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THE APPLICATION OF INTERNET OF THING (IOT) TO ENHANCE PRODUCTIVITY AND SUSTAINABILITY IN NIGERIAN AGRICULTURE: A REVIEW

Agballa U.B., Odonwodo C.U., Agida J., Bature R.S., Kabir U., and Onunka O.
Nigerian Institute of Leather and Science Technology, Zaria, Nigeria
Correspondence: fabu2k2@gmail.com

ABSTRACT

Agriculture is a cornerstone of Nigeria's economy, providing livelihoods to a significant portion of the population. With the challenges of population growth, climate change, and resource limitations, there is a pressing need to adopt innovative technologies. The Internet of Things (IoT) offers a transformative approach to address these challenges in agriculture. This paper explores the diverse applications of IoT in Nigerian agriculture, examining case studies, benefits, and challenges. By analyzing successful implementations and considering the unique agricultural landscape of Nigeria. It was observed that in Nigerian, IoT enhance productivity in agriculture by enabling precision farming techniques, real-time monitoring of crop conditions, and efficient resource management to enhance productivity and yield but comes with numerous challenges as it regards to limited access to reliable internet connectivity in rural areas and the high cost of IoT devices. Hence, hindering widespread adoption among farmers. This paper therefore aims to summarize and analyze accurately the existing position of use of the internet of things (IoT) in agriculture with its strong influence and difficult tasks being recognized. Define the IoT infrastructure required for agricultural applications, including sensors, actuators, communication networks, and data processing systems to drive productivity, resource efficiency, and sustainability.

KEYWORDS
Agriculture, Internet of Things (IoT), productivity, food quality, IoT in agriculture, IoT sensors, smart agriculture

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INTRODUCTION

Agriculture in Nigeria faces multifaceted challenges, including fluctuating weather patterns, inefficient resource utilization, and the need for increased productivity. There is need for Nigeria to diversify its economy from crude oil to agriculture due to low selling prices of crude oil (Gavrilova., 2020) , diversification into agriculture is very crucial for Nigeria due to its potential to reduce the country's heavy reliance on oil revenue, fostering economic resilience and food security while providing employment opportunities for its rapidly growing population. And also the need to balancing investments in agricultural technologies and infrastructure could catalyze this shift toward a more diversified and sustainable economy.

For the African continent, agriculture is predicted to take Africa out of poverty if technology is properly utilized for mechanized farming (Gassner *et al.*, 2019). However it is pertinent to note that, most Nigerians and Africans are still practicing agriculture using traditional approaches. This calls for the government and related agencies in Nigeria and other African countries to invest heavily into smart agriculture in order to get the country and continent out of poverty (Poverty, 2017). The integration of IoT technologies holds the promise of revolutionizing agricultural practices by providing real-time data, precision insights, and automation.

Hence this paper aims to summarize and analyze accurately the existing position of use of the internet of things (IoT) in agriculture with its strong influence and difficult tasks being recognized. Define the IoT infrastructure required for agricultural applications, including sensors, actuators, communication networks, and data processing systems to drive productivity, resource efficiency, and sustainability.

To achieve the aim of this study, the researchers carefully observed how farm practices are being done. Also, previous works from science direct, Springer, and journals of Computer Applications were reviewed. From our review, we, therefore, concluded that IoT has come to stay and there is a need to embrace it because it has the strength to rebrand rural agriculture to modern agriculture.

IOT IN AGRICULTURE: A PARADIGM SHIFT

The expression "Internet of Things" describes the idea that the Internet is now more than just a platform for people to use to communicate with one another online. It also refers to the idea that devices can use the Internet to electronically communicate with their surroundings. As a result, information is constantly flowing between devices. Hence, IoT in agriculture refers to the interconnected network of devices, sensors, and technologies that collect, transmit, and analyze data from farming environments, enabling farmers to monitor and manage crops, livestock, and agricultural processes in real-time for optimized decision-making, resource allocation, and productivity enhancement. The Internet of Things (IoT) is based on the technologies that make it up, such as the usage of sensors, RFID chips, nanotechnologies, identity systems (chips, cards, SIMs), and others. The most accurate way to describe it is probably as a group of interconnected technologies that may be used to produce fascinating goals (Sriveni & Bilal., 2020). IoT in agriculture involves connecting sensors, devices, and machinery to gather data and enable data-driven decision-making. This interconnected ecosystem offers a novel approach to optimize farming practices and enhance productivity (Douglas *et al.*, 2023).

IOT APPLICATIONS IN NIGERIAN AGRICULTURE

Precision Farming

IoT-enabled sensors collect data on soil moisture, temperature, and nutrient levels, allowing farmers to tailor irrigation and fertilization, resulting in improved yields and resource conservation as shown in figure 1.

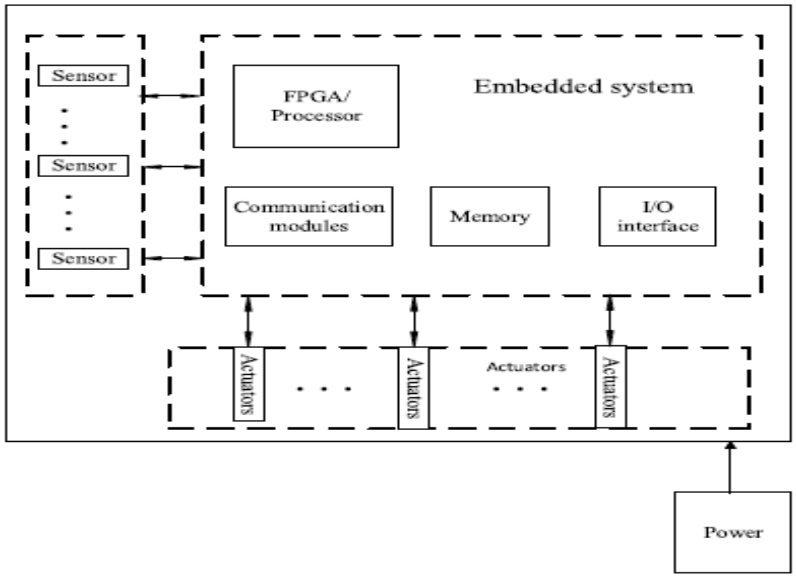

Fig 1.0 Architecture of IoT device.

The embedded system consists of field programmable gate arrays or microprocessor, communication modules, memory and input/output interfaces. The sensors are used to monitor and to measure different farm variables (example soil nutrients, weather data, soil moisture, temperature) and factors that affect production. The sensors can be classified into location sensors, optical sensors, mechanical sensors, electrochemical sensors, and airflow sensors (Li *et al.*, 2010). These sensors are used to gather information, such as air temperature, soil temperature at various depths, rainfall, leaf wetness, chlorophyll, wind speed, dew point temperature wind direction, relative humidity, solar radiation, and atmospheric pressure.

Livestock Monitoring

IoT devices equipped with GPS and health sensors track the location, health, and behavior of livestock, enabling timely interventions and better management. The factor to be monitored in livestock depends on the types of animals under consideration (Shinde & Prasad, 2017). For example, the conductivity of milk from buffaloes and cows can give information about the health state of the animals. Other factors are temperature, humidity, yield, pest attack, and water quality (Mainetti, 2013). The deployment and implementation solution also allow farmers to track and query the location of their livestock by tagging individual animal with RFID device, thereby

preventing animal theft. Other areas, such as storage monitoring which includes water, fuel, and animal's feeds can also be monitored, and the data can help the farmers to plan ahead and save cost. While several solutions have been provided in the area of monitoring, the adoption in small and medium scale farms are very much limited especially in developing countries due to lack of awareness and deployment cost. The potential to develop cost effective agricultural base IoT solutions is still a very open area. IoT is also applied in asset tracking as it is used in livestock monitoring to improve companies supply chain and logistics (Huang & Liu., 2014).

Crop Health Management

Drones equipped with IoT technology capture high-resolution images of crops, identifying diseases and nutrient deficiencies for targeted interventions. This involves an automatic disease detection using the leaf or the general well-being of crop under investigation (Thorat *et al.*, 2017).

Weather Forecasting

IoT-based weather stations provide real-time weather data, enabling farmers to make informed decisions about planting, irrigation, and harvesting. In crop farming, there are several environmental factors that affect farm produce. Acquiring such data help to understand the patterns and process of the farm. Such data includes the amount of rainfall, leaf wetness, temperature, humidity, soil moisture, salinity, climate, dry circle, solar radiation, pest movement, human activities, etc. (Zhao *et al.*, 2010). The acquisition of such detailed record enables optimal decision making to improve the quality of the farm produce, minimize risk, and maximize profits. For instance, the solar radiation data gives information about the plants exposure to sunlight from, where the farmer can identify if the plants are properly exposed or over exposed. The soil moisture content gives information on the dampness of the soil which can help in controlling soil conditions and reduce the risk of plant diseases. Furthermore, timely and accurate weather forecasting data, such as, climatic changes and rainfall, can improve the productivity level (Kodali *et al.*, 2016) (Na *et al.*, 2016).

Opportunities and Challenges

Opportunities

The application of the Internet of Things (IoT) presents numerous opportunities to significantly enhance productivity and sustainability in Nigerian agriculture. One key opportunity lies in the ability of IoT technologies to provide real-time monitoring and data-driven insights across various stages of agricultural production. By deploying IoT sensors and devices in the field, farmers can collect valuable information on soil moisture levels, weather conditions, crop health, and livestock status. This data can then be analyzed to optimize resource use, improve decision-making, and maximize yields (Farrell, 2015). For example, IoT-enabled precision agriculture techniques allow for precise irrigation and fertilization, reducing water and chemical usage while increasing crop productivity.

Furthermore, IoT solutions offer the potential to enhance agricultural resilience to climate change and variability (Utku & Enver 2019). In a country like Nigeria, where agriculture is highly vulnerable to extreme weather events and shifting climatic patterns, IoT-based monitoring systems can provide early warnings for droughts, floods, and pest outbreaks. By integrating weather forecasts with real-time field data, farmers can implement adaptive strategies to mitigate risks and protect their crops and livestock. Additionally, IoT-enabled smart farming practices can help farmers adapt to changing environmental conditions by optimizing planting schedules, selecting climate-resistant crop varieties, and implementing soil conservation measures.

Another significant opportunity lies in the role of IoT in improving supply chain efficiency and market access for Nigerian farmers. IoT technologies can track and trace agricultural products from farm to market, ensuring transparency, quality assurance, and food safety compliance (Gokul & Gawande, 2017). By implementing IoT-enabled logistics and inventory management systems, farmers can reduce post-harvest losses, minimize transportation costs, and access higher-value markets. Additionally, IoT platforms can facilitate direct communication and transactions between farmers and buyers, enabling fairer pricing and increased market opportunities for smallholder farmers.

Moreover, the adoption of IoT in Nigerian agriculture can contribute to sustainable development goals by promoting resource efficiency, environmental conservation, and inclusive growth. IoT-based monitoring of water usage, soil quality, and energy consumption can help farmers optimize resource use and minimize waste, leading to more sustainable agricultural practices. Furthermore, by providing smallholder farmers with access to IoT technologies and digital platforms, the agricultural sector can become more inclusive and equitable, empowering rural communities and reducing poverty.

Overall, the opportunities offered by IoT in Nigerian agriculture are vast and diverse, ranging from increased productivity and resilience to enhanced market access and sustainability. By harnessing the power of IoT technologies and fostering collaboration among stakeholders, Nigeria has the potential to transform its agricultural sector and unlock new opportunities for growth and development.

Challenges

While the application of the Internet of Things (IoT) holds immense promise for enhancing productivity and sustainability in Nigerian agriculture, several challenges must be addressed to realize its full potential. One major challenge is the lack of adequate infrastructure and connectivity in rural areas, where the majority of Nigerian farmers reside. Limited access to reliable electricity and internet connectivity hinders the deployment and operation of IoT devices and sensors in agricultural settings. Without robust infrastructure, farmers may struggle to access real-time data and utilize IoT-based solutions effectively (Shiva *et al.* 2019). Hence limiting their ability to make informed decisions and optimize agricultural practices.

Furthermore, the high cost of IoT technologies and limited financial resources among Nigerian farmers pose significant barriers to adoption. Many smallholder farmers in Nigeria operate on small profit margins and face challenges in accessing affordable financing for investment in agricultural technologies. The upfront costs associated with purchasing IoT devices, sensors, and data analytics platforms may be prohibitive for resource-constrained farmers, particularly those with limited access to credit and financial services (Shiva *et al.* 2019). As a result, widespread adoption of IoT in Nigerian agriculture may require innovative financing models, public-private

partnerships, and targeted support programs to make technology more accessible and affordable to farmers.

Another critical challenge is the lack of technical skills and digital literacy among Nigerian farmers and agricultural extension workers. Effective implementation of IoT solutions requires a certain level of technical expertise in data collection, analysis, and interpretation. Many farmers may lack the necessary training and knowledge to install, maintain, and troubleshoot IoT devices (Ray, 2017) ring their adoption and utilization. Moreover, agricultural extension services in Nigeria often lack the capacity and resources to provide adequate training and support for IoT-enabled practices. Addressing this challenge will require investments in capacity building, training programs, and knowledge dissemination initiatives to empower farmers with the skills and knowledge needed to leverage IoT technologies effectively.

Additionally, concerns related to data privacy, security, and ownership present significant challenges to the adoption of IoT in Nigerian agriculture. IoT devices collect vast amounts of sensitive data on agricultural operations, including crop yields, land holdings, and financial transactions (Asplund & Nadjm, 2016). Without proper safeguards and regulatory frameworks in place, there is a risk of data breaches, unauthorized access, and misuse of farmer data by third parties. Farmers may be hesitant to adopt IoT technologies if they perceive them as a threat to their privacy and data sovereignty (Gokul & Gawande, 2017). Therefore, it is essential to establish clear guidelines and regulations governing data governance, security, and ownership to build trust and confidence among farmers and ensure responsible use of IoT-enabled solutions.

Therefore, while IoT holds great promise for transforming Nigerian agriculture, several challenges must be addressed to overcome barriers to adoption and ensure successful implementation. By addressing infrastructure limitations, affordability concerns, capacity building needs, and data governance issues, stakeholders can create an enabling environment for the widespread adoption of IoT technologies in Nigerian agriculture, unlocking new opportunities for improved productivity, sustainability, and resilience in the sector.

Strategies for Successful IoT Adoption in Nigerian Agriculture

Successful adoption of IoT (Internet of Things) in Nigerian agriculture necessitates a multi-faceted approach encompassing technological, infrastructural, and policy considerations. Firstly, creating awareness and education among farmers about the benefits and functioning of IoT technologies is crucial. This can be achieved through workshops, demonstrations, and collaborations with agricultural extension services. Providing accessible training programs tailored to the needs and capabilities of Nigerian farmers will empower them to leverage IoT solutions effectively.

Secondly, addressing infrastructural challenges is imperative for IoT implementation in Nigerian agriculture. This involves ensuring reliable internet connectivity, particularly in rural areas where many farms are located. Government and private sector initiatives to expand internet coverage and improve network reliability will facilitate the seamless integration of IoT devices on farms. Additionally, investing in energy infrastructure to mitigate power outages and provide consistent electricity supply is essential for the uninterrupted functioning of IoT systems.

Furthermore, fostering an ecosystem conducive to innovation and entrepreneurship is vital for the sustainable growth of IoT in Nigerian agriculture. Encouraging collaboration between technology developers, agricultural experts, and policymakers can spur the development of tailored IoT solutions that address the specific needs and challenges of Nigerian farmers (Sharma *et al.*, 2018). Providing incentives such as grants, subsidies, and tax breaks for IoT adoption can incentivize farmers to invest in these technologies.

Moreover, ensuring data security and privacy is paramount to building trust and confidence among farmers regarding IoT adoption. Implementing robust cybersecurity measures and regulatory frameworks to safeguard sensitive agricultural data is essential (Gokul & Gawande, 2017). Collaboration between government agencies, industry stakeholders, and cybersecurity experts can help establish guidelines and standards for data protection in the agricultural sector.

However, successful adoption of IoT in Nigerian agriculture requires a holistic approach encompassing awareness-building, infrastructure development, ecosystem support, and data security measures. By addressing these key areas, Nigeria can harness the transformative potential

of IoT to enhance agricultural productivity, sustainability, and resilience, thereby contributing to food security and economic development.

DISCUSSION

As an innovative ideology that has changed the process of farming, IoT takes the place of communication and computing in the time ahead. It is also used in smart traffic management, smart homes, and cities. Generally, IoT with its wide range of applications can almost be made the best use of in every sector. The topic of this article "IoT Applications in agriculture –Challenges and Impacts" acknowledges crop management, crop monitoring/field monitoring, resource management, cost-effective farming, and enhanced crop quality. Thus, with the help of the internet of things, the value and effectiveness of every practical front of increasing agricultural productivity are enhanced, making cropping systems intelligent and considerate. Equally, IoT has played a good role as a smart device in pest and crop disease detection and information transmission about them. This disease and pest detection ability of IoT technology at the early stage of crop farming enables high revenue generation for the farmers. By leveraging IoT technologies, farmers can gather real-time data, make informed decisions, and optimize resource utilization, ultimately leading to increased yields, reduced environmental impact, and improved livelihoods.

CONCLUSION

IoT applications have the potential to revolutionize Nigerian agriculture by addressing challenges, enhancing productivity, and promoting sustainability. While challenges such as connectivity and data security persist, strategic interventions can pave the way for successful IoT integration. The main contributions of the paper revolve around showcasing how IoT applications in Nigerian agriculture significantly enhance productivity and sustainability. It highlights how the integration of IoT technologies optimizes resource usage, facilitates data-driven decision-making, and improves agricultural processes, thereby fostering increased productivity while promoting sustainable farming practices in Nigeria. Therefore, the Nigeria's agricultural sector can harness the transformative power of IoT to create more efficient, resilient, and sustainable farming practices.

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