Chapter 3

Prospects of Precision Agriculture for Improving Agricultural Production in Nigeria

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Abstract

Precision agriculture can be referred to as science for improving crop yields and assisting management decisions using high technology sensor and analysis tools. It is a new concept adopted throughout the world to increase production, reduce labor time and ensure effective management of farm inputs and irrigation processes in order to maximize production. It uses a large amount of data and information to improve the use of agricultural resources, yields and the quality of crops. Precision agriculture is a data-driven approach to farm management that can improve productivity and yields, thereby increasing the overall profitability of farming. It also helps reduce the need for inputs such as water and artificial fertilizers and pesticides, thus reducing the environmental footprint of farming. Advances in digital technologies like mobile phones, remote sensing using satellites, unmanned aerial vehicles (UAVs), Internet of Things (IoT), artificial intelligence (AI), and cloud computing, as well as their growing affordability are making precision agriculture applications accessible to smallholder farmers in developing countries.

Keywords: Precision agriculture, prospects, agricultural production, technologies, productivity

1. Introduction

Nigeria is West Africa's largest economy and second largest in sub-Saharan Africa. The country is vast with approximately 68 million hectares of arable land, 12.6 million hectares of freshwater supplies, and an ecological diversity that provides the supplies required to produce and grow a wide variety of crops (Ewetan, Adebisi and Emmanuel, 2017). Agricultural output makes approximately a quarter of Nigeria's overall nominal Gross Domestic Product (GDP).

The Food and Agriculture Organization (FAO) estimated a 70% increase in global food production by the year 2050. Also, the population of the African continent is projected to reach two billion by 2050 (Ishengoma and Athuman, 2018). Feeding this population would be quite challenging with limited farming methods. Currently, farmers in sub-Saharan Africa cultivate less area of land and harvest less due to lack of technological development in the agricultural sector. Besides, traditional farming techniques predominantly used in the region results in low crop yield compared to mechanized farming methods. Africa has 25% of the world's arable land, yet it contributes only 10% of the global agricultural output (Ishengoma and Athuman, 2018). Use of precision agriculture can be seen as a farming practice that will increase the production of crops by farmers in Nigeria if adopted and well managed.

2. Concept of Precision Agriculture

Precision agriculture is a farming method that uses approaches and tools to give farmers more control over their fields. Gary (2004) defined precision agriculture as a comprehensive system designed to optimize agricultural production through the application of crop information, advanced technology and management practices. It is a very modern aspect of agricultural practice. It can also be referred to as technologies for managing and controlling all resources to achieve sustainable development of agriculture based on information technology. This is bringing agriculture into the information and digital age. This incorporates technologies like geographic information system (GIS), satellite remote sensing and global positioning system (GPS) in practice. Precision agriculture is an agricultural mechanization method which depends strongly on electronics, information communication technology with technical skill of man power for plant and animal specific needs (Asoegwu, 2007).

According to Banu (2014), precision agriculture is an information and technology-based farm management system which highlights the fact that an understanding of variability within a crop field will achieve increased agricultural production. The goal is not to obtain the same outputs or yields all over the farm, but to evaluate the environment and distribute different site-specific inputs. This method can optimize agricultural benefits and produce a strong return on investment (Banu, 2014). In precision agriculture, the gap between mechanized farming and ICT is bridged by collecting farmland information and applying data analysis based inputs. Farm operations such as application of herbicides, fertilizers and irrigation can be done smartly, enabling farmers to achieve high yields, exact inputs use, reduce wastage

and maximize income (Beluhova-Uzunova and Dunchev, 2019). The use of precision agriculture technologies have the potentials to help manage agricultural resources and also boost production.

Precision agriculture is a revolutionized agriculture, site specific crop management that merges data collection and remote sensing with Global positioning system (GPS) and Geographic Information System (GIS) that allow farmers respond to in-field variability with their crop. According to Gorevlisi and Kekec (2023), precision agriculture have already increased farmers' production by 4%, reduced fertilizer use by 7%, decreased herbicide application by 9%, lowered fossil fuel use by 6% and gained a 4% savings in water use. According to Cheng et al. (2022), currently precision agriculture in developed countries has shifted from a soil science base to a computer science base over the past 10 years. However, in developing countries like Nigeria, precision agriculture and its objectives still remain strongly aligned with soil science and managing soil variability. Singh et al. (2022) noted that precision agriculture uses data and information to improve the use of agricultural resources, yields and the quality of crops. However, it is a new advanced innovation and optimized field level management strategy used in agriculture fields, where farmers provide optimized inputs to ensure productivity, quality and yield, thus, being sure of the crop health in the real time at high spatial resolution with precision agriculture support. In addition, precision agriculture is a management concept that relies on intensive data collection and data processing for guiding targeted actions which improve the efficiency, productivity and sustainability of agricultural activities.

Precision agriculture according to Barnes et al. (2021), is an advanced agricultural technology adopted and used in improving crop yields, assessing management decisions using high technology sensors and analysis tools, which involves monitoring crop conditions by assessing and measuring variables such as plant health, soil conditions, fertilizers, irrigation, pesticides effects and crop yields. Also, it involves gathering, processing and analyzing large amounts of data from multiple sources for field operations and decision-making in the management of crop production (Tripathy et al., 2021; Heideka et al., 2020; Mefaddan et al., 2023).

Precision agriculture requires integration of three elements: (1) positioning capabilities (currently, global positioning system or GPS) to know where equipment is located; (2) real-time mechanisms for controlling nutrient, pesticide, seed, water or other crop production inputs; and (3) databases or sensors that provide information needed to develop input response to site-specific conditions (Karlen et al., 1998).

Summarily, principles of precision agriculture are based on information, technology and management. Information (data) is modern farmers' most valuable tool in all phases of production from planning to post-harvest activities. This information are crop characteristics, soil properties, fertilizer requirements, role of populations, plant growth, response to harvest data and post-harvest processing data. Figure 1 gives a summary of precision agriculture technologies.

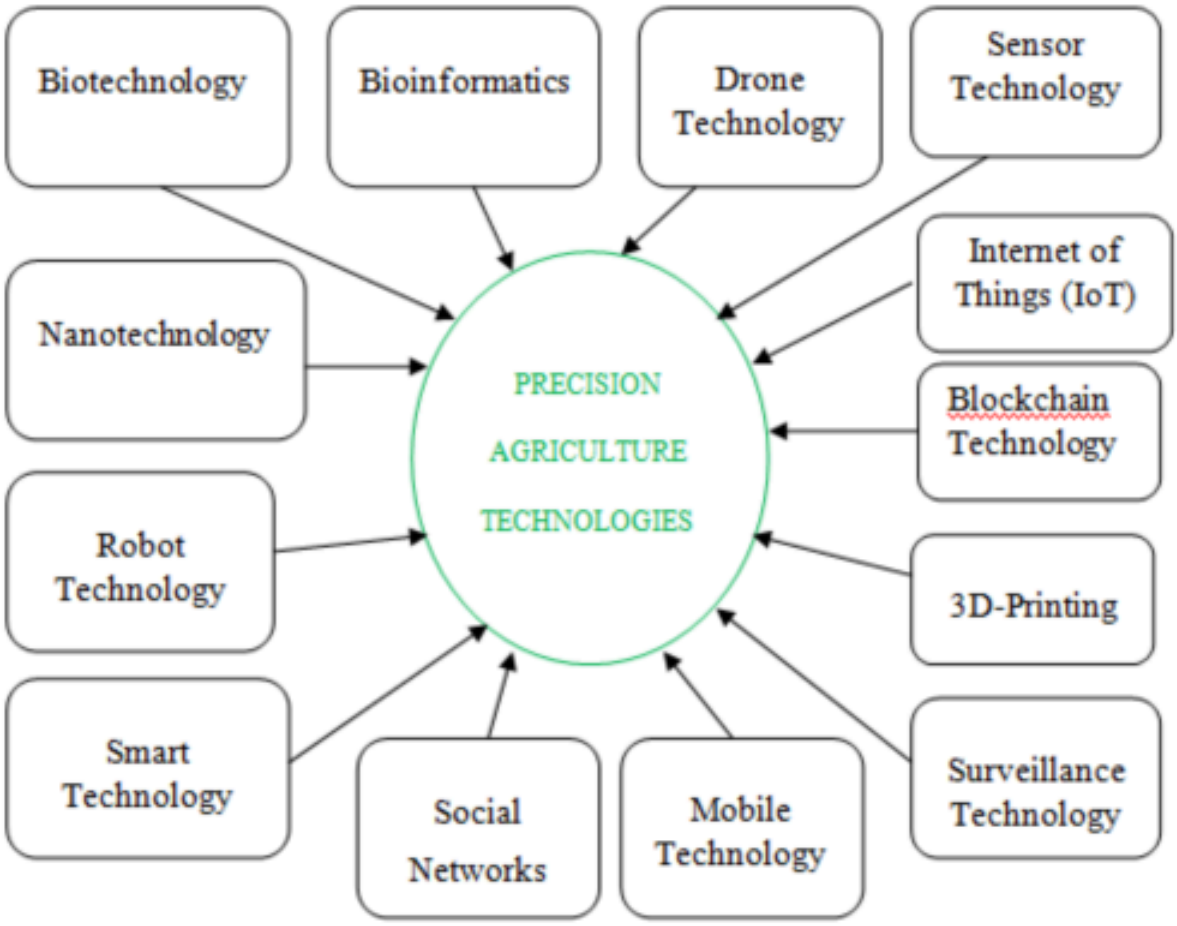

Figure :1 Precision agriculture technologies

3. Case Studies Of Precision Agriculture

The application of technology in agriculture has increased in recent times due to its potential to improve agricultural activities, operations and methods. Adah (2012) stated that the application of mobile (GSM) technology in the farming system is making the work of farmers effective and efficient. Emerging technologies mitigate the perceived difficulties in farming which often scares young educated people from engaging in farming.

Daudu (2023) also stated that the following technologies are in use in Nigeria: Augmentation of database and further development of spatial analytic applications include utilizing some locally unavailable technologies such as Light Detection and Ranging (LiDAR). Drones are being used in agriculture in order to enhance various agricultural practices. Tractor: The firm generates tractor operators' information and tracks the revenue generated during the time it is in use.

Probity Farms: The app solves the problems of recording farm practices, expenses and yield, and provides information on access to market to farmers.

Novus Agro: The Novus Agros agricultural information exchange services share farmers' data, market price intelligence and agricultural advisory and weather information through its online platform and SMS.

Ignitia: This is a Swedish tech company, is providing daily, monthly and seasonal weather forecast updates to rural farmers in Nigeria through subscription. The company uses GPS to create localized weather forecasts that are delivered to farmers via SMS. Variable rate drills and planters, fertilizer spreaders, and sprayers are commercially.

IITA herbicide application and CDA nut expert available for upscaling.

NIMET SRP-Combining forecast data with the crop models allows for recommendations that are implementable at small and large scales

Pavithra (2018) observed that an intelligent monitoring device for the agricultural greenhouse was presented. The system utilizes IoT infrastructure made up of nodes of a wireless sensor network to provide a monitoring feature for a greenhouse. The system monitors water level, temperature, soil moisture, humidity and light intensity. However, it does not possess a control feature for remotely managing farm operations.

Similarly, Naresh and Munaswamy (2019) presented a smart agriculture system using IoT technology. The system makes use of a wireless sensor network to monitor power supply, soil moisture, humidity, temperature and water levels. The system is controlled by an ARM 7 processor and transmits the data to a web server via a Wi-Fi module. This system also does not possess a feature for remotely controlling the farm operations.

Ji et al. (2015) presented an IoT and mobile cloud-based architecture for smart planting. Here, a system initiative for remote monitoring of agricultural parameters was designed. The system uses technologies such as 3G, GPRS and RFID to implement a remote monitoring feature. The data from the sensors can also be visualized via devices such as tablets and mobile phones. Although the design presented an architecture for the platform, no specific information was given regarding the techniques and schemes used in the design. Smart agriculture IoT with Cloud, Fog, and edge computing techniques was presented by Nandhini et al. (2019). The proposed system utilizes a machine learning edge-based IoT system for remote monitoring of agricultural parameters. The technique provides low latency and secure connectivity for IoT operations. However, the system provides no remote control techniques.

Furthermore, Olaniyi et al. (2019) worked on a remote monitoring and control system for poultry feed dispensing. The system uses Global System for Mobile Communications (GSM) and Short Messaging Service (SMS) technologies to monitor and control poultry feed dispensing in a deep litter poultry farm. The system has an average response time ranging from 1.6 seconds to 3.6 seconds depending on the network operator used. The system, however, had limited coverage due to its use of SMS and has the potential of being improved upon with Wi-Fi technologies.

A review of the state of the art IoT in precision agriculture was presented by Shi et al. (2019). The study did a literature survey on existing technologies as well as the limitations of current

schemes. Although several IoT based systems exist for agricultural operations, there also exists significant challenges in the field. These challenges include but are not limited to network issues, hardware and software challenges in terms of cost, durability and availability, security challenges and environmental factors.

Similarly, Ayaz et al. (2019) worked on a review of IoT based smart agriculture. The authors explored the use of unmanned aerial vehicles (UAVs), sensors and communication techniques for the development of a smart agriculture system based on IoT.

4. Benefits of Using Precision Agriculture

Precision agriculture increases production using farmer resources and maintains high-quality standards. It uses tools and strategies relevant to local needs at the sub-field level to improve the quality of crops and productivity of farm lands.

Reduces costs and manages waste: Precision farming provides enough data to find out the accurate/exact areas for using fertilizers, herbicides and seedlings and informs where it is not economical to use resources so that inputs are mostly utilized in the precise place to eliminate extra costs (Dhaya and Kanthavel, 2022).

Increased productivity: It aids farming business optimize efforts and resources, diseases control, wastes and apparently enhance productivity. It makes farming operations management simple, easy and very effective to cope with the increasing food demands.

Enhances sustainability and less of an environmental impact: Precision agriculture helps to understand critical inputs and their appropriate application such as the right seeds to plant, determining field specific treatments and reducing excessive use of fertilizers by precise placement. With the internet of things (IOT) farmers make more precise decisions and can manage their inputs and nutrients more carefully (Stata, 2021; Ghafar et al., 2023).

Increase land values: Precision agriculture by assessment of land provides accurate levels of what it needs to produce more. Therefore, when farmers provide the field areas with appropriate inputs, accelerate the production and profitability of land, inherently, better production and profitability, increase land market value and rate (Correndo et al., 2022).

Better Harvest ability: Precision agriculture determines the nutritional levels and soil texture across the farmland. All fields and regions differ widely in agriculture, so also their nitrogen mineralization, water holding capacity, waste formation, CO2, among other factors vary. When farmers understand these variables, they can be sure of the exact quantity (level) of nitrogen application, increase nutrients where they are low to optimize harvest ability. Consequently, it will result in increase in productivity (Kumari and Patil, 2018; Hunda et al., 2023; Leip et al., 2020).

Precision agriculture uses high powered technologies such as robot-mounted or stationary sensors and drones with embedded cameras wirelessly connected to computers to send images and information on individual plants such information like stem size, leaf shape and soil moisture of the plant. The computers make use of the data to determine the plant health and

stress which will be disseminated to farmers with real-time feedback that help farmers deliver optional quantities of resources to the regions that require items. In addition, this enables farmers in real time decision making for appropriate times for planting, harvesting, among others (Britannia, 2021; Shin et al, 2022).

Precision agriculture benefits farmers in many ways as the tools used in crop production is site specific crop management that uses precise GPS as well as location-specific measurements for collecting in-field data to identify variability in fields, with the data collected from management zones of the field. Precision agriculture enables farmers adjust treatments with field operation to meet the exact needs of each site which helps farmers to use the right inputs leading to better crop yields (Ventatrama nan et al., 2021; Hao et al., 2020).

Precision agriculture enables farmers to know more precise information for better decision making with real time action on the information which results in a better use of resources enabling more sustainable practices and save time, increase income and profitability.

The strength of precision agriculture has played a vital role in improving production, crop preparation, varietal development, harvest and post-harvest through adoption of appropriate innovation technologies that ensure sustainable production in shaping the future of farming (Hasan et al., 2024; Cheng et al., 2022).

5. Challenges of Precision Agriculture

Challenges on adopting precision agriculture in Nigeria as stated by Daudu (2023) are:

Data intensive: vast amount of information is required and this is mostly not available for use by Nigerian farmers.

Knowledge intensive: Collecting data is just the first step. Interpreting and acting on the collected data can be complex and farmers might need assistance in understanding how to optimize their practices based on the information.

Limited technical knowledge by farmers: Farmers in remote or underdeveloped areas may lack access to the necessary technology and the skills to effectively use and interpret the collected data. The use of the technology can require advanced knowledge and skills which can be very challenging if the farmers are not familiar with the technologies.

Availability and cost of management time with smallholder producers: Some precision agriculture technologies are designed for larger and more homogenous fields. Smallholder farms with diverse crops and smaller plots might face difficulties adapting these technologies to their unique conditions.

Investment/relatively higher start-up cost: Implementing precision agriculture technologies can require a significant upfront investment in equipment, sensors, software and training. This cost might be a barrier for farmers with limited financial resources.

6. Conclusion

Precision agriculture is the future of farming and is necessary for increased productivity in the Nigerian agricultural system. With precision agriculture in Nigeria, farmers will efficiently manage their farms especially by reducing waste of inputs and land both of which are major factors that reduce productivity and food availability in the Nigeria. While increasing speed and productivity, precision agriculture will also combat the issue of food insecurity as the nation's population increases daily.

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