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Artificial Intelligence for Food Production Among Smallholder Farmers: Towards Achieving Sustainable Development Goals (Sdgs) In Nigeria

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Abstract

Smallholder farmers have been contributing to agricultural productivity in the country. Artificial intelligence (AI) has been growing and it has been playing positive roles in various sectors of the economy. The primary objective of this study is to explore artificial intelligence for food production among smallholder farmers in Nigeria in order to achieve sustainable development goals (SDGs) in the country. Content analysis and systematic literature review is used in this study. The findings of the study demonstrated that the application of artificial intelligence can contribute to realization of SDG 2 (Zero Hunger) with appropriate government interventions in the sector. In addition, it is also shown that artificial intelligence (AI) can be used for weeding, spraying pesticides, monitoring livestock, and automating harvesting processes. It is further noted that digitalization of agriculture through AI tools reduces middlemen, expands market opportunities, and enhances productivity and livelihoods of small-scale farmers. It is therefore suggested that the stakeholders in the agricultural sector should actively involve in training smallholder farmers in digital skills for efficient application of AI.

Keywords: *Artificial Intelligence, Food Production, Smallholder Farmers, Sustainable, Development Goals (SDGs), Digital Skills.*

Introduction

Agriculture contributes to gross domestic product (GDP) in many African countries including Nigeria. More specifically, smallholder farmers play important role in fostering food security, food production and overall socio-economic development in Nigeria (Sabo, Isah, Chamo and Rabiu, 2017; Chiaka, Zhen, Yunfeng, Xiao, Muhirwa and Lang, 2022). However, various challenges that hinder their productivity and financial stability in the country. Studies reveal that these farmers experience difficulties accessing financing, with a significant financing gap and high financial vulnerability which calls for transformation of the sector through effective and efficient agricultural policies (Mgbenka, Mbah, and Ezeano, 2016). Additionally, constraints such as lack of training, inadequate extension services, limited access to credit facilities, and insufficient inputs like improved seeds and fertilizers impede their agroforestry production efficiency in most developing countries including Nigeria (Ofana, Efefiom and Omini, 2016). Moreover, low food production and declining yields of essential crops like rice, sorghum, soybean, cassava, and yam contribute to inadequate food supply, especially in terms of cereals, highlighting the need to address yield gaps and post-harvest losses (Balana and Oyeyemi, 2022). Furthermore, challenges exacerbated by factors such as price hikes, reduced sales, and unhealthy competition from larger farmers, emphasizing the necessity for government support and capacity-building initiatives for small-scale poultry farmers (Ofana, Efefiom and Omini, 2016; Balana and Oyeyemi, 2022).

Nigeria has been advocating for attainment of Sustainable Development Goals (SDGs) and clamouring for zero hunger is the core aspect of SDGs. Thus, the contributions of smallholder farmers in achieving SDGs cannot be underrated. However, achieving Sustainable Development Goals (SDGs) in Nigeria faces several challenges. These include the lack of technological knowledge, inadequate funding, insufficient e-learning and ICT facilities, corruption, political motivated projects, over-politicization of programmes, poor policy implementation and among others (Ofana, Efefiom and Omini, 2016). The country's struggle to bridge the gap between rapid global technological advancements and its own infrastructure hinders progress towards sustainable development. Additionally, the scepticism surrounding the achievability of SDGs in Africa due to the opposing imperatives of growth, development, and ecological sustainability further compounds the

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challenges faced by Nigeria in meeting these goals. Overcoming these obstacles requires comprehensive policy frameworks, community education for awareness and participation, effective policy implementation, eradication of corruption, and continuity of policies between governments.

Thus, the motivation for this study springs from the fact that there has been application of Artificial Intelligence (AI) in various sectors of economy and its application in the agriculture will play a paramount role in this regard. Undoubtedly, there is a gap in the existing body of knowledge relating to food production among smallholders in harmonizing Artificial Intelligence (AI). This study tries to bridge this gap by utilizing Artificial Intelligence (AI) for improving food production among smallholder farmers in order to achieve sustainable development goals (SDGs) in the country. Undoubtedly, Artificial Intelligence (AI) presents significant opportunities for maximizing food production in Nigeria, yet it also comes with challenges. The use of AI in agriculture can enhance efficiency, improve soil health, and increase crop production, addressing issues like unpredictable climate change and food insecurity. Additionally, the deployment of AI in food production raises concerns about transparency, accountability, and sustainability, especially in developing countries like Nigeria. This study therefore explicitly explores the utilization of Artificial Intelligence (AI) among smallholder farmers in order to maximize food production in the country.

An Overview of Smallholder Farmers in Nigeria

Smallholder farmers in Nigeria play a crucial role in food production and studies have highlighted low production and declining yields of key crops, indicating inadequate food supply in Nigeria (Balana and Oyeyemi, 2022). Agricultural policies in Nigeria, such as the Anchor Borrowers Programme, aim to support smallholder farmers by providing access to credit, modern agricultural technologies, and empowerment opportunities (Kamara, Conteh, Rhodes and Cooke, 2019). These policies are crucial as smallholder farmers play a significant role in food production, yet face challenges like low productivity and limited access to resources (Onogwu, Audu and Igbodor, 2017). Commercializing smallholder agriculture not only boosts rural employment but also reduces rural-urban migration, highlighting the importance of government support and private-public partnerships in the agricultural sector (Adebayo, Olagunju and Ogundipe, 2016). Disparities in gender-based farm performance among rice farmers in Nigeria underscore the need for targeted interventions to empower women in agriculture and bridge productivity gaps (Oyewole and Sennuga, 2020). By addressing these issues through tailored policies and interventions, Nigeria can enhance food security, increase agricultural productivity, and promote sustainable rural development.

Furthermore, Smallholder farmers in Nigeria exhibit varying levels of efficiency and effectiveness in resource utilization and crop choices in achieving sustainable rural development in the country (Kamara, Conteh, Rhodes and Cooke, 2019). Research indicates that smallholders generally demonstrate efficiency in their resource allocations, but there are instances of underutilization of resources among cooperative producers specializing in vegetable production, highlighting inefficiencies in resource use within certain groups (Fadeyi, 2018). The dynamics of production efficiency among smallholder farmers fluctuate over time, with factors like farm size, labour, and input usage significantly influencing productivity, while access to extension services and farming systems can reduce efficiency (Adebayo, Olagunju andOgundipe, 2016). Despite government investments to improve livelihoods, rural poverty remains widespread, emphasizing the need to enhance technical efficiency effects on poverty reduction among smallholder farmers in Nigeria (Oyewole and Sennuga, 2020). Efforts to improve resource utilization, crop choices, and technical efficiency are crucial for enhancing the overall effectiveness of smallholder farmers in Nigeria (Kim-Soon, Salama, Mohammad, Lim, Nallapaneni, Rabei, and Umashankar, 2020) .

However, Smallholder farmers in Nigeria face various challenges and opportunities based on the research findings. Studies show that smallholder agroforestry farmers are predominantly male, educated, and practice profitable agroforestry systems, with constraints like lack of training and inputs (Jamilu, Atala, Akpoko and Sanni, 2015). In the Federal Capital Territory, access to broadcast media agricultural content is high, but farmers find the timing and effectiveness of information on dry season agriculture inadequate, impacting their adoption of such practices (Oyewole and Sennuga, 2020). Additionally, the willingness of smallholder farmers in Nigeria to embrace Resilient Farming Practices (RFPs) is influenced by factors like age, education, and land tenure, highlighting the importance of secure land rights for adoption (Ibitola, Fasakin,

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Popoola, and Olajide, 2019). Furthermore, digital platforms like ThriveAgric, EZ Farming, and Farmcrowdy are used to link investors with smallholder farmers, offering benefits like reduced post-harvest losses but facing challenges like untimely input delivery. It is reiterated that, pesticide handling behaviour among farmers in Southwest Nigeria reveals gaps in knowledge and PPE use, emphasizing the need for improved information dissemination to enhance safety practices through financial inclusion among smallholder farmers in achieving sustainable development goals (Adegbite and Machethe, 2020).

Sustainable Development Goals (SDGs)

Sustainable Development Goals (SDGs) are a global agenda aimed at addressing economic, social, and environmental challenges to ensure a prosperous future for all. Literature contends that Nigeria has been striving to achieve sustainable development (SDGs) in various sectors (Abata-Ebire, Adebowale and Ojokuku, 2018). Research indicates that SDG-related studies focus on economic and social impacts, utilize exploratory and case study methodologies, and are conducted in both industrialized and developing nations (Oleribe and Taylor-Robinson, 2016; Dansabo, 2017). The localization of SDGs is crucial, with grassroots efforts, particularly through Social and Solidarity Economy (SSE) organizations, playing a significant role in achieving effective implementation of SDGs in different countries including Nigeria (Modibbo, Ali and Ahmed, 2021). Higher education institutions are key players in promoting sustainable development, with initiatives like the QualEnv consortium emphasizing the operationalization of SDGs within universities (Modibbo, Ali and Ahmed, 2021). Understanding the interlinkages between SDG targets is essential for effective policy design and implementation, highlighting the need for intersectoral strategies focusing on interconnected targets for successful SDG achievement (Adenle, Azadi and Manning, 2018).

The implementation of Sustainable Development Goals (SDGs) significantly impacts agricultural development in Nigeria whereby the government policies are being formulated to achieve zero hunger which is the focus of SDG 2 (Echendu, 2022). Furthermore, the impact of Covid-19 on farm households poses obstacles to SDGs related to poverty, hunger, health, and economic growth (Bakare, Olaniyi and Oloruntola, 2019). Understanding the rise of medium-scale farming is essential for agricultural commercialization and achieving SDGs in Africa. Literature emphasizes how farmers-herders' conflicts in Nigeria, like in Benue State, impede the realization of SDG 2 (Zero Hunger) despite government interventions. However, research reveals limited awareness of SDGs among female entrepreneurs, agribusiness and smallholder farmers in Nigeria, hindering gender equality efforts in small businesses and agricultural activities which impede the positive impact in achieving Sustainable Development Goals (SDGs) (Adebayo, Olagunju and Ogundipe, 2016; Oyewole and Sennuga, 2020; Egberi, 2023). Nonetheless, climate-smart agriculture (CSA) plays a crucial role in achieving SDG 2 by enhancing food security and resilience to climate change as literature contends (Egberi, 2023). Additionally, literature posits that communication plays an important role in achieving SDGs in agricultural sector of the economy by enhancing productivity and emphasizing the importance of sustainable practices (Ayobolu, 2019).

Initiatives like the Agricultural Productivity Programme (APP) have demonstrated tangible benefits for sustainable agricultural practices, such as increased income for smallholder farmers in particular and farmers in general. Thus, this has demonstrated an improved access to nutritious food, showcasing the positive outcomes of SDG-aligned interventions at the grassroots level as literature posits (Akinloye, 2018; Rao, Bathla, Kumar and Jha, 2018). Furthermore, the government's involvement in agriculture, as highlighted in a study on poverty reduction, underscores the necessity of robust agricultural policies and investments to alleviate poverty and ensure food production and food security through which rural economy and GDP can be improved in Nigeria (Okunola, 2016; Aderemi, Olanipekun, Bamidele, Hassan, Osabohien and Azuh, 2021). Nonetheless, there is less focus of attention in exploring the paramount importance of artificial intelligence in enhancing food production and food security in achieving SDGs in the country (Uddin, Ullah, Saqib,2023) .

Artificial Intelligence (AI) for Maximizing Food Production

The challenges of food insecurity and inadequate food production hinder the supply of foods for achieving zero hunger (Mgbenka, Mbah and Ezeano, 2016; Songol, Awuor and Maake, 2021). Literature has

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emphasized the need for integrating digital technologies into agricultural activities (Funke, 2021). Thus, harmonization of artificial intelligence is being regarded as an integral part of technologies in promoting agriprenurs (Omole and Fasina, 2024). Artificial Intelligence (AI) which refers to the application of computer systems in performing complex tasks such as problem-solving can address the aforementioned problems of food insecurity and inadequate food production in Nigeria (Deji, Alabi, Famakinwa and Faniyi, 2023). There are problems in various processes involve in agricultural activities especially in Nigeria where most farmers heavily rely on traditional farming system that hinder maximum productivity (Eli-Chukwu, 2019). Indeed, there is a projection that a global population would exceed 9 billion by 2050. As a result of this projection, it is paramount to note that Artificial Intelligence (AI) in agriculture is crucial for transformation of the sector towards ensuring food production and food security, sustainability, and resilience to climate change which will cater for food production and food security as literature posits (Sampene, Agyeman, Robert and Wiredu, 2022).

It is not disagreeable to say that applications of technologies in general and Artificial Intelligence (AI) in particular is revolutionizing the agricultural sector by enhancing productivity, sustainability, and efficiency (Umar, Sani, Suleiman and Tijjani, 2022). AI applications in agriculture include computer vision, machine learning, predictive analytics, and robotics for tasks like weeding, spraying pesticides, monitoring livestock, and automating harvesting processes (Olagunju, 2024). It is further asserted that, AI aids in improving soil health, crop production, and addressing challenges like climate change, population growth, and food insecurity. Precision farming techniques utilizing AI provide insights on water and nutrient management, optimal planting times, and crop rotation schedules, contributing to increased yields and reduced costs which are important determinants in fostering socio-economic development (Ndubisi and Ikechukwu-Anthony, 2022).

The integration of Artificial Intelligence (AI) has significantly transformed the agricultural industry, particularly enhancing crop yield and productivity. AI technologies such as machine learning, convolutional neural networks, IoT, big data, robotics, and computer vision are being increasingly applied in agriculture to optimize resources, increase efficiency, and predict outcomes (Umar, Sani, Suleiman andTijjani, 2022). These technologies enable quicker performance of traditional farming practices like weeding, pesticide spraying, and irrigation, leading to reduced water wastage, enhanced soil fertility, and increased crop yield (Deji, Alabi, Famakinwa and Faniyi, 2023). Additionally, AI aids in precision agriculture, crop monitoring, predictive analytics, and supply chain optimization, contributing to improved productivity, efficiency, and sustainability in the agri-food sector (Omotoso, Daud, Okojie and Omotayo, 2022; Olagunju, 2024).

Artificial Intelligence (AI) plays a crucial role in enhancing food production among smallholder farmers in Nigeria, contributing to the achievement of Sustainable Development Goals (SDGs) (Ikelegbe and Edokpa, 2013). AI offers innovative solutions to address challenges in agriculture, such as climate change impacts and supply-demand gaps. Implementing Climate-Smart Agriculture (CSA) practices, supported by AI technologies, can significantly improve food security and sustainability in the country. Digitalization of agriculture through AI tools reduces middlemen, expands market opportunities, and enhances productivity and livelihoods of small-scale farmers, emphasizing the importance of training extension staff and farmers in digital skills (Funke, 2021).

The implementation of AI technologies in agriculture faces challenges such as lack of standardization, high implementation costs, job losses, and affordability issues. Additionally, uneconomical nature, lack of expertise, and big data requirements hinder AI penetration in agriculture (Umar, Sani, Suleiman and Tijjani, 2022). The convergence of AI and IoT in smart agriculture introduces challenges like data integration, automatic analysis, and addressing pest management issues. To address these challenges, it is argued that improving model transparency, assigning clear responsibility, overcoming fairness concerns, and ensuring data ownership, privacy, and security. Despite these obstacles, AI technologies offer solutions to optimize resources, increase productivity, and enhance crop yield, which are vital in meeting the growing food demand in the country.

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Materials and Methods

The methodological approach employed in this research entails content analysis within a qualitative research framework. Previous studies have predominantly utilized systematic literature reviews to establish connections among different pieces of research such as entrepreneurship (Kraus, Breier Dasí-Rodríguez 2020; Kraus, Breier, Lim, Dabić, Kumar, Kanbach, Ferreira, 2022; Kraus, Mahto, and Walsh, 2023); business and marketing (Klimanov and Tretyak, 2019; Bougie and Sekaran, 2019); economy practices (2022). However, there has been a noticeable lack of emphasis on systematic literature reviews within studies pertaining to the integration of artificial intelligence (AI) into agricultural sector, particularly in fostering food production among smallholder farmers. This study aims to address this gap by employing systematic literature review to explore the use of artificial intelligence (AI) for improving food production in Nigeria in order to achieve sustainable development. The research extensively examines various scholarly works through content analysis and systematic literature review. Furthermore, it specifically delves into policy-related studies on the key factors of the study. A wide range of databases, library sources, and Google Scholar were thoroughly searched for relevant scholarly articles. The study utilized Visualization of Similarities (VOS) to identify key themes, which are as follows: smallholder farming, food security, artificial intelligence and sustainable development goals. A total of fifty-six (56) articles were reviewed and analysed as secondary sources for this study. The content analysis conducted in this research meticulously elucidates the findings, contributing significantly to the existing literature on agricultural sector. This study offers valuable insights and guidance for future empirical research in the broader field of agriculture (Ibrahim, Yu, Hassan, Ajide, Tanveer and Khan, 2022).

Results and Discussion

This section presents the overall results and discussion of findings which are presented in the subsequent subheadings.

Artificial Intelligence (AI) in Promoting Sustainable Agricultural Development

The analysis of this study has established that Artificial intelligence (AI) plays a crucial role in promoting sustainable agricultural development by offering innovative solutions to address challenges in the agricultural sector. AI technologies such as predictive models, weed control systems, and resource management tools contribute to enhancing agricultural productivity while ensuring environmental sustainability. This is in consonance with previous studies that contend that by leveraging AI tools like drones, sensors, and biosensors, farmers can monitor soil conditions, detect diseases, and optimize crop health, thereby increasing crop productivity and promoting sustainable practices and socio-economic development (Ndubisi and Ikechukwu-Anthony, 2022). Additionally, AI aids in smart harvesting through agrometeorology and precision agriculture, benefiting small and marginal farmers by overcoming accessibility challenges. This assertion is in agreement with the position of the cursory literature that says that the integration of AI in agriculture not only boosts efficiency but also addresses environmental concerns, aligning with the broader goal of achieving sustainability in the agricultural sector (Olagunju, 2024).

Furthermore, Artificial intelligence (AI) plays a crucial role in optimizing sustainable agricultural practices and enhancing crop yields by offering innovative solutions. This is in agreement with previous studies that posited that by leveraging technologies like Computer Vision (CV), Machine Learning (ML), and Deep Learning (DL), AI models can predict crop outcomes, manage resources efficiently, control weeds, and provide advanced care for crops as part of transformations of the agricultural sector (Sampene, Agyeman, Robert and Wiredu, 2022). AI aids in monitoring soil conditions, detecting diseases, and pests through biosensors and drones, enabling timely interventions for increased productivity. Furthermore, AI helps in optimizing irrigation and fertilizer application based on soil moisture levels and weather patterns, reducing costs and maximizing crop yields even in adverse climatic conditions. This in consonance with previous studies that emphasized for the integration of AI in agriculture not only enhances efficiency, soil health,

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and production but also addresses challenges like climate change, population growth, and food insecurity, ensuring sustainable agricultural practices (Funke, 2021; Olagunju, 2024).

Implementing AI technologies in sustainable agricultural development presents several challenges and limitations. These include the need to ensure the ethical and trustworthy use of AI to avoid unforeseen risks and hazards. The adoption of AI in agriculture requires overcoming obstacles related to testing and effectively integrating new technologies in diverse agricultural environments (Umar, Sani, Suleiman and Tijjani, 2022). Additionally, the continuous enhancement of AI models in agriculture functions necessitates addressing limitations in building the next generation of sustainable agriculture using AI, such as the need for robust predictive models and efficient resource management systems (Modibbo, Ali and Ahmed, 2021). Furthermore, the reliance on AI for sustainable agriculture highlights the importance of prioritizing safety, security, and human values to create a safe and secure society while leveraging technology for the benefit of society through sustainable agricultural practices (Adenle, Azadi and Manning, 2018).

AI-driven precision agriculture plays a vital role in alleviating the adverse environmental effects of traditional farming techniques and promoting long-term sustainability. Through the utilization of technologies such as artificial intelligence, unmanned aerial vehicles (drones), sensors, and the Internet of Things (IoT), farmers have the ability to supervise soil conditions, optimize resource allocation, and improve crop health, thus resulting in more effective and sustainable agricultural methods (Echendu, 2022). Precision agriculture not only enhances economic and agronomic efficiency but also contributes to environmental sustainability by diminishing carbon emissions, boosting farm productivity, and tackling the challenges posed by climate change as part of effort to reduce high rate of poverty in the country (Igbokwe-Ibeto, 2019; Aderemi, Olanipekun, Bamidele, Hassan, Osabohien and Azuh, 2021). Nevertheless, ethical concerns relating to data privacy, biases, and the apprehension regarding the displacement of conventional farming practices by AI solutions must be carefully considered. In essence, the incorporation of artificial intelligence in precision agriculture presents a promising avenue towards sustainable farming practices that harmonize productivity with environmental stewardship (Oyakhilomen and Zibah, 2014; Osabohien, Osabuohien and Ohalete, 2019).

Policy Interventions, Smallholder Farmers and Sustainable Development Goals (SDGs)

The analyses of cursory studies have emphatically stressed that the current policies and interventions aimed at supporting smallholder farmers in Nigeria play a crucial role in achieving the Sustainable Development Goals (SDGs). Similarly, Studies emphasize the significance of programmes like the Homegrown school feeding programme (HGSF) in enhancing food security, food production and poverty reduction among smallholder farmers (Omodero, 2021). Additionally, agricultural policies, such as the E-wallet and Fadama programmes, influence the adoption of sustainable agricultural practices, impacting farmers' productivity and sustainability efforts (. However, challenges like inadequate funding and coordination hinder the holistic performance of climate-smart agriculture, which is vital for achieving SDG 2 and ensuring food security in Nigeria (Abata-Ebire Adebowale and Ojokuku, 2018; Egeri, 2023).

Smallholder farmers in Nigeria play a crucial role in contributing towards achieving the United Nations Sustainable Development Goals (SDGs) by producing most of the food supply in the country. However, challenges such as low food production, declining yields for certain crops, and inadequate per capita food supply persist, especially in terms of cereals, indicating a need for improvement in agricultural practices and productivity (Osabohien, Adeleye and De Alwis, 2020). Factors influencing smallholder farmers' willingness to embrace Resilient Farming Practices (RFPs) include age, education, gender, cooperative membership, land tenure security, and farming techniques like agroforestry and good agricultural practices (Ojeleye, 2018). Climate change further exacerbates these challenges, affecting farming operations and livelihoods, with notable impacts on fertilizer application, pest control, and farm income. Understanding the evolving agricultural landscape, including the rise of medium-scale farming sectors, is essential for policymakers to harness the potential of smallholder farmers and achieve sustainable agricultural commercialization in Nigeria (Omodero, 2021).

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Smallholder farmers in Nigeria play a crucial role in food production, yet face challenges such as low yields and financial vulnerability, impacting their contribution to achieving Sustainable Development Goals (SDGs). Studies highlight the need to enhance local production of key crops like rice, sorghum, soybean, cassava, and yam to improve food security (Umar, Eboh, Obidike and Ogwuru, 2014). Adoption of Sustainable Agricultural Practices (SAPs) among smallholder farmers, influenced by socio-demographic factors, can increase productivity and resilience to climate change risks. Financial vulnerability among smallholder farmers in Nigeria hinders their ability to undertake climate-resilient practices, emphasizing the importance of improved access to finance for sustainable production in order to improve livelihood of the citizens through agricultural innovations (Adebayo, Olagunju and Ogundipe, 2016). Furthermore, the utilization of formal risk management services by smallholder farmers in Southeast Nigeria is insufficient, indicating a need for tailored services to support their livelihoods (Adebayo, Olagunju and Ogundipe, 2016). Addressing socio-economic characteristics like education and government policies is crucial to enhancing food security among smallholder farming households in Nigeria, aligning with SDG targets as being reflected in some states like Taraba, Katsina, Oyo and Ogun (Onogwu, Audu and Igbodor, 2017; Ibitola, Fasakin, Popoola and Olajide, 2019; Oyewole and Sennuga, 2020).

To effectively support and empower smallholder farmers in Nigeria in the long term, the government should focus on closing the yield gap for cereals, reducing post-harvest losses, promoting dry-season cultivation through irrigation, and encouraging the use of modern inputs through training and reduced transaction costs from medium-scale farms (MSFs) as literature posits (Adeniyi, 2019). Additionally, direct provision of loans to farmers, sensitization of farmers in remote areas about agricultural support programmes like the Anchor Borrowers' Programme, and the development of policies tailored to engage small-scale farmers are crucial (Olomola, 2013). Enhancing farmer education, promoting labour-saving technologies, facilitating access to market information, and developing a results-oriented food policy are also essential steps to improve food security among smallholders and rural communities in Nigeria (Adeniyi, 2019).

International organizations and foreign aid can play a crucial role in shaping and supporting future policies aimed at improving the livelihoods of smallholder farmers in Nigeria. Literature has emphatically stressed that, by collaborating with the government and local stakeholders, these entities can provide financial support, technical assistance, and knowledge transfer to enhance agricultural practices, reduce post-harvest losses, and increase food production efficiency (Tofu and Wolka, 2023). Additionally, international organizations can advocate for sustainable agricultural policies that prioritize small-scale farmers and address food insecurity challenges in the country. Through targeted interventions, such as improving access to affordable financing options and incentivizing the production of low-cost postharvest technologies locally, foreign aid can help smallholder farmers adopt innovative practices, increase their incomes, and ultimately improve their livelihoods (Jayne, Fox, Fuglie and Adelaja, 2021).

Artificial intelligence (AI) for improving Food Production

Undoubtedly, literature has established an interconnectedness between Artificial Intelligence (AI) and food production in developed and developing countries. This study has reiterated that Artificial intelligence (AI) plays a crucial role in revolutionizing food production by enhancing efficiency, sustainability, and safety across various stages of the food supply chain. This is in agreement with a number of studies that said that AI technologies are utilized in agriculture for tasks such as detecting plant diseases, classifying weeds, managing water resources, and forecasting weather (Eli-Chukwu, 2019; Deji, Alabi, Famakinwa and Faniyi, 2023). Similarly, literature such as Songol, Awuor and Maake (2021) have identified that the application of AI in food production helps in addressing challenges like food fraud, safety hazards, and improving crop productivity. From crop and livestock production to food distribution and waste management, AI algorithms are increasingly being employed to optimize processes and decision-making in the food system, ultimately contributing to global food security, food production and consequently contribute to poverty reduction (Omodero, 2021). AI advancements in precision agriculture, crop monitoring, predictive analytics, and supply chain optimization are transforming the agri-food sector by boosting productivity, reducing waste, and enhancing food quality and safety (Sampene, Agyeman, Robert and Wiredu, 2022).

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Furthermore, Artificial intelligence (AI) plays a crucial role in improving food security by revolutionizing various stages of the food system, as highlighted in several studies (Eli-Chukwu, 2019). AI applications range from crop and livestock production to food distribution and waste management. During public health emergencies like the Covid-19 pandemic, AI enhances situational awareness by monitoring social media for food security-related discourse, aiding in resource allocation and emergency response as part of effort for transformations of various sectors in Africa (Sampene, Agyeman, Robert and Wiredu, 2022). Machine learning tools, such as text mining and topic modeling, help classify, predict, and improve food assistance efforts, although there is a need for more implementation and evaluation during disaster phases (Umar, Sani, Suleiman and Tijjani, 2022). Integrating AI and GIS technologies into sustainable farming practices can significantly increase efficiency and effectiveness, particularly in developing countries facing severe food insecurity challenges. This is in agreement with cursory literature that posits that by leveraging AI across the food system, from production to distribution, developing countries can make significant strides in achieving global food security goals (Ikelegbe and Edokpa, 2013.

Artificial intelligence (AI) presents a promising solution to enhance food security in Nigeria by revolutionizing agricultural practices. By incorporating precision agriculture tools like drones, remote sensing, and AI algorithms, Nigerian farmers can significantly boost productivity and combat food insecurity (Ahungwa, Haruna and Muktar, 2014). Additionally, AI techniques can be utilized to optimize farming operations in inaccessible areas through the collective use of AgriTech drones inspired by bird swarms, ultimately improving farming productivity in countries with limited capacity (Ayinde, Otekunrin, Akinbode and Otekunrin, 2020). Moreover, a human-centric AI-based probabilistic approach can provide predictive forecasting for global food security, aiding policymakers in making informed decisions to ensure favorable conditions for food security on a global scale as literature posits (Ahungwa, Haruna and Muktar, 2014).

Artificial intelligence (AI) plays a pivotal role in enhancing food production by revolutionizing various aspects of agriculture (Olagunju, 2024). AI technologies, such as deep learning algorithms, enable precision agriculture, crop monitoring, predictive analytics, and supply chain optimization, ultimately improving productivity, efficiency, and sustainability in the agri-food sector (Sampene, Agyeman, Robert and Wiredu, 2022). Hence, by utilizing AI in agriculture, farmers can optimize resources, reduce waste, and enhance food safety and quality, leading to increased crop yields and improved soil health. Moreover, AI facilitates the detection of plant diseases, classification of weeds, management of water resources and soil, and forecasting of weather conditions, all contributing to more effective and sustainable food production practices (Omotoso, Daud, Okojie and Omotayo, 2022). The integration of AI technologies in agriculture not only boosts productivity but also addresses challenges like climate change, population growth, and food insecurity, ensuring a more resilient and efficient food production system for the future. Literature contends that AI has the potential to revolutionize the agri-food sector by improving productivity, efficiency, and sustainability, there are still social, ethical, and legal challenges that need to be addressed (Olagunju, 2024). Explainable AI (XAI) is regarded as a tool to overcome limitations and ensure trustworthiness, bias mitigation, and expertise in utilizing AI in critical sectors like agriculture in Nigeria. In a nutshell, despite the challenges such as cost, cultural changes, and expert skill requirements, the benefits of AI in the food industry outweigh the obstacles, with ongoing research focusing on optimizing production processes using AI (Abunadi, Amjad, Khalid, Lorena, and Jaime, 2022).

Conclusion and Suggestions

The paper has extensively explained that several efforts have been made to achieve sustainable development goals (SDGs). Undoubtedly, the paper has also elucidated the important roles played by smallholder farmers in contributing to gross domestic product (GDP) and sustainable development goals (SDGs) for attaining SDG 2 (Zero Hunger) through the interventions of the government. Food production has been a serious impediment for achieving zero hunger. This paper has demonstrated that artificial intelligence (AI) has potential to maximize food production in order to improve livelihoods, rural poverty remains widespread, emphasizing the need to enhance technical efficiency effects on poverty reduction among smallholder farmers in Nigeria. Integration of digital technologies into agricultural activities in the country. It has been

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further indicated that through an effective policy intervention, smallholder farmers significantly contribute to sustainable development goals (SDGs). Nonetheless, there are several challenges such as: inadequate funding and coordination which hinder the holistic performance of climate-smart agriculture and artificial intelligence, which is vital for achieving SDG 2 and ensuring food security in Nigeria. This paper is without limitation where it relies using secondary data. However, the paper has provided a substantial direction for future empirical studies in exploring the variables of this study. Therefore, the following suggestions are made in accordance with the thesis of the study:

Precision agriculture, enabled by AI technologies, offers opportunities for smallholder farmers to access new markets, enhance their bargaining power, and boost their income levels.

AI-driven equipment and smart systems contribute to strengthening food security, generating economic growth, and combating poverty in the agricultural sector.

The integration of AI in agriculture, such as predictive micro-climate technologies, empowers farmers with data-driven insights for sustainable and profitable farming practices, ultimately leading to inclusive growth and sustainable development.

By leveraging AI in food production, smallholder farmers can overcome information asymmetry, reduce transaction costs, and improve market access, thereby promoting inclusive growth and sustainable development in the agricultural sector.

By leveraging AI technologies, Nigeria can enhance agricultural productivity, increase food production, and strengthen sustainable food security measures in the country.

Efforts should be made to align Nigeria's agricultural policies with SDGs 1 and 2 are crucial to address food security threats and enhance the country's economic and social structures in support of sustainable development goals.

Efforts to alleviate poverty among smallholder farmers in Nigeria should focus on enhancing access to finance, markets, and essential resources while promoting income diversification and strengthening agricultural production.

To fully realize the potential of AI in food production, comprehensive support from the government and stakeholders is essential to mitigate climate change effects and ensure sustainable agricultural practices for achieving SDGs in Nigeria.

To effectively support smallholder farmers and meet the SDGs, there is a need for comprehensive support from the government and stakeholders, focusing on funding, capacity building, and integration in the agricultural supply chain.

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