

Adopting Precision Agriculture Technology in Nigeria: Towards Achieving a Sustainable Development Goals in Food Security and Mitigating Climate Change

*¹Mohammed Inusa Nguru, ²Bulama Ali, ³Abubakar Liman and ⁴Karagama Kolo Geidam

¹Department of Science Laboratory Technology, Mai Idris Alooma Polytechnic Geidam Yobe State

²Department of Forestry and Wildlife Federal University Gashua

^{3,4}Department of Survey and Geoinformatics Mai Idris Alooma Polytechnic Geidam

Corresponding author: ngurumuhammad1970@gmail.com

Abstract

As postulated by Malthus human population is growing at geometric progression while the resources are growing at arithmetic progression. With this exponential population growth, the world population is predicted to reach 9.2 billion by 2050. The current unsustainable agricultural system is exposing the environment to soil degradation, erosion, frequent drought, diseases, pollution, and ultimately to climate change. The World must adopt a kind of production with minimum input and maximum output. A kind of production that is sustainable with little or no detrimental consequences to the environment. Precision agriculture or smart agriculture is the answer to this. Precision Agriculture (PA) deals with the fine-tuned management of the agricultural inputs including, seeds, fertilizers, water, pesticides, and energy to create savings on these inputs, increase yield, augment profitability and conserve the environment. PA technologies include soil mapping, variable rate application (tillage, seeding, fertilizing, irrigation, and pesticide application), yield monitoring mapping, automatic guidance, and autonomous vehicles. It is an approach to farm management that uses information technology to ensure that crops and soil receive what they need for optimum health and productivity. It allows farmers to make data -driven decisions while implementing sustainable practices that preserve natural resources. Adopting PA technologies has apparent benefits for agricultural production management, cost savings, and environmental sustainability. The method is a game changer in the world agricultural landscape, despite the huge benefits its adoption has remained low among farmers in Nigeria despite the country's economic size.

Keywords: Adoption, Precision Agriculture, Climate change, sustainable development, Food security

Adopting Precision Agriculture Technology in Nigeria: Towards Achieving a Sustainable Development Goals in Food Security and Mitigating Climate Change

Introduction

Nigeria faces food insecurity due to exponential human population growth and a need for 480 million tons of food grain by 2050 (Mondal, 2009). Despite efforts to eradicate hunger and combat poverty, Nigeria ranks 20th in the 2006 Global Hunger Index (Adekunle, 2013).

Advanced technologies are needed to boost fisheries, cattle, and crops output (Daniel et al., 2023). The global community aims to eradicate poverty, hunger, inequality, and violence by 2030. Precision agriculture, or smart farming, is the best way to combat climate change and food insecurity (Abraham, 2022).

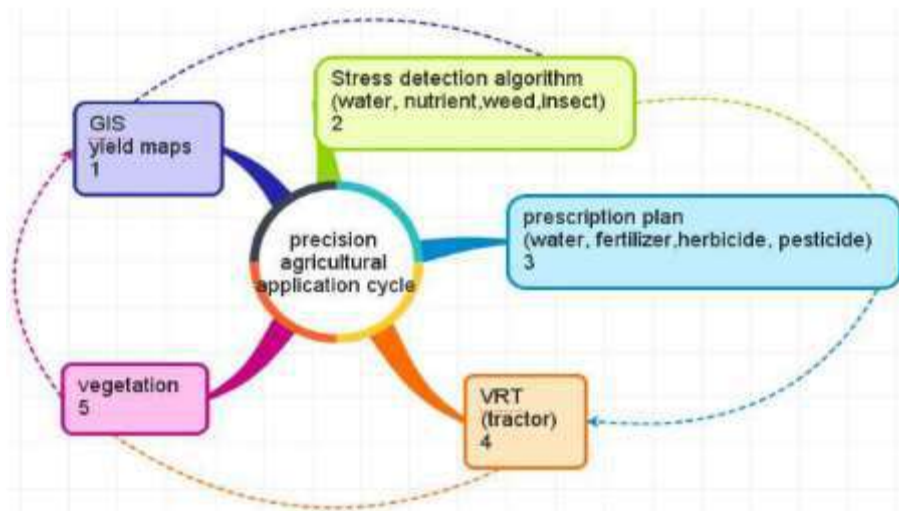


Figure 1: The cycle of precision Agriculture Abdullahi and Sheriff 2017

Precision agriculture is a system that uses crop information, technology, and management techniques to maximize agricultural productivity (Abdulsalam, 2019). It involves real-time control of inputs like fertilizer, pesticides, and water, GPS for equipment location, and remote sensors

for input responses (Adeoye, *et al.*, 2018). This approach focuses on the five "R" principles: right place, time, amount, source, and way. Precision agriculture promotes sustainable development in agricultural fields and has evolved over time, from hunting and gathering to mechanized agriculture in the 18th century (Degila, *et al.*, 2023).

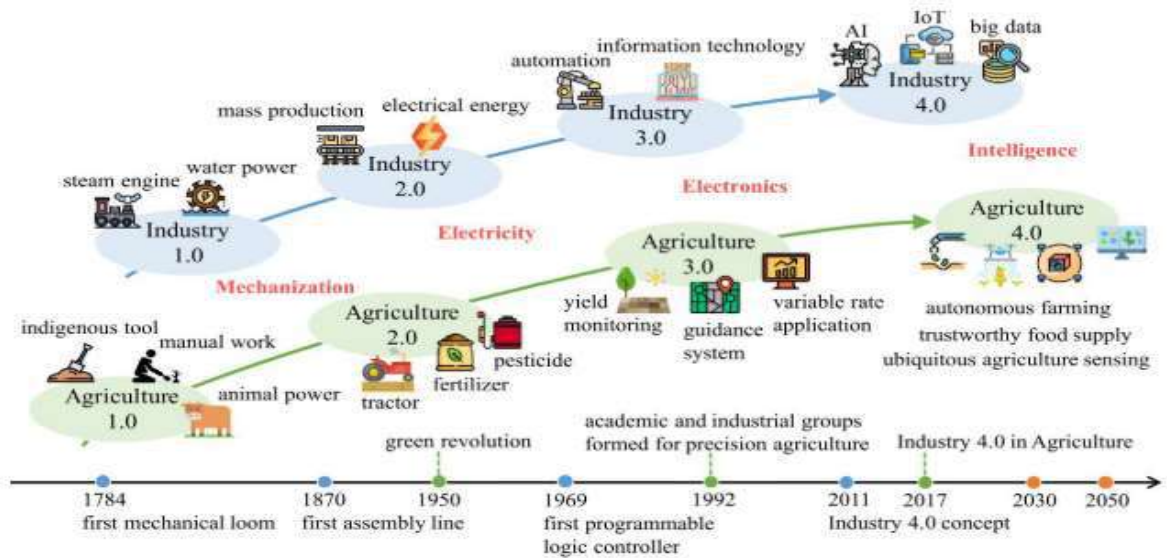


Figure 2 Roadmap of industrial and agricultural revolution (Adapted from (Degila, et al., 2023))

The fourth stage of the agricultural revolution, Agriculture 4.0, involves the use of high-tech technologies like cloud computing, biotechnology, drones, sensors, robots, precision agriculture, and smart farming (Jellason, 2021; Monteleone, *et al.*, 2020). This system integrates sustainable food production and better agricultural systems. IoT plays a

crucial role in agriculture, allowing models to evaluate crop development and soil resources. Precision farming, using AI, Big data, IoT, GNS, VR, and blockchain, can mitigate social and economic challenges and improve ecological wellbeing for growing populations (Yarashynskaya, 2022).



Figure 3 scope of adoption of precision agriculture(Gawande et al., 2023)

Adopting Precision Agriculture Technology in Nigeria: Towards Achieving a Sustainable Development Goals in Food Security and Mitigating Climate Change

Precision farming uses a four-stage process to observe spatial variability, geolocate data, and use remotely sensed images to identify issues at the smallholder farm level (Sule and Mayaki, 2020).. Researchers, extension agents, and smallholder farmers collaborate to adapt the method (Bamigboye,2016).. The Internet of Things (IoT) enhances daily living and agriculture by integrating sensors, real-world objects, machinery, and vehicles for data collection and exchange, promoting sustainable agriculture and disease risk management (Idowu, *et al.*, 2017).

Technological Tools required in precision farming.

Since they became commercially available in the 1990s, PF tools have significantly aided farm management across a range of industries, including viticulture, crop farming, horticulture, and zootchnics. They also support the Climate Smart Agriculture framework, which was introduced in 2009 and tackles the challenging problem of achieving sustainable agricultural growth for food security in the face of climate change. PFTs are employed less frequently than anticipated because of significant hurdles, as seen by the low acceptance rate in Europe despite these applications. Adoption is a process that takes time to complete and is influenced by a wide range of factors, including information-related factors, organizational and institutional factors, farm structure, location, and farmer characteristics. This intricate situation u

ses a conceptual framework of drivers and obstacles that has been extensively studied (Vecchio, 2020). Basically, the components of precision farming include the six major factors listed below by Ajewole, (2010): -

Variable Rate Technology (VRT) is a technique used in agriculture to regulate the rate at which crop inputs and tillage activities are applied, ensuring optimal fertilizer use in high-productivity areas and enhancing its application in low-productivity areas. Remote sensors gather image data from crops and soil, process it, and add it to a Geographic Information System (GIS) database. Computer hardware and software are used to analyze this data, providing comprehensible formats like charts, graphs, maps, and reports. Crop yield monitoring devices display information on crop yield, and GIS software creates yield maps using this data. GPS, a network of 24 satellites, is used for yield data collection and triangulation fix.

-

Unmanned Aerial Vehicle (UAV)

Unmanned Aerial Vehicles (UAVs) are used in agriculture for sustainable output increase. These mechanized devices, like quadcopters, use data analysis tools and sensor technologies for crop monitoring and irrigation systems (Ilyass, 2019). UAVs offer benefits like terrain independence, reduced costs, and immediate information provision.



Figure 4 Tools for precision farming (Gawande, *et al.*, 2023).

IoT technology in precision farming make it easier to follow farm products from the farm to the fork, enabling all parties involved in production, processing, and transportation to have the information they need to do their jobs (Bamigboye *et al.*, 2016).

According to Gawande *et al.* (2023), precision agriculture is used to accomplish the following goals. 1) rise in the output of food, 2) reducing expenses, 3) reducing adverse effects on the environment, such as drought, deforestation, flooding, and soil erosion. Precision farming is a method of agricultural management that uses technology to customize inputs for each field, improving crop productivity efficiency (Gawande *et al.*, 2023). It involves using advanced sensors like GPS, satellite remote sensing, and GIS to forecast weather patterns and increase crop yields (Ifeanyieze F. O., 2014). This approach has gained popularity due to its ability to adjust to varying farm sizes, lower costs, and increase accessibility of farming tools and methods (Singh *et al.*, 2020). It relies on electronics, information and communication technology, and human technical competence (Ifeanyichukwu, 2020).

According to (Onyango *et al.*, 2021) precision agriculture is a system in which decisions are made by humans as well as a variety of technologies, such as soil and crop sensors, GNSS (global navigation satellite system) such as the global positioning system (GPS), GIS, and variable rate application (VRA) technologies. The term SMART stands for - S- Specific, M-measurable, A-Attainable, R-Realistic and T- Timebound. In precision farming variable rate technology is achieved through the use of Soil moisture sensor, Humidity sensor, Temperature sensor, wireless sensor network, Arduino, Networking, WIFI and IoT (Internet of Things). In precision farming farmers apply information from most agriculture IoT products to take agricultural decisions about planting, irrigating, harvesting and many other agronomic practices (James, 2022). Geoinformatics uses remote sensing, global positioning system (GPS) and geographic information systems principles and products to collect, analyses and define agricultural suitability areas for precision farming (Rilwani, 2011).

Adoption of precision agriculture in Nigeria and other African countries

Adopting Precision Agriculture Technology in Nigeria: Towards Achieving a Sustainable Development Goals in Food Security and Mitigating Climate Change

Nigeria's space agency has enabled continuous aerial monitoring and surveillance of agricultural plants using satellites and remote sensing technologies, enabling optimization of crop production through precision agriculture (Abdullahi,2017). Nigeria's National Space Research and Development Agency has launched five satellites, including SAT 1, which provided images of the US east coast after Hurricane Katrina (Chizea,2019; Anthony,2019), Geoinformatics techniques in agricultural land evaluation and precision farming are yet to receive adequate attention in Nigeria (Rilwani, 2011 Ifeanyieze,2014).

Benefits of precision agriculture to Nigerian Economic growth.

Precision agriculture (PA) has the potential to revolutionize production agriculture by increasing efficiency by putting the right number of inputs in the right locations at the right times. According to Mintert,(2019) PA can achieve yields with the same number of inputs, equivalent yields with less inputs, or a combination of increased yield and fewer inputs. According to Gawande et al. (2023), It addresses resource variability in spatial and temporal dimensions, addressing two primary issues: alleviating food insecurity and adapting to climate change impacts (Bosompem, 2019). Precision farming (PF) is a significant agricultural breakthrough, based on smart technologies and digital data management. PF uses techniques for unique internal plot variability management, focusing on crop needs and soil chemical-physical parameters. Benefits include increased production optimization, rationalized inputs, lower costs, and favorable environmental effects (Masi, 2023). Precision agriculture (PA) is a technology that incorporates technology into conventional farming methods to increase productivity and sustainability (Finger,2019). It is essential for the world's

expanding population, as increasing food and animals is not enough to feed it. PA considers temporal and spatial variability to increase the sustainability of agricultural production (Danbaki,2020). In Sub-Saharan African (SSA) nations, agriculture is the most important economic sector, employing over two-thirds of the labor force and contributing one-third of the GDP (ISPA, 2018, Nyaga,2021). As the world's natural resources and arable land are limited, increasing food production is crucial to feed the estimated 9 billion people by 2050(Shaheb, 2022).According to Ifeanyieze *et al.* (2014), Precision agriculture (PA) and emerging technologies are crucial for increasing global agricultural productivity sustainably. PA enhances crop yields and supports management decisions using advanced tools like GPS, remote sensing, and GIS. To feed the 9 billion people, the world needs to increase food production. Climate change, caused by natural events and human activity, is a persistent variation in meteorological state.

Factors militating the adoption of precision farming in Nigeria.

New technology can benefit agronomy, the economy, and the environment by improving precision and saving time (Singh,2020). However, Nigeria faces challenges such as lack of electricity, water, technology, land allocation, and lack of understanding among farmers (Adeoye,2018). Precision agriculture (PA) technologies optimize agricultural production, allowing farmers to predict disease occurrences, apply inputs correctly, use less phytosanitary products, and perform labor-intensive tasks with less energy. This minimizes CO² emissions and maximizes chemical inputs and equipment usage (Yathrib, 2020).

Summary, conclusion and recommendation.

Adopting Precision Agriculture Technology in Nigeria: Towards Achieving a Sustainable Development Goals in Food Security and Mitigating Climate Change

Precision agriculture technologies can help Nigeria harness human, natural, and manmade resources for sustainable agricultural production and improved crop yields. The Malthusian hypothesis suggests a rise in sustainable food supply due to population growth. The internet of things has modernized agricultural operations, increased production, and opened new revenue streams. Nigerian agriculture must improve by providing internet-based facilities, equipment, and training programs to achieve the increased production seen in rich nations (Abdulwaheed, 2019).

References

- Abdullahi, H. S. (2017). Case Study to Investigate the Adoption of Precision Agriculture in Nigeria Using Simple Analysis to Determine Variability on a Maize Plantation. *Journal of Agricultural Economics and Rural Development*, 279-292.
- Abdulwaheed, A. (2019). Benefits of Precision Agriculture in Nigeria. *London Journal of Research in Science*: , 29-34.
- Abdusalam, A. (2019). Benefits of Precision Agriculture in Nigeria. *London Journal of Research in Science*: , 29-34.
- Abraham Ayegba Alfa, J. K. (2022). Smart Rice Precision Farming Schemes in Sub-Saharan Africa : Process and Architecture. In *Sustainable Rice Production – Challenges, Strategies and Opportunities* (pp. 1-17).
- Adekunle, I. O. (2013). Precision Agriculture : Applicability and Opportunities for Nigerian Agriculture. *Middle-East Journal of Scientific Research*, pp. 1230-1237.
- Adeoye. (2018). BENEFITS OF IMPLEMENTING PRECISION AGRICULTURE TECHNOLOGIES IN NIGERIAN AGRICULTURAL SYSTEM : A REVIEW. *1st International Civil Engineering Conference (ICEC 2018)* (pp. 1-10). Minna: Department of Civil Engineering Federal University of Technology, Minna , Nigeria.
- Adeoye, P. ..., Kutigi, I., Musa, J., Adesiji, R., & Obasa, P. (2018). BENEFITS OF IMPLEMENTING PRECISION AGRICULTURE TECHNOLOGIES IN NIGERIAN AGRICULTURAL SYSTEM : A REVIEW. *1st International Civil Engineering Conference (ICEC 2018) Department of Civil Engineering Federal University of Technology, Minna, Nigeria*, (pp. 1-10). Minna.
- al., N. e. (2021). Precision agriculture research in sub - Saharan Africa countries : a systematic map. *Precision Agriculture*, 1217-1236.
- Anthony. (2019). AN OVERVIEW OF EMERGENCY PREPAREDNESS , RESPONSE AND DISASTER MANAGEMENT IN NIGERIA : A STUDY OF NEMA. *World Educators Forum: An International Journal* , 285-305.
- Bamigboye, F. O. (2016). Internet of Things (Iot): It ' s Application For Sustainable Agricultural Productivity In Nigeria. *Proceedings of the iSTEAMS Multidisciplinary Cross-Border Conference University of Professional*

Adopting Precision Agriculture Technology in Nigeria: Towards Achieving a Sustainable Development Goals in Food Security and Mitigating Climate Change

- Studies, Accra Ghana 2016*, (pp. 309-312). Accra .
- Bosompem, M. (2019). PREDICTORS OF EX-ANTE ADOPTION OF PRECISION AGRICULTURE TECHNOLOGIES BY COCOA FARMERS IN GHANA. *Journal of Sustainable Development in Africa*, 89-110.
- Chizea, e. a. (2019). NASRDA 's Experience in Human Capacity Development and Capability Accumulation in satellite Technology. *Advances in Sciences and Humanities*, 70-75.
- Danbaki, e. a. (2020). Precision Agriculture Technology : A Literature Review. *Asian Journal of Advanced Research and Reports*, 30-34.
- Daniel, G., Izuagu, C., & Njoku, L. C. (2023). A Review of the Digitalization of Agriculture in Nigeria. *Journal of Agricultural Extension*, pp. 47-64.
- Degila, J., Ida, S., Honfoga, A.-c., Ariane, C., Sodedji, K., Hospice, G., & Peace, S. a. (2023). A Survey on Digital Agriculture in Five West African Countries. *agriculture*, 1-15.
- Finger, e. a. (2019). Precision Farming at the Nexus of Agricultural Production and the Environment. *Annu. Rev. Resour. Econ.*, 315-335.
- Gawande, V., aikanth, D. R., Sumithra, B. S., & Aravind, S. A. (2023). Potential of Precision Farming Technologies for Eco-Friendly Agriculture. *International Journal of Plant and Soil Science*, 101-112.
- Idowu, L. L., Ibrahim, I. A., & Abdullahi, U. G. (2017). Towards Diversification of Nigeria Economy through Adoption of IoT for Smart and Precision Agriculture. *International journal of Computer science and Information technology Research*, 209-222.
- Ifeanyichukwu, H. I. (2020). PROSPECT OF PRECISION AGRICULTURE IN NIGERIAN ECONOMY. *Journal of Inventive Engineering and Technology*, 35-41.
- Ifeanyieze. (2014). Techniques in Utilizing Remote Sensor Technology for Precision Crop Production by Farmers as Climate Change Adaptation Strategy in Nigeria. *Agricultural Sciences*, 1476-1482.
- Ifeanyieze, F. O. (2014). Techniques in Utilizing Remote Sensor Technology for Precision Crop Production by Farmers as Climate Change Adaptation Strategy in Nigeria. *Agricultural Sciences*, 1476-1482.
- Ilyass. (2019). Application of UAV ' s in Agriculture : Nigeria ' s Case. *International Journal of Advanced Research in Computer and Communication Engineering*, 103-106.
- Jellason, N. P. (2021). Agriculture 4 . 0 : Is Sub-Saharan Africa Ready ? *applied sciences*, 1-11.
- Keskin, S. a. (2018). ADOPTION OF PRECISION AGRICULTURE TECHNOLOGIES IN DEVELOPED AND DEVELOPING COUNTRIES. *The Online Journal of Science and Technology*, 7-15.
- Masi, M. (2023). Precision Farming : Barriers of Variable Rate Technology Adoption in Italy. *land*, 1-18.
- Mintert, B. a. (2019). FARMER PERCEPTIONS OF PRECISION AGRICULTURE TECHNOLOGY BENEFITS. *Journal of*
- Adopting Precision Agriculture Technology in Nigeria: Towards Achieving a Sustainable Development Goals in Food Security and Mitigating Climate Change*

- Agricultural and Applied Economics*, 142-163.
- Mondal, P. A. (2009). Adoption of precision agriculture technologies in India and in some developing countries : Scope , present status and strategies. *Progress in Natural Science*, pp. 659-666.
- Monteleone, S., & Moraes, E. A. (2020). Exploring the Adoption of precision Agriculture for Irrigation in the Context of Agriculture 4 . 0 : The Key role of Internet of Things. *Sensors*, 1-32.
- Nyaga. (2021). Precision agriculture research in sub - Saharan Africa countries : a systematic map. *precision Agriculture*, 1217-1236.
- Onyango, C. M., Nyaga, J. M., Nyaga, J. M., Wetterlind, J., & Söderström, M. a. (2021). Precision Agriculture for Resource Use Efficiency in Smallholder Farming Systems in Sub-Saharan Africa : A Systematic Review. *sustainability*, pp1-17.
- Say, S. M., Keskin, M., & Sehri, M. a. (2018). ADOPTION OF PRECISION AGRICULTURE TECHNOLOGIES IN DEVELOPED AND DEVELOPING COUNTRIES. *The Online Journal of Science and Technology*, 7-15.
- Shaheb, R. (2022). Precision Agriculture for Sustainable Soil and Crop Management. In *Soil Science - Emerging Technologies*, *Global Perspectives and Applications systems* (pp. 1-22).
- Sherif, A. a. (2017). Case Study to Investigate the Adoption of Precision Agriculture in Nigeria Using Simple Analysis to Determine Variability on a Maize Plantation. *Journal of Agricultural Economics and Rural development*, 279-292.
- Singh, P. (2020). 8. *Hyperspectral remote sensing in precision agriculture: present status, challenges, and future trends*. Elsevier Ltd.
- Sule, I. M., & Mayaki, J. a. (2020). Effects of Climate Variability on Crop Yield and its Implications for Smallholder Farmers and Precision Agriculture in Guinea Savanna of Nigeria. *Journal of Geography, Environment and Earth Science International*, 1-13.
- Vecchio, Y. e. (2020). Adoption of Precision Farming Tools : The Case of Italian Farmers. *International Journal of Environmental Research and Public health*, 1-16.
- Yarashynskaya, A. a. (2022). Precision Agriculture Implementation Factors and Adoption Potential : The Case Study of Polish Agriculture. *agronomy*, 1-16.
- Yatribi, T. (2020). FACTORS AFFECTING PRECISION AGRICULTURE ADOPTION : A SYSTEMATIC LITERATURE REVIEW. *Economics*.