Leveraging Precision Agriculture for Sustainable Food Security in Nigeria

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ABSTRACT

This article reviewed opportunities and challenges of emerging technologies with precision agriculture to address challenges of food security amid the growing population in Nigeria. Providing sufficient, safe and nutritious food to all people is one of the major global concerns historically and in the twenty-first century. Food security is usually framed in four dimensions, food availability, access to food, food use/utilization and food stability. The objectives of precision farming as reviewed by this study are to; optimize resource use, enhance crop yields, improve sustainability, and reduce environmental impact and are attainable. Precision farming harnesses data, technology, and innovation to transform these objectives into reality. Precision farming is a modern management strategy that employs the details of site-specific nutrient management, remote sensing, global information system, global positioning system, and variable rate application to precisely manage the farm. It was researched that they are installed on tractors and other field equipment to check or enhance equipment operations. Limitations identified were high costs of some of the technologies, other key barriers include the lack of digital infrastructure like Internet and electricity, lack of awareness and digital skills among farmers, and societal barriers like gender and cultural practices. Also, lack of digital skills and literacy among smallholder farmers remains a major barrier to leveraging the potential of digital technologies. Agriculturists are therefore encouraged to adopt precision farming to increase production efficiency, reduce cost of production/ waste and improve the quality of farm produce.

INTRODUCTION

World agriculture needs to undergo a major transformation to meet the future demands of a growing population. Over the years there have been issues surrounding food production. Global changes in population, economy, and climate continue to impose grand challenges on agriculture By 2050, the food industry will have to face the daunting challenge of feeding about 10 billion people by almost sustainably doubling its food supply (UNDP, 2021). Providing sufficient, safe and nutritious food to all people is one of the major global concerns historically and in the twenty-first century. Food security is usually framed in four dimensions food availability, access to food, food use/utilization and food stability (FAO, 2016). These dimensions build the overall framework of the definition established by the Food and Agriculture Organization of the United Nations (FAO 2016): "Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" Across all countries, people living in rural areas are the most exposed to food insecurity, owing to limited access to food and financial resources (FAO, 2016). Among them, 50 percent are smallholder farmers, producing on marginal lands that are particularly sensitive to the adverse effects of weather extremes, such as droughts or floods (UNCTAD, 2017).

Recent developments in digital technologies and big data combined with precision agricultural strategies can enable farmers to better understand the agronomics of crop production and to vary their management practices in response to site-specific growing conditions. This can increase the efficiency of input use and reduce agricultural pollution (Finger *et al*. 2019). Gene editing provides the promise of creating crop varieties that are more robust to climatic conditions, pests, weeds, and nutrient deficiency and the potential to enhance resource use efficiency in agricultural production (Sedeek *et al*. 2019). Recent improvements in nitrate uptake, transport, and use made through gene editing demonstrate the potential of this technology to reduce nitrogen losses (Fan *et al*. 2017, Kant 2018). Precision agriculture technologies are transforming the face of modern farming. Digital advancements such as wireless communication, data analytics, and data-driven genome editing, are rapidly being applied in agriculture as they provide more accuracy in decision making and practice. Being able to accurately decrease fertilizer, herbicide or seed rates in areas where it will not be economical to utilize is one of the key benefits of precision agriculture. Increasing yields because of applying agronomic principles at a high resolution, while reducing costs increases overall profitability. Satellite and Global Positioning System (GPS) technologies, sensors, smart irrigation, drones, and automation, to list a few, provide the means for precision agriculture, which further aids in effective resource utilization.

Two key problems of food security have been identified from the 2016 agriculture promotion policy which are: the inability to meet domestic food requirements and the inability to export at quality levels required for market success (FMARD, 2023). The inability to meet the domestic food requirement is largely attributed to inefficient farming models and lack of inputs such as fertilizers, irrigation crop protection and necessary support from the agricultural communities. On the other hand, the poor knowledge of target markets and inefficient system for enforcing the food quality to meet international standards are the limiting factors to exportation and successful market. Malnourished people are less productive, hungry children get no or little education, and become less capable adults even if hunger is overcome. Even short-term food insecurity has a long-term lasting impact on growth potential for the economy. The 11th edition of the Global

Food Security Index (GFSI) published in 2023, showed that Nigeria ranked 107th (scoring 42.0 points) out of 113th countries globally in the food security index. This suggests that 12.9 per cent of the global population in extreme poverty was found in Nigeria as of 2022. Precision agriculture will enhance the sustainable development goal, SDG aims to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture". Intrinsically related to society, economy, and the environment, is key to the success for food security (FAO 2016). Although poor countries tend to show greater reliance on farming activities, food production and consumption is fundamental to any economy and permeates every society. The eradication of hunger requires SDG targets and indicators aligned with the four pillars of food security: availability (having available sufficient quantities of food, whose continued production also depends on a healthy environment), access (having the economic and physical means to obtain a nutritious diet), utilization (having adequate dietary intake and the ability to absorb and use nutrients in the body), and stability (ensuring the other three pillars on a consistent basis) (FAO, 2016).

These problems can be addressed by shifting from manual driven agricultural system to a technology and data driven or smart agricultural models. This involves application of precision and smart agriculture for irrigation, water detection, soil analysis, field monitoring for pest control, tracking and monitoring of farm animals, monitoring of farm products during transportation, storage, and other farm operations. Precision agriculture (PA) can be referred to as the gathering of information dealing with spatial and temporal variation within an agricultural field and then using that information to manage inputs and farm practices efficiently. It has the potential to revolutionize agriculture and contribute to increased productivity and sustainable farming practices.

The Role of Precision in Modern Agriculture

The use of modern technology in agriculture can ensure that farmers grow large quantities of food in the shortest possible time. GPS technology has been used in the development of self-driving sprayers and tractors that do not require a driver (UNDP, 2021). These vehicles can perform tasks like planting, spraying, and harvesting with minimal human intervention. Precision agriculture reduces the need for agricultural inputs like water, fertilizers, and pesticides, thereby reducing costs and the environmental footprint of agricultural production. The use of technology also cuts down the need for physical labour and improves productivity, ultimately enhancing the profitability of farming as a source of livelihood. Digital technologies are making precision agriculture solutions increasingly affordable and accessible to even smallholder farmers in developing countries (Corallo *et al*, 2020). The adoption of these technologies is also driven by the growing mobile phone and Internet penetration and the falling costs of data worldwide. The mobile phone is perhaps the most transformative technology enabling precision agriculture for smallholder farmers. Examples of precision agriculture technologies include GPS and mapping systems, sensors, remote sensing technologies, satellite imagery, variable rate application equipment, autonomous or vehicles, and drones. Also automation technologies, such as robotics and Artificial Intelligence (AI), can improve efficiency and reduce labour costs in agro-food processing (UNDP,2019). For instance, robots can harvest crops, reducing the need for manual labour and increasing productivity (Lezoche *et al*., 2020).

Goals of Precision Agriculture in Food Production

Mobile phones enable two-way communication between farmers and experts, real-time monitoring, and the digitization and easy collection of field data. Smartphones with cameras, GPS, various sensors, and a processor offer additional capabilities. Cost-effective and scalable mobile phone-based farming advisory services are already helping millions of farmers worldwide, overcome the challenges of conventional agricultural extension. Through mobile phones, farmers can receive customised and localised advice on what, when, and how to grow, as well as alerts on weather, pests, and diseases. Remote sensing using satellites is also supporting precision agriculture (UNDP, 2019). This is made possible through the increasing availability of high-resolution imagery from satellites. Various onsite sensors can also be used to collect accurate farm-level data (e.g., soil moisture and pH, temperature, humidity) to help farmers make decisions related to sowing, irrigation, fertiliser application, and harvesting. This is enabled by advances in wireless networking technologies like Low-Power Wide Area Networks (LPWAN) and cloud computing (Lezoche *et al*., 2020. Sensors are being used to track food products, manage inventory, and reduce waste, leading to a more efficient and sustainable supply chain. Sensors can also help you track and trace your food products throughout the supply chain, ensuring traceability and accountability. Some examples of sensor technology that can improve your food quality are infrared, hyperspectral, and biosensors. Technologies can help reconcile the necessity for sustainable and profitable food production. The challenge is to identify what technologies work best in specific circumstances, and define and provide the right incentive framework, to facilitate the achievement of sustainability goals in ways that enhance global welfare, in accordance with policy principles agreed upon by United Nations Development Programme, 2012.

Reconciling food production and environmental goals can sometimes be achieved through the adoption of appropriate technologies. Sometimes those goals can be reconciled simply by changing the level, type and location of agricultural production. Reconciling those goals, however, also means that the rights and responsibilities of farmers regarding the adoption of technologies and practices need to be clearly defined and applied (taking into account the current distribution of property rights), and thus the situations under which they are entitled to remuneration (provider gets) or obliged to pay (polluter pays). The attribution of property rights has important implications for the distribution of income, wealth and equity. Technological change has been the basis for increasing agricultural productivity and promoting agricultural development. Research affects the productivity of farming systems by generating new technologies that, if appropriate to farmers' circumstances, will be rapidly adopted. Historically, researchers and extension workers have been primarily responsible for identifying and injecting economic and environmental factors into the process of developing and introducing an agricultural innovation (Devereux *et al*., 2020, Corallo *et al* .,2020, Adelaja and George, 2019). This is typically characterised as a top-down process, whereby researchers develop the innovation, extension workers promote its use, and farmers either adopt or reject the innovation based on the features important to them.

Benefits of Precision Agriculture

Precision agriculture is based on the ability to identify inter and intra-field variability and to use this information for more targeted crop management (Adelaja and George, 2019). By using resources more efficiently, precision agriculture can make agriculture more productive and sustainable. These precision agriculture sensors are used to determine the variety, distance, and height of any position within the required area (Sedeek *et al* ., 2019). They utilize the help of GPS satellites for this purpose. They are installed on tractors and other field equipment to check equipment operations as used thus:

i. Technologies that precisely target pests and diseases.

The need for medicines and pest control agents in agriculture is not likely to disappear any time soon, however, technological advances in the science of pest control are expected to continue to produce chemical control agents that over time are at least as effective in controlling pests as the ones they replace, but which are also less toxic, less persistent and less mobile through the soil. The greater application of monitoring and knowledge-based systems, aided by reductions in the costs of electronic sensors and computers, should also enable farmers to be more economical in their use of pest control agents, especially insecticides: applying them only when and where necessary, rather than according to predetermined dosages and schedules.

ii. Technologies that administer nutrients more efficiently

Farmers have traditionally relied on two main practices to supply nutrients to root zones: manuring and burning. Inorganic fertilisers allowed the separation of crop production from animal husbandry, restored fertility to depleted soils, and contributed to the development of livestock production based on grain and other feed ingredients. Research into the specific needs of particular crop-soil combinations and livestock has led over the years to more scientifically formulated fertilisers and feeds (Lezoche *et al,* 2020). Wider application of technologies that administer fertilisers only at the times and in the amounts needed can be expected to increase crop yields further while reducing the leaching and runoff of nutrients.

iii. Technologies that administer water more efficiently.

Many of the technologies still used for irrigating crops are as old as civilisation itself. The problem is that conveying water through open channels and furrows is wasteful: much of the water evaporates before it reaches the root zone. In Nigeria, much of the water used in agriculture is carried to fields by pipes; but technical efficiency could still be improved through greater application of technologies, like precision fertilisation, combine more accurate measurement of actual crop needs with means to deliver the water more accurately and in more precise dosages.

iv. Technologies that reduce wastage following harvesting.

The demand for primary agricultural commodities is a derived demand, which is determined in part by wastage between producer and final consumer. Technologies used in Organisation for Economic Cooperation and Development (OECD) countries to harvest, transport, store, process and distribute farm commodities are already highly efficient, and result in much lower levels of wastage than in countries where the requisite capital and infrastructure are in much shorter supply (Ortiz *et al*, 2019). Virtually all parts of most crops and animals are recovered for some commercial use only for feed, fertiliser or energy. Some further reduction in post-harvest losses is achievable, but the most wastage (in proportion to the quantity purchased) takes place at the point of final consumption.

v. Technologies that disseminate knowledge.

Historically farmers relied on their own experience and that of their neighbours with regard to adopting "good farming practices" (Kant, 2018). Advice and information from publicly funded agencies and agri-food industries are increasingly focused on environmental effects. The Internet provides further developments in the dissemination of information on sustainable technologies. More sophisticated medicines to some extent took pressure off from natural resistance. However, as consumers in OECD countries started demanding products that use fewer or none of these agents, a renewed stress on developing natural resistance can be expected.

Limitations of Precision Agriculture

The adoption of precision agriculture by farmers in developing countries is still at a nascent stage and is limited by several factors. High costs of some of the technology, other key barriers include the lack of digital infrastructure like Internet and electricity, lack of awareness and education, lack of data management and analytical skills among farmers, and societal barriers like gender (Kant , 2018). Also, the lack of digital skills and literacy among smallholder farmers remains a major barrier to leveraging the potential of digital technologies.

Solution

Overcoming these challenges requires cross-sector collaboration among the public and private sectors, civil society, and the academia. Solutions should be user-centred and designed considering the local context such as language, social and political barriers and inclusion challenges. An open approach (e.g., open source, open standards) to designing digital solutions will increase collaboration among stakeholders, ensure interoperability between solutions, and prevent duplication of efforts (Miao and Popp, 2014). The availability of digital infrastructure is a major bottleneck in scaling precision agriculture solutions, particularly in rural and remote areas. Public-private partnerships and technological innovation will play an important role in making available at least basic Internet coverage for all farmers.

Enabling policies addressing issues of data ownership and management, privacy and cybersecurity are essential for spurring innovation in the agritech sector and scaling the adoption of digital solutions. The public and private sectors can partner with civil society organisations (CSOs) and leverage their on-ground presence (e.g., agricultural extension workers) for delivering hands-on pieces of training and building the digital capacities of farmers.

CONCLUSION AND RECOMMENDATION

The precision agriculture relies upon specialized equipment, software and IT services. This includes accessing real-time data about the conditions of the crops, soil and ambient air, along with other relevant information such as hyperlocal weather predictions, labour costs and equipment availability. Agriculturists are encouraged to practice precision farming to increase production efficiency, reduce cost of production and improve the quality of farm produce to achieve food security. Therefore this research recommends that Government and other stakeholders should create more awareness about precision farming, provide specialized training and equipment, software and IT services at affordable prices.

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