



PROSPECTS OF DIGITAL AGRICULTURE IN ACHIEVEMENT OF FOOD SUFFICIENCY IN NIGERIA

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Abstract

Agriculture is the principal source of food and livelihood of many Nigerians. Although agriculture contributes high percentage of the total Gross Domestic Product (GDP) in Nigeria, challenges such as poor land tenure system, low level of irrigation farming, climate change, land degradation, low technology usage, high production cost and poor distribution of inputs, limited financing, high post-harvest losses and poor access to markets hinders it from producing sufficient food for the nation. The paper presents a study conducted between January and April 2024 to identify and analyze the prospects of digital agriculture in achievement of food sufficiency in Nigeria. Descriptive research design was adopted for this study. The data for the study; secondary data were obtained from researches on digital agriculture and food production in Nigeria. The findings of the study showed that digital agriculture can enable efficient use/management of land, efficient use of technologies in farming and marketing of produce, access to adequate information and sufficient finance, adequate use of inputs, reduction of effects of climate change, and post-harvest losses and ensures security of farmers, laborers, land and produce and these factors enhance productivity and ensures food sufficiency. It was recommended that digital agriculture should be adopted in order to achieve food sufficiency in Nigeria.

Keywords: Digital Agriculture, Technology, Food Production, Food Sufficiency, Challenges.

Introduction

In Nigeria, agriculture is the principal source of food and livelihood and employs nearly three-quarters of the nation's work force. Although over 70% of Nigerians engaged in agriculture sector are mainly subsistence farmers, agriculture contributed to 22.35 percent of the total Gross Domestic Product (GDP) between January and March 2021 (Food and Agricultural Organization [FAO], 2022). There has been a recent rise in agricultural productivity but agricultural yields have stayed the same or declined over the past two decades (Phillip, Nkonya, Pender, & Oni, 2022).

Furthermore, Nigeria is the most populous country in Africa with a population of over 206 million people. Despite being densely populated, Nigeria has not being able to produce enough food for her ever growing population (Ezekiel, 2021) and this evident in the increasing hunger,

poverty and malnutrition experienced in the nation. The food insufficiency is caused by many challenges that impact on its productivity. The challenges include poor land use/management, inadequate use of inputs, low use of technologies, poor finance, climate change, poor marketing of produce, high post-harvest losses, lack of information and poor infrastructure amongst others (Anjeinu & Aondonenge, 2016; Ezekiel, 2021; Phillip *et al.*, 2022). These challenges have affected agricultural productivity negatively, affecting the sector's contribution to the country's GDP as well as increased food imports (FAO, 2022). These challenges and population rise have led to declining levels of food sufficiency.

Moreover, the Nigerian government has implemented several initiatives and programmes such as the Agriculture Promotion Policy (APP), Nigeria–Africa Trade and Investment Promotion Programme, Presidential Economic Diversification Initiative, Nigeria Erosion and Watershed Management Project (NEWMAP) and Action Against Desertification (AAD) Programme among others (FAO, 2022) to overcome the challenges. The initiatives and programmes are aimed at increasing agricultural productivity in order to provide sufficient quantities of food to meet domestic demand and abundance of commodity crops for export, reversing forest loss and degradation, promoting sustainable management of natural resources, rehabilitating degraded lands and reducing erosion and climate vulnerability. Upon these objectives of the initiatives and programmes, Nigeria still suffers from food insufficiency.

Furthermore, Nigeria's population is estimated to reach 400 million by 2050 (FAO, 2022). With this increasing population, food production needs to be increased to meet up with the increasing demand. So, increasing and sustaining agricultural productivity should be a critical component of programs that seek to increase food production and attain food security in Nigeria. Adaptation of new agricultural technologies and innovations can enhance agriculture productivity and ensure food sufficiency and security. Technologies such as digital agriculture can help in achieving food sufficiency and security in Nigeria.

The aim of this work is to identify and analyze the prospects of digital agriculture in achieving food sufficiency in Nigeria.

Food Production in Nigeria

Agriculture was the main source of food revenue generation in Nigeria until the advent of crude oil. Till now, agriculture is the principal source of food and livelihood for Nigerians. Agricultural yields have stayed the same or declined over the past two decades (Phillip *et al.*, 2022). even though agricultural sector employed nearly three-quarters of the nation's work force. In addition, agriculture contributed to 22.35 percent of the total Gross Domestic Product (GDP) between January and March 2021 (FAO, 2022).

Nigeria has 70.8 million hectares of agriculture land area with maize, cassava, guinea corn, yam beans, millet and rice being the major crops (FAO, 2022). Other crops grown in Nigeria include vegetables, plantain, banana and cash crops like coco, kola nut and groundnut amongst others. Nigerians consumed 6.7 million metric tons of rice annually and only 57% of it is locally produced (FAO, 2022) and this leads to a deficit of about 3 million metric tons, which is either imported or smuggled into the country illegally. In order to stimulate local production, the Government banned importation of rice in 2019. According to FAO (2022), Nigeria produced 59

million tons of cassava (approximately 20 percent of global production) in 2017, making it the world's largest producer. The high production was achieved through use of improved varieties and production techniques. The FAO also revealed that animal production has remained underexploited. Livestock mostly reared by farm families in Nigeria are the small ruminants like goats (76 million), sheep (43.4million), and cattle (18.4 million). The ecology in the northern part of the country makes it famous for livestock keeping. Poultry products are also insufficient in Nigeria; domestic demand outweighs production despite several interventions by development partners to improve production and safeguard against diseases including transboundary animal diseases. The population of poultry stands at 180 million poultry in 2017 (FAO, 2022).

Nigeria is the largest fish consumer in Africa and among the largest fish consumers in the world with about 3.2 million metric tons of fish consumed annually (Ezetoha, Opara, Chukwuchekwa, Akande, & Anyalewechi, 2023). Its fisheries and aquaculture are among the fastest growing subsectors in the country. With a coastline of 853km and over 14 million hectares of inland waters, total fish production per year is close to 1 million metric tons (FAO, 2022). In addition, fishing is a vital livelihood for the poor as well as an important protein source at the household level in Nigeria (Payne, 2000). The aquaculture sub-sector is considered a very viable alternative to meeting the nation's need for self-sufficiency in fish production and nutritional needs (Ezetoha *et al.*, 2023).

The Nigerian government has implemented several initiatives and programmes to enhance food production so as to provide sufficient quantities of food to meet domestic demand as well as an abundance of commodity crops for export in the international market. The initiatives and programmes include the Agriculture Promotion Policy (APP) and Nigeria–Africa Trade and Investment Promotion Programme. Other programmes include Presidential Economic Diversification Initiative, Economic and Export Promotion Incentives and the Zero Reject Initiative, Reducing Emission from Deforestation and Forest Degradation (REDD+); Nigeria Erosion and Watershed Management Project (NEWMAP); Action Against Desertification (AAD) Programme, among others (FAO, 2022).

Challenges facing food production in Nigeria

Despite the contribution to the economy, Nigeria's agricultural sector faces many challenges which impact on its productivity. Several research works have identified a number of constraints to increasing food production in Nigeria. The FAO (2022) identified poor land tenure system, low level of irrigation farming, climate change, land degradation, low technology, high production cost and poor distribution of inputs, limited financing, high post-harvest losses and poor access to markets as challenges faced in food production in Nigeria. Phillip *et al.* (2022) identified poor agricultural pricing policies, low fertilizer use, low access to agricultural credit, land tenure insecurity, land degradation, poverty and gender issues, low and unstable investment in agricultural research, and poor market access and marketing efficiency as constraints to food production and agricultural productivity in Nigeria. Other constraints include high cost of improved varieties of crops, species of animals, agrochemicals (fertilizers and insecticides) and animal feeds. Anjeinu and Aondonenge (2016) also identified lack of access to credits, inadequate land availability, and poverty, infertility of the soil, lack of non-farm income generating activities, storage and processing problems were identified as some of the factors militating against the achievement of food security in the study area as constraints such as to

food production in Nigeria. A study by Ezekiel (2021) identified low food production, farmers/herders clashes, insurgency, lack of mechanized farming systems and poor storage facilities as challenges faced in food production in Nigeria. The challenges facing food production in Nigeria are summarize in Table 1.

Table 1: Challenges of food production in Nigeria

S/N	Challenges	Causes
1	Poor land use/management.	Poor land tenure system, insufficient land, land degradation and manmade erosion.
2	Inadequate use of inputs.	High cost and inadequate use of improved varieties of crops and species of animals, poor distribution of inputs, ignorance of farmers and high cost of animal feeds.
3	Low use of technologies in farming.	Low use of modern Agro technologies, low and none use of mechanized and irrigation farming, dependence on traditional method of farming and low and unstable investment in agricultural research.
4	Inadequate or improper use of Agrochemicals.	Low use of fertilizer, pesticides and herbicides.
5	Poor finance.	Insufficient capital, high cost of labor and loan, low access to loan and grant.
6	Climate change (global warming).	Greenhouse <u>gas emissions caused by bush burning</u> , use of firewood, vehicle and generators and deforestation.
7	Poor marketing of produce.	Poor access to market and pricing, use of middlemen in sales and inadequate preservation facilities.
8	High post-harvest losses	Inadequate preservation facilities, lack of market, poor transportation network, high cost of transportation and insecurity.
9	Insecurity.	Herders and farmers clash, banditry/kidnapping, communal clash and theft.
10	Lack of information.	Ignorance, poor research on use of technologies and use of information tools, inadequate or lack of collaboration and poor research and record keeping
11	Poor Infrastructure	Lack of good roads, poor supply or lack of water, and electricity

These challenges of food production have stifled agricultural productivity, affecting the sector’s contribution to the country’s GDP and increased food imports due to population rise hence declining levels of food sufficiency.

Digital Agriculture

Digital agriculture or smart farming or e-agriculture (Organisation for Economic Co-operation and Development [OECD], 2019), consists of tools that digitally collect, store, analyze, and share electronic data and/or information in agriculture. The aim of digitalization of agriculture is to optimize food systems (Cornell University, 2019)). The term food system describes the interconnected systems and processes that influence nutrition, food, health, community development and agriculture. A food system includes all processes and infrastructure involved in

growing, harvesting, processing, packaging, transporting, marketing, consumption, distribution, and disposal of food and food-related items. Digital agriculture includes (but is not limited to) precision agriculture and it impacts the entire agri-food value chain-before, during, and after on-farm production (Shepherd, Turner, Small, & Wheeler, 2018). Digital agriculture encompasses on-farm technologies (precision agriculture technologies), blockchain-enabled food traceability systems, e-commerce platforms, e-extension services, warehouse receipt systems, and input rental Apps amongst others.

Digital agriculture technologies

Digital agriculture technologies include, but are not limited to precision agriculture technologies, distributed ledger technology, digital platforms, digital communications technologies, cloud computing/big data analysis tools, artificial intelligence, machine learning and Internet of Things (Wikipedia, 2023).

Precision agriculture technologies

Precision agriculture technologies have multiple applications along the agricultural value chain including:

- Sensing using sensors. The sensors include food sensors, environmental condition sensors, water quality sensors (Ezetoha et al. 2023), soil sensors and crop growth sensors.
- Advanced imaging technologies- including satellite and drone imagery that provides images of temperature, fertility and moisture gradients, and anomalies in a field (Zhang & Kovacs, 2012).
- Guidance and tracking systems- used for observing persons or objects on the move and supplying a timely ordered sequence of location data for further processing (Kamel, & Berry, 2012).
- Automated machinery- machine or machine tool (such as a spinning machine or lathe) which operates automatically after being set.
- Agricultural robots- deployed for harvesting, weed control, cloud seeding, planting seeds, environmental monitoring and soil analysis.
- Variable-rate input technologies- that allows machinery and equipment used for application of an input (such as fertilizer, seed, or pesticides) to work at varying rates to match the requirement at that specific location.
- Automatic section control- used for automatic turning OFF planter sections or individual rows in areas that have been previously planted or unplanted areas.

Distributed ledger technology

Distributed ledger technology (DLT) include blockchain (a distributed ledger with growing lists of records or blocks that are securely linked together via cryptographic hashes) and smart contracts (Maull, Godsiff, Mulligan, Brown, & Kewell, 2017). Smart contracts are computer programs or transaction protocols intended to automatically execute, control or document events and actions according to the terms of contract or agreement.

Digital platforms

Digital platforms include e-commerce platforms like agro information Apps that provide digital information on agro inputs and products delivery, agro-advisory Apps and animal diseases and e-extension website which help farmers to extend their profits.

Digital communications technologies

Digital communications technologies include electronic mail, voice-over-internet protocol (VoIP), websites, short message service (SMS), multimedia messaging service (MMS), chat and instant messaging, social media, blogs, wikis and Internet forums.

Cloud computing/big data analysis tools

Cloud computing/big data analysis tools include applications, servers (physical servers and virtual servers), data storage, development tools and networking capabilities hosted at a remote data center managed by a cloud services provider (or CSP) (Wolfert, Ge, Verdouw, & Bogaardt, 2017).

Artificial intelligence

Artificial intelligence (AI) include applications such as advanced web search engines such as Google Search, recommendation systems, speech recognition, self driving cars, generative and creative tools (Ezetoha, 2019).

Machine learning

Machine learning (ML) is a form of AI that finds application in crop, water and soil and livestock management (Ezetoha, 2019).

Internet of Things

The Internet of Things (IoT) comprise of devices with sensors, processing ability, software and other technologies that connect and exchange data with other devices and systems over the Internet or other communications networks (Gabbai, 2018; Gillis, 2021).

Impact of Digital Agriculture on Food Production

Digital agriculture can aid achievement of increased food production and sufficiency. Digital technologies can transform agriculture and food production. Specifically, in the agriculture and food sector, the spread of mobile technologies, remote-sensing services and distributed computing are already improving smallholders' access to information, inputs and markets, increasing production and productivity, streamlining supply chains and reducing operational costs. Digital agriculture can enable efficient use/management of land, efficient use of technologies in farming and marketing of produce, adequate information, access to sufficient finance, adequate use of inputs, reduction of effects of climate change, and post-harvest losses and security of farmers, laborers, land and produce.

Efficient use/management of land

Digital agriculture can help overcome the challenges such as poor land tenure system, insufficient land, land degradation and manmade erosion. Digital agriculture can aid achievement of increased food production while maintaining (or reducing) the land used in agriculture (Searchinger, 2019). Variable-rate application reduces input use, lowers costs and lessens negative environmental impacts (Tekin, 2010). Precision farming including variable rate nutrient application, variable rate irrigation, machine guidance, and variable rate planting/seeding can minimize use of agricultural inputs for a given yield (Bongiovanni, &

Lowenberg-Deboer, 2004). Minimization of use of agricultural inputs could mitigate negative environmental externalities (European Parliament, 2014), like greenhouse gas (GHG) emissions (Eory *et al.*, 2017), soil erosion, and fertilizer runoff (Pedersen, & Lind, 2017). In addition, off-farm digital agriculture has the potential to improve environmental monitoring. For example, satellite and drone imagery can track land use and/or forest cover (World Bank, 2019). Digital agriculture provides farmers with more real-time information about their farms, allowing them to make better decisions. Technology allows for improved crop production by understanding soil health (Wikipedia, 2023).

Adequate use of inputs

Digital agriculture can help overcome the challenges such as high cost and inadequate use of improved varieties of crops and species of animals, ignorance of farmers and high cost of animal feeds. While precision agriculture technologies can increase yields (Pedersen, & Lind, 2017), on-farm, precision agriculture technologies can minimize inputs required for a given yield. For example, variable-rate application (VRA) technologies can apply precise amounts of water, fertilizer, pesticide or herbicide. Variable-rate application improves input use efficiency (Tekin, 2010). Precision farming including variable rate nutrient application, variable rate irrigation, machine guidance, and variable rate planting/seeding can minimize use of agricultural inputs for a given yield (Bongiovanni & Lowenberg-Deboer, 2004; Eory *et al.*, 2017). Reduction of input use leads to waste reduction, lower costs and less negative environmental impacts.

Efficient use of technologies in farming

Low use of modern Agro technologies, low and none use of mechanized and irrigation farming, dependence on traditional method of farming and low and unstable investment in agricultural research cause inefficient use of technologies in farming and low production. Mobile phones, online ICTs, e-commerce platforms, digital payment systems, and other digital agriculture technologies can enhance productivity, mitigate market failures and reduce transaction costs throughout the value chain (Wikipedia, 2023).

Digital agriculture can enable small scale farmers to hire machines such as tractors via equipment-sharing platforms like Hello Tractor (Diaz, 2016) and MachineryLink Solutions (Zuckerman, 2016), and this facilitate farmer rental of expensive machinery. Use of mechanized farming improves productivity. In addition, e-extension platforms can provide real-time recommendations to farmers. For example, the machine-learning-enabled mobile app Plantix, Krisikart India diagnoses crops' diseases, and nutrient deficiencies based on a smartphone photo (World Bank, 2019).

Adequate use of agrochemicals

Inadequate or improper use of fertilizer, pesticides and herbicides affects productivity negatively. Mobile technologies, remote-sensing services and distributed computing improve smallholders' access to information and inputs these help in increasing production and productivity. Digital agriculture allows for improved crop production by understanding soil health, use of fertilizer, pesticide and herbicide. It allows farmers to use proper and adequate fertilizer and fewer pesticides on their crops (Wikipedia, 2023).

On the other hand, variable-rate application can reduce input use such as fertilizer, pesticides and herbicides, lowers costs and lessens negative environmental impacts (European Commission, 2013). In addition, on-farm precision agriculture technologies can minimize inputs required for a given yield. For example, variable-rate application (VRA) technologies can apply precise amounts of water, fertilizer, pesticide and herbicide thereby improving input use efficiency (Tekin, 2010)).

Sufficient finance

Insufficient capital, high cost of labor and loan and low access to loan and grant affects productivity negatively. Digital agriculture can improve the allocation efficiency of physical capital within and between farms. Farmers without the resources to make big investments can better access equipment to improve their productivity from equipment-sharing platforms like Hello Tractor (Diaz, 2016), MachineryLink Solutions (Zuckerman, 2016). Digital agriculture also improves labor productivity through decreased labor requirements. Automation inherent in precision agriculture from milking robots on dairy farms to greenhouses with automated climate control can make crop and livestock management more efficient by reducing required labor (Seabrook, 2019).

Digital agriculture technologies can also expand farmers' access to credit, insurance, and bank accounts. In addition, digital technology such as real-time digital communication platforms and blockchain/distributed ledger technology/smart contracts can create and facilitate trust between farmers and financial institutions and can also reduce the costs of verifying farmers' expected riskiness. In Kenyan, M-Shwari company uses customers' phone and mobile money records to assess creditworthiness (Wikipedia, 2023).

Reduction of effects of climate change

Effects of climate change caused by bush burning, use of firewood, vehicle and generators and deforestation can be reduced by adoption of digital agriculture. Digital agriculture can aid achievement of increased food production while cutting greenhouse gas emissions (Searchinger, 2019). Off-farm, digital agriculture has the potential to improve environmental monitoring and food system traceability (World Bank, 2019). For example, satellite and drone imagery can track land use and/or forest cover; food sensors can monitor temperatures to minimize contamination during storage and transport.

Efficient marketing of produce

Farmers can overcome poor access to market and pricing, use of middlemen in sales and inadequate preservation facilities and increase production by use of digital agriculture technologies. Digital agriculture technologies can make agricultural markets more efficient; mobile phones, online ICTs, e-commerce platforms, digital payment systems, and other digital agriculture technologies can mitigate market failures and reduce transaction costs throughout the value chain (Goldfarb & Tucker, 2017). The technologies reduce information asymmetry (Fafchamps, & Aker, 2015; Goyal & Aparajita, 2010), match buyers and sellers (Zeng, Jia, Wan, & Guo, 2017), lower transaction costs in commercial markets (Jouanjean, 2019), and lower transaction costs in government services (Martin, Harihareswara, Diebold, Kodali, & Averch, 2016).

E-commerce or other market linkage platforms can connect a small farmer directly to consumers around the world thereby avoiding middlemen that often extract exorbitant rents from farmers when purchasing their harvest or livestock for several reasons. Connecting producers with final consumers can eliminate intermediaries' monopsony power, thereby raising producer profits (Goyal, 2010).

Low post-harvest losses

Inadequate preservation facilities, lack of market, poor transportation network, high cost of transportation, pests and insecurity affects productivity negatively. Off-farm, digital agriculture has the potential to improve environmental monitoring and food system traceability. For example, sensors can monitor temperatures to minimize contamination during storage and transport (World Bank, 2019), pests and people in farms such as bandits, herders, kidnappers and thieves that cause losses to farmers.

Security of farmers, laborers, land and produce

Herders and farmers clash, banditry/kidnapping of farmers, communal clash and theft of farm produce affects productivity negatively. Off-farm, digital agriculture has the potential to improve environmental monitoring and food system traceability. For example, satellite and drone imagery can track land use and/or forest cover (World Bank, 2019); trackers can track herders and farmers in a clash, bandit/kidnappers and thieves that cause losses to farmers.

Adequate information

Ignorance, poor research on use of technologies and use of information tools and inadequate or lack of collaboration affects productivity negatively. Digital agriculture can enable individual farmers to work in concert, collecting and sharing data using technology thereby improving their knowledge on production. Digital agriculture improves labor productivity through improved farmer knowledge. E-extension (electronic version of traditional agricultural extension services) allows for farming knowledge and skills to diffuse at low cost. For example, the company Digital Green works with local farmers to create and disseminate videos about agricultural best practices in more than 50 languages (World Bank, 2017). E-extension services can also improve farm productivity via decision-support services on mobile apps or other digital platforms. Using many sources of information such as weather data, GIS spatial mapping, soil sensor data, and satellite/drone pictures amongst others; e-extension platforms can provide real-time recommendations to farmers. Use of technologies such as mobile phone for receiving agricultural advice via SMS messages help in increasing yields (Casaburi, Mullainathan, Kremer, & Ramrattan, 2014).

Conclusion

This study has identified and analyzed the prospects of digital agriculture in achievement of food sufficiency in Nigeria. The study initially identified poor land use/management, inadequate use of inputs, low use of technologies, poor finance, climate change, poor marketing of produce, high post-harvest losses, lack of information and poor infrastructure as constrains to food production.

The study finally identified that digital agriculture can enable efficient use/management of land, efficient use of technologies in farming and marketing of produce, adequate information, access

to sufficient finance, adequate use of inputs, reduction of effects of climate change, and post-harvest losses and security of farmers, laborers, land and produce and these factors enhance productivity and ensure food sufficiency.

It is important that digital agriculture should be adopted in order to achieve food sufficiency in Nigeria

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