the forecast results

Results and discussion

The forest-based forecast analysis performed on food production revealed that the production of milk, livestock, eggs and beans in Africa remained consistent within 10-year years. Thus, from the analysis, 2022 was the year predicted to have high production of milk (Mean [M]= 89.1, Maximum [Max]= 115 and Sum= 5258 and Standard Deviation [SD]= 31.1) (Table 2). Even though 2022 recorded the highest production of milk, there is little difference when comparing its total (Sum) production to that 2028 year, which recorded the lowest milk production. Thus, the margin increase does not exceed 50 metric tons. Moreso, there is a significant increase in livestock production in 2028 (M= 92.0, Max= 137, Sum= 5429, SD= 29.2). When assessed from 2028 to 2020 (M= 91.5, Max= 137, Sum= 5401, SD= 29.1), the livestock production margin was very small, an approximately 28 metric tons increase, even though 2020 recorded the lowest livestock production.

In Figure 1, the production of milk across the African continent in 2030 clearly shows equal production distribution in the continent. In most countries, milk production ranges between 92 to 181 metric tons. West Sahara, Cote D'lvoire, Burkina Faso, Chad and Botswana were the countries that recorded the lowest production of milk between 0 to 90 metric tons. Notwithstanding, the production of livestock in the African continent depicts that almost all African countries except for Western Sahara recorded between 182 to 272 of livestock production. Western Sahara recorded the lowest production of livestock, between 0 to 90. Moreso, low egg production is more concentrated in western, central and some parts of eastern Africa. These areas recorded production of eggs between 0 to 91. In general, most of the continent's egg production ranges between 92 to 181. Furthermore, the concentration of the lowest beans production is more prevalent in the central, eastern and other western parts of Africa. This region's beans production falls between 0 to 90. Most of the high bean's production, between 92 to 181 was prevalent in the Sahel region, easternmost and the northernmost part of the continent. Although production across the continent was low, Mozambique recorded the highest production of beans, that is between 364 to 453.

Milk production plays a central role in Africa's economic and sustainable development. It contributes to food security, combats malnutrition and reduces regional poverty (Mohajan, 2022). Milk production in Africa has also created rural employment (nearly 80% of the African population resides in the countryside) and increased the economic potential of pastoral areas (Holechek et al., 2017). In Figure 1, five (5) countries produce low milk production (0-91), including Western Sahara, Ivory Coast, Chad, Botswana and Burkina Faso. Despite substantial growth in recent years, the milk sector in these African countries faces significant drawbacks, such as high production costs and low yields. This is due to the lack of infrastructure and appropriate equipment in the production process (Obokoh & Goldman, 2016). Another factor that affects animal health is low-grade feed. Moreover, conflicts are also a significant factor contributing to low milk production in some countries, as they disrupt access to grazing lands, water, and veterinary care.

Table 2. Forest-based forecast on protein food production from 2020–2030

Variables	Years	Mean	Min	Std. Dev.	Max	Sum	Skewness	Kurtosis
Milk	2020	88.6	0	31.1	123	5225	-2.3	7.0
	2021	89.0	0	31.1	120	5253	-2.4	7.1
	2022	89.1	0	31.1	115	5258	-2.4	7.1
	2023	89.0	0	31.1	114	5253	-2.4	7.1
	2024	89.0	0	31.1	114	5249	-2.4	7.1
	2025	88.7	0	30.9	114	5235	-2.4	7.2
	2026	88.7	0	31.1	120	5234	-2.3	7.1
	2027	88.3	0	30.9	121	5209	-2.3	7.1
	2028	88.3	0	31.0	118	5209	-2.3	7.0
	2029	88.5	0	31.1	117	5221	-2.3	7.0
	2030	89.0	0	31.2	117	5250	-2.3	7.0
Livestock	2020	91.5	0	29.1	137	5401	-2.6	8.7
	2021	91.6	0	29.1	137	5404	-2.6	8.7
	2022	91.8	0	29.1	137	5414	-2.6	8.8
	2023	91.9	0	29.1	137	5420	-2.6	8.8
	2024	91.9	0	29.1	137	5423	-2.6	8.8
	2025	91.9	0	29.1	137	5419	-2.6	8.8
	2026	92.0	0	29.2	137	5426	-2.6	8.8
	2027	92.0	0	29.2	137	5425	-2.6	8.7
	2028	92.0	0	29.2	137	5429	-2.6	8.7
	2029	92.0	0	29.2	137	5428	-2.6	8.7
	2030	91.9	0	29.2	137	5424	-2.6	8.7
Egg	2020	85.6	0	33.8	140	5051	-1.8	5.2
	2021	85.9	0	33.8	140	5067	-1.8	5.3
	2022	86.3	0	34.0	140	5094	-1.8	5.3
	2023	86.7	0	34.0	140	5113	-1.8	5.4
	2024	86.4	0	33.9	140	5099	-1.8	5.4
	2025	86.9	0	34.2	140	5125	-1.8	5.3
	2026	87.1	0	34.4	140	5139	-1.8	5.3
	2027	87.3	0	34.5	140	5149	-1.8	5.3
	2028	87.2	0	34.6	140	5145	-1.7	5.2
	2029	87.1	0	34.6	140	5137	-1.7	5.2
	2030	86.9	0	34.4	140	5124	-1.8	5.2
Beans (dry)	2020	60.5	0	54.0	191.2	3571	0.0	1.7
	2021	62.5	0	57.3	240.3	3686	0.3	2.6
	2022	62.5	0	58.4	277.1	3686	0.6	4.0
	2023	62.7	0	59.5	291	3701	0.7	4.6
	2024	63.4	0	60.6	298.6	3740	0.8	4.7
	2025	62.9	0	60.4	303.8	3709	0.9	5.1
	2026	63.5	0	62.7	324.2	3745	1.1	6.0
	2027	63.8	0	64.6	354.5	3764	1.4	7.8
	2028	63.9	0	65.8	372.9	3770	1.6	9.1
	2029	64.7	0	68.1	394.3	3817	1.8	10.1
	2030	65.2	0	72.7	453.3	3844	2.5	14.6

Source: own study

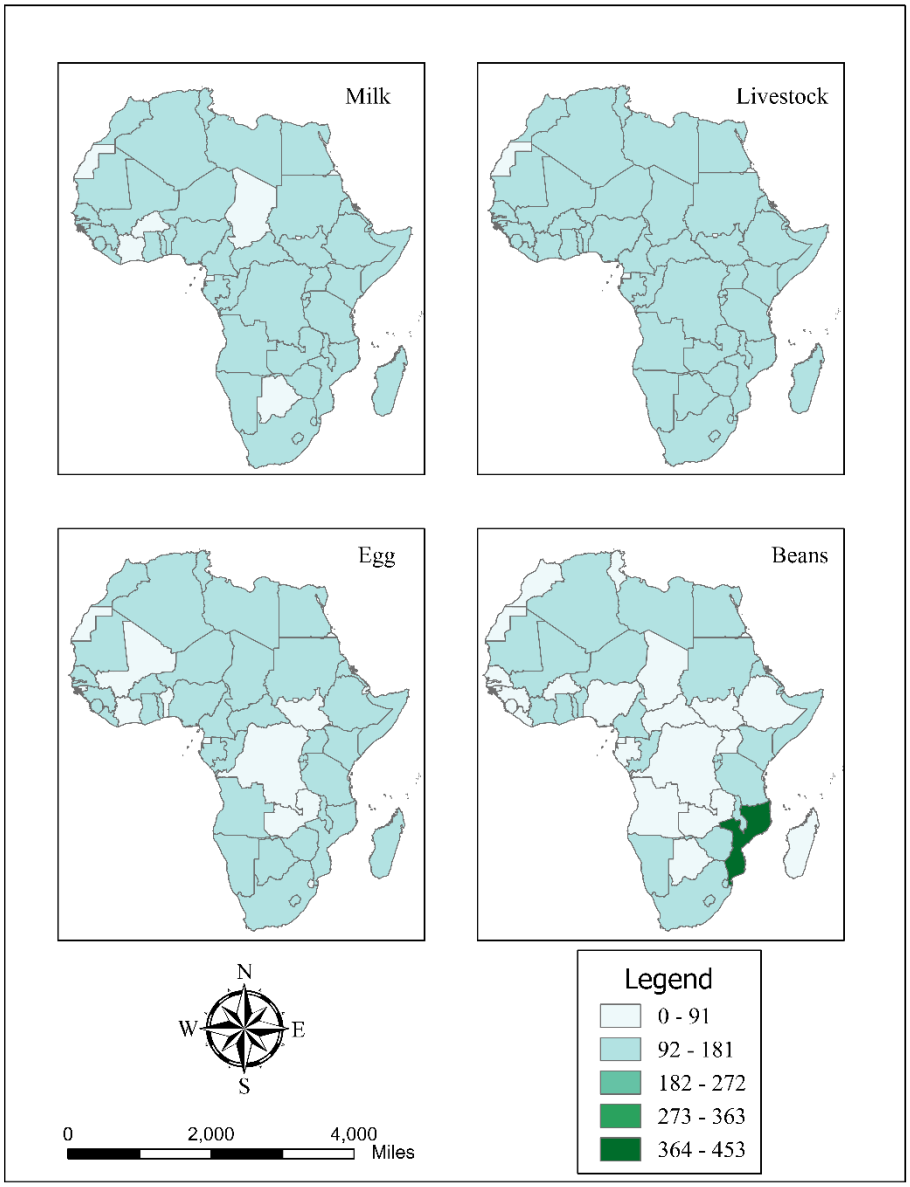

Figure 1. Forest-based forecast on food production from 2020–2030

Source: own study

These conditions lead to stress, malnutrition, and poor animal health, all of which significantly reduce milk yield. Aside from these five countries, milk production is very high in Africa because there are about 48 million nomadic herders and agro-pastoralists participating in the milk sector in contrast, others trade and transport products (Merem et al., 2022). Milk production provides many non-marketed economic benefits, including manure for use on-farm as fuel or organic fertilizer (in several farming systems manure is the sole source of nutrients for crop production).

Africa's livestock accounts for one-third of the global livestock population and about 40% of agricultural GDP in Africa, ranging from 10% to 80% in individual countries (Oluwatayo & Ojo, 2016). Livestock will be increasingly important in the future in sub-Saharan Africa (SSA) because the demand for animal-source food (ASF) is projected to increase due to population

growth, increased incomes, and urbanization (Enahoro et al., 2019). According to Dong (2016), livestock are so important to Africa that the future of African livestock will influence the development of the entire continent. The livestock sector contributes between 30 to 50 per cent of agricultural GDP and supports the food security and livelihoods of about one-third of Africa's population, or about 350 million people (Molina-Flores et al., 2020). Livestock are critical to rural incomes, nutrition and food security, and resilience in much of Africa's smallholder mixed crop or livestock and pastoral systems (Sekaran et al., 2021). According to the Agricultural Development Bank (2015), in most African countries 60–80 per cent of rural households keep livestock as mobile and liquid assets, income generators and for household food security and nutrition. As well, manure and animal traction make indirect and critical contributions to crop production (ADB, 2015). Livestock also play a crucial role in providing eggs, which are a highly nutritious food rich in essential fatty acids, choline, vitamins A and B12, as well as bioavailable iron, zinc, and iodine.

The trend analysis on egg production which forecast eleven years of production from 2020-2030 gives us a general overview of food production in the continent. The limited variation in total egg production suggests that total egg production will stay consistent over ten years. As the population grows with little or no increase in egg production, it will substantially impact human growth, particularly for children in Africa. That is, a scarcity of eggs would result in a lack of nutrition in many people across the continent. The unavailability of poultry feed is one of the primary causes of low egg production. An acute feed shortage is threatening the survival of the African poultry industry, especially in the western, central, and eastern parts of Africa. Despite being a very healthy food, eggs are rarely consumed in many low-income nations. Therefore, as eggs supply vital nutrients for human growth, egg production is extremely important for African development. Dry edible beans are an important food source in Africa, as they alleviate hunger and malnutrition and contribute to the African economy. The forecast on bean production provides convincing evidence as production remains constant over 10 years. Supposedly, if bean production continues as predicted, its consequences will have a long-term impact on human growth on the continent. The poor nutrition in Africa is likely to increase as the population exceeds beans production (Uebersax et al., 2023). Even though there is limited research on the causes of decreased bean production in Africa, climate change is a major factor. Other factors also contribute to the low production of beans including, crop diseases and pests, and the slow diffusion of improved agricultural technologies. Despite low bean production throughout Africa, Mozambique has seen a boost in production. According to Di Matteo, Otsuki, & Schoneveld (2016), large-scale South American production initially inspired Mozambique bean production. Over 10,000 smallholders are now included in new sorts of economic models, such as contract farming and sourcing, that have emerged concurrently.

Conclusion

This study examined the trends and future projections of protein food production in Africa from 2020 to 2030 using a forest-based forecasting approach. The findings indicate that milk production peaked in 2022, livestock production is projected to rise significantly

in 2028, egg production will reach its highest level in 2027, and bean production will peak in 2030. These results highlight both opportunities and challenges in ensuring food security on the continent. Despite Africa's vast agricultural potential, key challenges such as inadequate infrastructure, limited access to modern farming technologies, and inefficient distribution networks continue to hinder optimal protein production. The study identifies Western Sahara, Chad, and Burkina Faso as regions requiring urgent policy interventions to boost protein production. Addressing these disparities will require comprehensive agricultural policies, increased investments in technology and infrastructure, and targeted support for rural farmers. To enhance protein food security, African governments, stakeholders, and Non-Governmental Organizations (NGOs) must prioritize strategic initiatives that promote sustainable agricultural practices, improve food distribution channels, and mitigate climate-related risks. Strengthening research, technology adoption, and regional collaborations will be essential for achieving long-term food security and economic stability across Africa.

It is recommended that African governments, stakeholders (such as the African Union) and NGOs should bring policy development for protein production where we can develop comprehensive agricultural policies targeting protein food production and create targeted support for low-performing regions like Western Sahara, Chad, and Burkina Faso.

Nutritional Security and Economic Development should be focused on increasing egg and bean production to combat malnutrition and develop strategies to support rural household's dependent on livestock. They should also create economic opportunities in agricultural sectors, particularly for youth and rural populations

African governments and international partners should prioritize investments in modern agricultural technologies, storage facilities, and efficient distribution networks specifically tailored to protein food production. This includes cold chain infrastructure for milk and eggs, improved livestock management systems, and modern irrigation for bean cultivation, particularly targeting high-potential but underperforming regions.

In collaboration with regional agricultural research institutions and international climate funds, African governments should develop comprehensive climate adaptation programs for protein food production systems, including drought-resistant bean varieties, heat-tolerant livestock breeds, and water conservation techniques. They should establish early warning systems for climate-related threats and create financial mechanisms (such as agricultural insurance) to help farmers recover from climate-related production losses.

References

Adeyeye S.A. O. (2017). The role of food processing and appropriate storage technologies in ensuring food security and food availability in Africa. Nutrition & Food Science, 47(1), 122–139.

African Development Bank (2015). Feeding Africa, an Action Plan for African Agriculture Transformation: http://www.afdb.org/en/dakagri2015 [access: 07.11.2024].

Di Matteo F., Otsuki K., Schoneveld G. (2016). Soya bean expansion in Mozambique: exploring the inclusiveness and viability of soya business models as an alternative to the land grab. The Public Sphere Journal, 60–86.

Dong S. (2016). Overview: Pastoralism in the world. Building resilience of human-natural systems of pastoralism in the developing world: Interdisciplinary perspectives, 1–37.

Enahoro D., Mason-D'Croz D., Mul M., Rich K.M., Robinson T.P., Thornton P., Staal S.S. (2019). Supporting sustainable expansion of livestock production in South Asia and Sub-Saharan Africa: Scenario analysis of investment options. Global food security, 20, 114–121.

ESRI (2022). ESRI User Conference**:**. The State of Food Security and Nutrition in the World. Rome: Food and Agriculture Organization of the United Nations. https://mediaspace.esri.com/channel/2022+Esri+User+Conference/261131512FAO [access: 27.10.2024].

Holechek J.L., Cibils A.F., Bengaly K., Kinyamario J.I. (2017). Human population growth, African pastoralism, and rangelands: A perspective. Rangeland ecology & management, 70(3), 273–280.

Kim H., Sefcik J.S., Bradway C. (2017). Characteristics of qualitative descriptive studies: A systematic review. Research in nursing & health, 40(1), 23–42.

Merem E.C., Twumasi Y., Wesley J., Olagbegi D., Crisler M., Romorno C., Emakpor S. (2022). The analysis of dairy production and milk use in Africa Using GIS. Food Public Health, 12, 14–28.

Mohajan H.K. (2022). Food insecurity and malnutrition of Africa: A combined attempt can reduce them. Journal of Economic Development, Environment and People, 11(1), 24–34.

Nirmal, N., Anyimadu, C. F., Khanashyam, A. C., Bekhit, A. E. D. A., & Dhar, B. K. (2024). Alternative Protein Sources: Addressing Global Food Security and Environmental Sustainability. *Sustainable Development*.

Molina-Flores B., Manzano-Baena P., Coulibaly M.D. (2020). The role of livestock in food security, poverty reduction and wealth creation in West Africa. Accra: FAO.

Nzabarinda V., Bao A., Xu W., Uwamahoro S., Huan, X., Gao Z., Jiang Z. (2021). Impact of cropland development intensity and expansion on natural vegetation in different African countries. Ecological Informatics, 64, 101359.

Obokoh L.O., Goldman G. (2016). Infrastructure deficiency and the performance of small- and medium-sized enterprises in Nigeria's Liberalised Economy. Acta Commercii, 16(1), 1–10.

Oluwatayo I.B., Ojo A.O. (2016). Is Africa's dependence on agriculture the cause of poverty in the continent?: An empirical review. The Journal of Developing Areas, 50(1), 93–102.

Sans P., Combris P. (2015). World meat consumption patterns: An overview of the last fifty years (1961–2011). Meat science, 109, 106–111.

Sekaran U., Lai L., Ussiri D.A., Kumar S., Clay S. (2021). Role of integrated crop-livestock systems in improving agriculture production and addressing food security – A review. Journal of Agriculture and Food Research, 5, 100190.

Serraj R., Krishnan L., Pingali P. (2019). Agriculture and food systems to 2050: a synthesis. Agriculture & Food Systems to, 2050, 3–45.

Uebersax M.A., Cichy K.A., Gomez F.E., Porch T.G., Heitholt J., Osorno J.M., Bales S. (2023). Dry beans (Phaseolus vulgaris L.) as a vital component of sustainable agriculture and food security – A review. Legume science, 5(1), e155.

World Bank (2024). Food Production Index. https://data.worldbank.org/indicator/AG.PRD.FOOD.XD [access: 11.03.2025].

You D., Hug L., Anthony D. (2014). Generation 2030/Africa. UNICEF. 3 United Nations Plaza, New York, NY 10017.