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Smart Farming: Ai Technology for Farm Monitoring and Security in Nigeria

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ABSTRACT
Agriculture remains a critical sector in Nigeria, contributing significantly to the economy and providing livelihoods for a large portion of the population. However, Nigerian farms face numerous challenges including crop theft, livestock rustling, and inefficiencies in monitoring crop health and soil conditions. Leveraging Artificial Intelligence (AI) offers transformative potential to enhance farm monitoring and security, thus ensuring sustainable agricultural practices and food security.

This paper explores the application of AI technology in farm monitoring and security within the Nigerian context. It delves into various AI-driven solutions such as drone surveillance, IoT sensors, and machine learning algorithms for predictive analytics. These technologies enable real-time monitoring of farm conditions, early detection of diseases, and precise irrigation management

Despite the promising benefits, the implementation of AI in Nigerian agriculture faces challenges such as high initial costs, limited internet connectivity in rural areas, and a lack of technical expertise among farmers. In conclusion, AI technology holds significant promise for revolutionizing farm monitoring and security in Nigeria. By harnessing the power of AI, Nigerian farmers can achieve higher productivity, reduce losses, and contribute to the nation's food security goals.

Keywords: Agriculture, Artificial Intelligence, Security, Smart farming, Farming Monitoring

I. INTRODUCTION

Agriculture continues to be a vital sector in Nigeria, making a substantial contribution to the country's Gross Domestic Product (GDP). It has long been acknowledged as a basic sector in the country's economy, contributing considerably to its growth, development, and sustainability. According to the World Bank, agriculture accounted for approximately 24% of Nigeria's GDP in 2020 (World Bank, 2021). This underscores its substantial role in driving economic activities and providing livelihoods for millions of Nigerians. Agriculture plays a vital role in ensuring food security for Nigeria's growing population. Despite challenges such as inadequate infrastructure and climate change, the agricultural sector continues to produce a variety of food crops, including staples like maize, rice, and cassava in enhancing agricultural productivity and supporting smallholder farmers for achieving food security and reducing reliance on food imports (Abdulai & Eberlin, 2017).

The creation of jobs is one of agriculture's other major economic contributions to Nigeria. A large percentage of the labour force in the nation is employed in this industry, especially in rural areas where agriculture is the main source of income for many people. Smallholder farmers constitute the majority of agricultural workers, highlighting the sector's crucial role in poverty reduction and socio-economic development (Oluyole et al., 2020). Additionally, through the export of cash commodities like cocoa, palm oil, and rubber, agriculture helps Nigeria's foreign exchange profits. These commodities are vital revenue streams that support economic growth and the nation's foreign trade balance. However, there is a need to diversify agricultural exports and add value to raw agricultural products to maximize foreign exchange earnings (Adeoti et al., 2020).

Smart farming, also known as precision agriculture, is an innovative approach that leverages advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and big data analytics to optimize agricultural production (Dlodlo et al., 2020). Through the use of sensors, drones, and autonomous machinery, smart farming enables farmers to monitor and manage various aspects of

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crop cultivation and livestock management with precision and efficiency (Dlodlo et al., 2020).

This includes real-time monitoring of soil moisture levels, crop health, and weather conditions, as well as precise application of inputs such as fertilizers and pesticides (Dlodlo et al., 2020).

By harnessing data-driven insights and automation, smart farming empowers farmers to make more informed decisions, increase productivity, and minimize resource wastage, ultimately leading to improved yields and profitability (Dlodlo et al., 2020).

There are numerous potential advantages to smart farming. First of all, it enables farmers to minimise waste and its impact on the environment by carefully adjusting inputs like water, fertiliser, and pesticides to the unique requirements of their crops (Cobb et al., 2017). Second, data-driven insights from smart farming improve decision-making by helping farmers recognise patterns, foresee difficulties, and take prompt action to reduce risks and increase output (Cobb et al., 2017). Moreover, by automating repetitive tasks and streamlining operations, smart farming can significantly reduce labour requirements and operational costs, making farming more economically sustainable and attractive to new entrants (Cobb et al., 2017). Overall, the adoption of smart farming technologies holds great promise for revolutionizing agricultural practices and addressing the challenges of food security, sustainability, and climate resilience in the 21st century (Cobb et al., 2017).

Globally, traditional farming practices have undergone a radical transformation thanks to the use of Artificial Intelligence (AI) technology (Adekunle et al., 2021). AI is being used to improve agricultural operations in a number of areas, including animal management and crop cultivation, providing previously unheard-of levels of sustainability, accuracy, and efficiency. One crucial role of AI in transforming traditional farming practices is in predictive analytics and decision-making (Adekunle et al., 2021). By analyzing vast amounts of data collected from sensors, satellites, and other sources, AI algorithms can forecast trends, anticipate crop diseases, and optimize planting schedules. This predictive capability empowers farmers to make informed decisions regarding crop selection, irrigation, and pest management, ultimately leading to higher yields and reduced losses (Adekunle et al., 2021).

Precision agriculture is one area where AI technology has made a substantial contribution. Farmers can accurately monitor crop health, soil moisture levels, and nutrient shortages in real-time by utilising drones, satellite photos, and ground sensors that are integrated with artificial intelligence algorithms (Adekunle et al., 2021). This fine-grained level of information allows for focused actions, including the exact dosing of insecticides and fertilisers, which maximises resource efficiency and reduces environmental effects. Despite its importance, Nigeria's agricultural sector faces various challenges, including inadequate infrastructure, limited access to finance and technology, and climate change-induced disruptions (Adekunle et al., 2021). Addressing these challenges requires concerted efforts from government, private sector stakeholders, and development partners. Investments in agricultural research and extension services, infrastructure development, and policy reforms are essential for unlocking the sector's full potential. (Adekunle et al., 2021).

This review contributes significantly to the existing knowledge base by highlighting the transformative potential of smart farming, particularly within the Nigerian agricultural context.

This study contributes to existing knowledge base as follows:

(i) Provides a comprehensive exploration of the transformative potential of smart farming within the Nigerian agricultural context.

(ii) Emphasizes the integration of advanced technologies like IoT, AI, and big data analytics into agriculture to enhance productivity, sustainability, and resilience.

(iii) Offers insights into the role of AI technology in precision agriculture, demonstrating how predictive analytics and decision-making can revolutionize traditional farming practices.

(iv) Contributes to the existing knowledge base by addressing the gap in the literature regarding the application of smart farming technologies in the Nigerian agricultural sector.

(v) Identifies innovative approaches and strategies for improving agricultural practices, ultimately leading to higher yields and reduced losses.

The subsequent sections of the paper are structured as follows: Section 2 covers Smart Farming Technologies, AI in Farm monitoring is presented in Section 3. Case Studies using Babban Gona are addressed in Section 4. Finally, Section 5 presents the concluding remarks arising from this study and future research directions.

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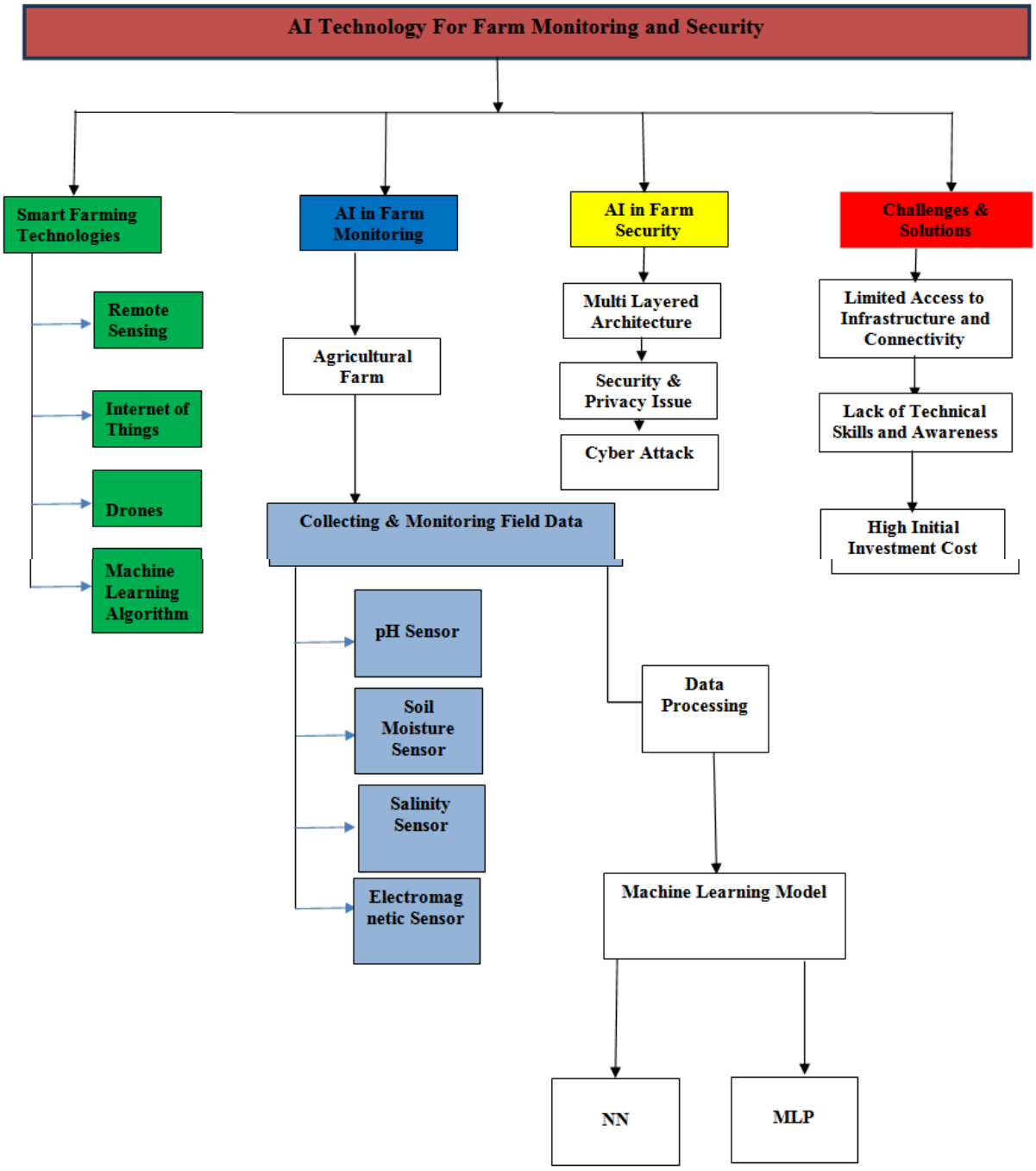

Fig. 1: Taxonomy of AI Technology For Farm Monitoring and Security.

II. SMART FARMING TECHNOLOGIES

Smart farming is one of the recent emerging technologies that is gaining stance in agricultural practices. These are artificial intelligence-based approaches. The smart farming technologies identified in this study include remote sensing, the Internet of Things, drones, and machine learning algorithms. Hence, it is discussed under the following subsection:

(i) Remote Sensing: This overview explores the applications of remote sensing in agriculture, highlighting its role in enhancing productivity, sustainability, and decision-making processes (Thenkabail et al., 2019). Remote sensing is a technology that involves gathering information about objects or areas from a distance. Equipped with various techniques, such as satellite imagery, drones, and ground-based sensors, remote sensing

has become a valuable tool in modern agriculture (Thenkabail et al., 2019).

Key application of remote sensing in farming is crop monitoring and management. Satellite imagery provides farmers with detailed insights into crop health, growth patterns, and stress factors such as pest infestations or nutrient deficiencies (Thenkabail et al., 2019). By analyzing these images, farmers can identify areas of concern and take targeted actions, such as adjusting irrigation levels or applying fertilizers, to optimize crop yields (Thenkabail et al., 2019).

(ii) Internet of Things (IoT): The Internet of Things (IoT) has emerged as a transformative technology with vast applications in the agricultural sector, offering innovative solutions to address various challenges faced by farmers (Llamas et al., 2019).

IoT in farming involves the integration of sensors, actuators, and other devices connected to the internet, enabling the collection, analysis, and management of data to optimize agricultural operations sustainability (Llamas et al., 2019).

A major application of IoT in farming is precision agriculture, where IoT sensors are deployed to monitor various parameters such as soil moisture, temperature, humidity, and crop health in real-time sustainability (Llamas et al., 2019). This data is then analyzed to provide insights into crop conditions and environmental factors, allowing farmers to make informed decisions regarding irrigation, fertilization, and pest control sustainability (Llamas et al., 2019). By precisely tailoring inputs to the specific needs of crops, precision agriculture enabled by IoT technology can significantly enhance productivity, reduce resource wastage, and improve sustainability (Llamas et al., 2019).

(iii) Drones: Unmanned Aerial Vehicles (UAVs), sometimes referred to as drones, have become a significant technology with a wide range of applications in agriculture (Huang et al., 2018). Because of their adaptability, simplicity of use, and capacity to gather high-resolution data from above, they are becoming essential instruments for contemporary farming methods (Huang et al., 2018). One of the most defining ways to harness the drones in agriculture is crop management and monitoring. With larger resolution cameras and sensors, drones enhance the ability of farmers to take images of fields from above and to assess the progress of crops, pest and diseases and fertilizer and irrigation results (Huang et al. , 2018). This real time can help farmers make better decisions, use the right amounts of resources required in his or her farm and take necessary corrective actions to get rid of losses incurred in the farm (Huang et al. , 2018).

(iv) Machine Learning Algorithm: From the field of artificial intelligence, or machine learning; several techniques have suddenly surfaced and are becoming proven strategies that offer solutions that help farmers tackle existing problems in the development of contemporary farming. The overall population received 77% of the total targeted messages; messages on hand hygiene reached 94%, while messages on wearing face masks were 80% according to Gavhane et al. (2020). These algorithms analyze data from sensors, drone, satellite, and other sources large data sets and offers informative results that can be useful in farming. Like earlier research presented within study by Gavhane et al. (2020). To address the various challenges facing the agricultural sector many machine learning techniques are applied, for instance, predicting crop yield, diagnosing diseases, assessing the quality of soil and controlling animals. Some studies (Gavhane et al. , 2020) have used , compartmentalization to refer to the act of isolating information. One significant ML algorithm applied in farming is Support Vector Machines (SVMs). SVMs are useful when it comes to classification problems, and they could be utilized to recognize crop diseases using images filmed with drones or smartphones. Hence, this study by Gavhane et al. (2020) is significant.

By training SVM models on labeled datasets of healthy and diseased plants, farmers can detect diseases early and implement targeted interventions, reducing yield losses and minimizing the need for chemical treatments (Gavhane et al., 2020). Random Forests is another popular machine learning technique used in agriculture. Random forests are useful for a range of agricultural applications because they perform well in both classification and regression tasks. To predict crop yields for various crops and regions, Random Forest models examine historical data on weather patterns, soil characteristics, and crop management techniques.(Gavhane et al., 2020).This information helps farmers make informed decisions regarding planting schedules, irrigation, and fertilization, optimizing resource utilization and maximizing yields (Parikh et al., 2019).

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Table 1: Smart Farming Technologies, description, strengths, and Weaknesses

Author	Technologies	Description	Strengths	Weaknesses
Islam, M. M., et al. (2020)	IoT sensors, drones	Drones Implementing sensor networks and drones for data	Real-time monitoring, data accuracy	Initial setup cost, technical skills
Mishra, A., et al.	GPS, AI, robotics	Utilizing GPS for precision agriculture	Increased efficiency, yield optimization	Cost of implementation, complexity
Llamas, R. M., Gomez-Gallego, M., &Lloret, J. (2019)	Machine learning, IoT	Developing platforms for farm data analysis	Scalability, innovation	Privacy concerns, dependence

2.1 AI in Farm Monitoring

Artificial Intelligence (AI) is revolutionizing crop monitoring by offering advanced solutions for real-time data analysis, disease detection, yield prediction, and precision agriculture (Kamilaris et al., 2018).

AI-driven technologies enable farmers to monitor crops more efficiently, make data-driven decisions, and optimize resource allocation. Several AI applications in crop monitoring have emerged, leveraging machine learning algorithms, computer vision, and sensor technology (Kamilaris et al., 2018).

The identification and diagnosis of plant diseases is a crucial use of AI in crop monitoring. Artificial intelligence (AI) systems, such as Convolutional Neural Networks (CNNs), examine photos taken by satellites, drones, or cellphones to detect signs of crop disease, pest infestation, or nutritional deficits. By training AI models on large datasets of annotated images, farmers can detect diseases early, implement targeted treatments, and prevent yield losses (Kamilaris et al., 2018).

Furthermore, AI, which draws metadata concerning weather conditions, soil type and state, crop developmental stages, and management practices, enables the prediction of agricultural production. Based on my research, here are my findings: In this study, yield history and current yield datasets along with GIS is used to provide yield forecasts for farming the crops through statistical models that are Random Forests and Support Vector Machines as pointed out by Huang et al. (2018). Such models help farmers in predicting future yield changes, crop sowing periods and thereby increasing their overall production. Because of this, Huang and his team have done a lot of research and the following are their findings: Other important application in crop monitoring is in precision agriculture whereby use of inputs like water, fertilizer, and pesticides are augmented in real time data.

AI systems in smart agriculture analyse data from IoT devices, satellites, and meteorological stations to supervise the moisture of the soil, nutrient density, and even insect activity (Huang et al. , 2018). Through the use of AI in conjunction with automated equipment and actuators, individuals such as farmers can attend to the site specific methods in farming that will produce healthy agricultural yields without damaging the environment as concluded by Mishra et al. in their analysis.

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By automating weed detection and intervention, AI technologies reduce the reliance on manual labour, improve efficiency, and optimize herbicide usage, contributing to sustainable agriculture practices (Wang et al., 2020).

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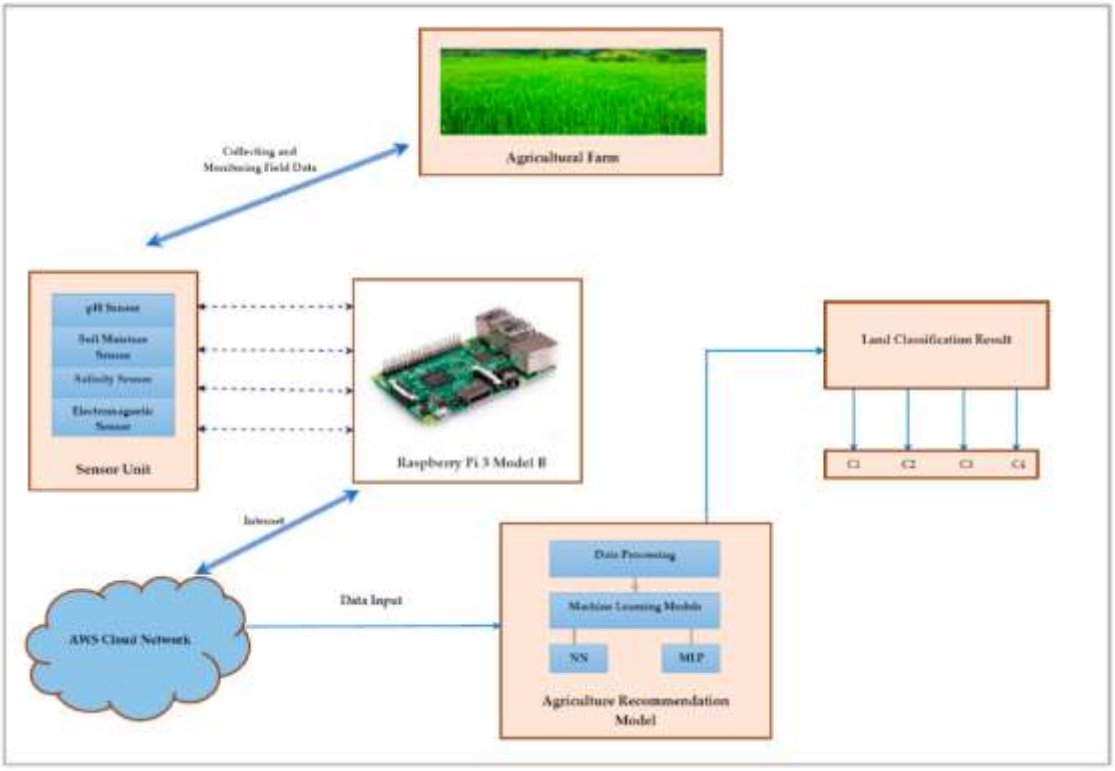

Figure 2: Architecture diagram of AI in Farm Monitoring

Sensor-based data collection requires three main steps: data acquisition, data communication, and data processing. For collecting the various parameter values concerning the properties of soil suitable for agriculture development, various sensors are used. The data acquisition is made using various sensor devices such as the pH sensor, soil moisture sensor, salinity sensor, and an electromagnetic sensor.

The raspberry Pi 3 system is used here to handle inputs from multiple sensors, and the data are sent to a cloud for storage, since it has the most powerful CPU comparatively, as well as the IEEE 802.11 wireless standard. A wi-fi facility is also available and is used to transfer the data from the remote agriculture land. For the better handling of data, the data is sent further to the cloud with the help of the internet. The cloud facility used here is Amazon Web Serive (AWS), and the stored data is used for machine learning for the purpose of analysis. The data is accessed on the local machine through a cloud facility. The algorithm is developed in the machine and it is tested on the collected data to verify the accuracy of the results obtained. The Raspberry Pi controller is used to collect the data from various sensors for a sampling period of one day. Then the average values of various sensors are moved to the AWS Cloud Network with the help of the Internet.

The Fig. states the architectural diagram of the proposed model. The steps involved in this process are shown in this figure. The data is collected from the farmland using sensors, and is then transferred and stored with the help of the Raspberry Pi system in the cloud. The stored data is used here to build the artificial intelligence recommendation model shown in the figure.

2.2 AI in Farm Security

A major area where AI is being applied in the farm is security as it facilitates effective monitoring, early detection, and prevention of threats that are likely to occur such as theft, vandalism, and trespassing. In its destination, the study relies on a number of previous investigations: Two empirical leadership studies that explored the relationship between leadership and outcome variable, Organisational enlightenment (Kalkidan et al. , 2018). I see the AI-based inventions as new opportunities for farmers to better protect their property, animals, and crops. There are various application of AI in farm security that include using machine learning algorithms, Computer vision, and Sensor technology. Values are from Kalkidan et al. , 2018. One applied form of artificial intelligence or AI in farm security is by using surveillance systems with computer vision algorithms to monitor agriculture property in real time Simpson and

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Yohannes (2015), Kalkidan et al. (2018) . These devices monitor the live stream of the proceeding going on in the farm through cameras placed in all corners in order to detect any human or animal intrusion or any suspicious movement. Local people believe that these plants are useful in traditional medications as well as in animal rearing (Kalkidan et al. , 2018). Through implementing AID-based object recognition and anomaly detection, farmers can be notified or alerted immediately when there is a possibility of a security breach hence can be able to prevent the occur (Kalkidan et al., 2018). Drones with AI capabilities are also being used more frequently for agricultural property patrols and aerial monitoring (Kawasaki et al., 2019).

These UAVs mounted with cameras and AI technologies can roam over big areas of farming and survey the land owned by farmers and threats of any insecurity. They differentiated their new product based on price, product quality, speed, reliability, and features and highlighted it via the Kawasaki et al. (2019) conceptualised value proposition canvas. By employing drones that are affixed with AI, farmers are capable of identifying any form of breaches such as downed fences, extraneous vehicles or persons, and take corresponding measures due to such emerging security risks (Kawasaki et al. , 2019). AI is also applied in development of smart fence that uses programs including machine learning as well as sensors that are used to detect intruders.

In addition, AI-powered predictive analytics tools are used to evaluate and reduce security threats on farms (Dinwiddie et al., 2021). Such systems are ready to analyse the data on previous security occurrences, weather conditions, and seasonal changes in order to identify patterns and predict probable security threats. Thus, the study (Dinwiddie, et al. , 2021) about the perpetration of elder abuse and neglect found that elder abuse and neglect are horrific and prevalent among the older adults. These insights help farmers to adopt preventive measures to protect their crops from the attack of pests and diseases such as; install adequate lighting, change doors locks, recruit security personnel especially during the vulnerable times as suggested by Dinwiddie et al. (2021).

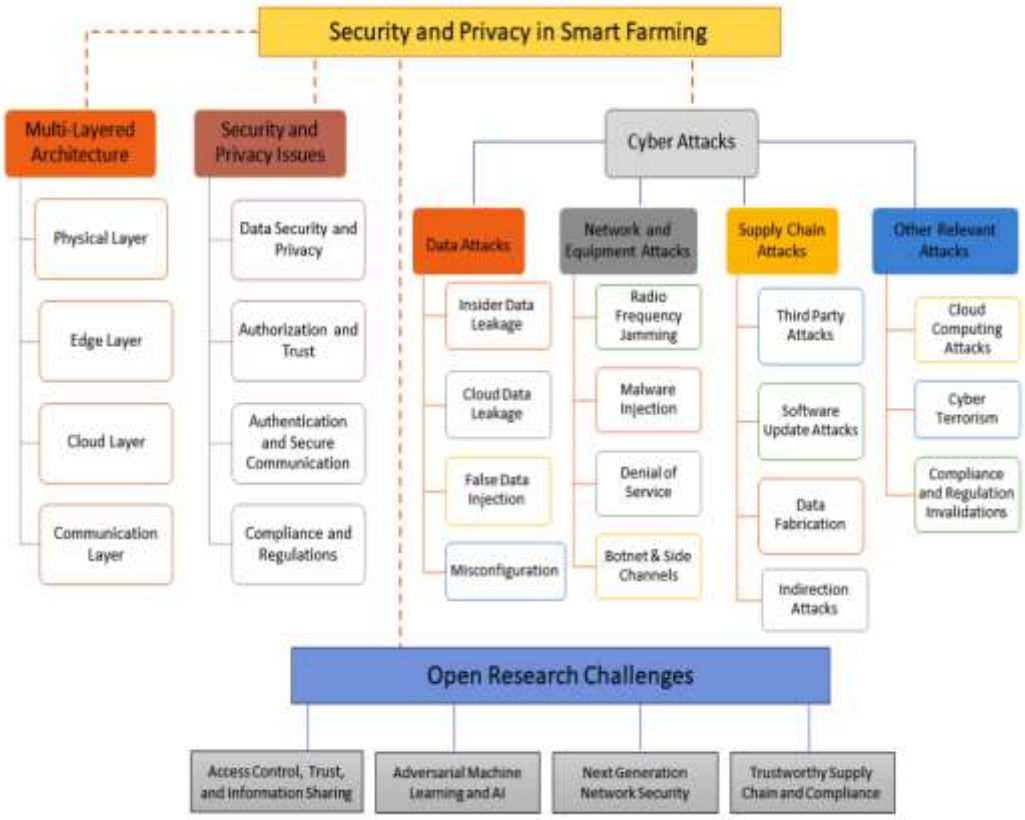

Figure 3: AI in Farm Security

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III. CASE STUDIES USING BABBAN GONA

Babban Gona is a commercial farming organization that works in Nigeria that brings together farmers and technology to assist them. Adekunle, B. A. , Adetunji, C. O. , & Chukov, S. I. (2021). The organization combines mobile technologies and analytics to enable farmers receive cheap credit, quality inputs and acquisition of training services Adekunle, T. , Adeosun, A. , Okunade, A. , Ojo, D. , Sobowale, A. , & Oyinlola, A. (2021). With the help of the modern technologies, such as weather data, soil fertility, customers' requirements for certain crops, Babban Gona can provide farmers with useful recommendations how to maximize their crops productivity Kofi Adedeji, Badmus Babalola Adeyinka, Adeleke Tijani Akande, Abdulraham Olamilekan Bakare, & Olufunmilayo David Ogunniyi 2021.

Through its innovative approach, Babban Gona has helped thousands of farmers in Nigeria achieve significant improvements in productivity and income, contributing to rural development and poverty alleviation.(Adekunle et al., 2021).

Fig. 4 Babban Gona makes farming more profitable for Nigeria's smallholders

3.1 Challenges and Solutions

(i) Limited Access to Infrastructure and Connectivity:

AI technology will help to offer sustainable solutions to the Nigeria's agricultural sector and thus help to reform farm productivity, and the efficiency of resources among farmers. Although there are different benefits of integrating AI into farming practices, there are some factors that should be considered before the AI technologies are fully applied in agriculture. Specifically this study identifies the major challenges of implementing AI technology in Nigerian agriculture and proffer a way forward. This way the channel confound caused by inadequate infrastructure and connectivity mostly realized in rural setting where majority of the farmers are situated can be addressed. Inadequate and sporadic internet access and unreliable power supplies also challenge the use of AI solutions by the farmers; the accurate real-time data, cloud-based analytics or the remote monitoring systems cannot be employed. Alhassan et al. (2020) have pointed out that; this is because, for applied benefits of AI to realize their independent potential for improving decision-making, resourcing decisions, and productivity enhancement, there is needed to desirable infrastructure and connectivity .

Additionally, Adesina et al., (2019) highlighted the importance of technical knowledge and awareness among Nigerian farmers as a significant obstacle in adopting AI technology for agricultural purposes. Numerous farmers, especially those with small plots of land, lack the necessary education or training in digital literacy, which means they may not possess the skills required to effectively utilize AI-powered solutions.

(ii) Lack of Technical Skills and Awareness:

Furthermore, not many people are aware of the potential advantages of AI in enhancing farming methods and raising yields.(Adesina et al., 2019). Without adequate training and awareness-raising

initiatives, farmers may be reluctant to adopt AI technology, fearing complexity or uncertainty about its effectiveness (Adesina et al., 2019).

(iii) High Initial Investment Costs:

Many Nigerian farmers, especially smallholders with low financial means, find it difficult to use AI technology in their farming methods due to the large initial investment costs involved (Adekunle et al., 2021).Investments in sensors, software, hardware, and data analytics platforms are frequently needed for AI-driven solutions, in addition to continuing technical support and maintenance (Adekunle et al., 2021).Farmers may also be reluctant to invest in these advances since they may not immediately see the return on investment (ROI) from implementing AI technology (Adekunle et al., 2021). Without access to affordable financing options and incentives to offset initial investment costs, many farmers may be unable to adopt AI-driven solutions, limiting their potential to enhance productivity and competitiveness (Adekunle et al., 2021).

IV. CONCLUSION

In conclusion, the use of AI technology for security and farm monitoring procedures is a major breakthrough for Nigerian agriculture. To safeguard their agricultural assets, farmers can gain from enhanced proactive risk management, automated reaction mechanisms, and real-time data insights. It is impossible to overestimate the importance of AI technology in farm security and monitoring since it enables farmers to maximize output, reduce losses, and protect their livelihoods from security risks. Nigeria's aspirations to attain food security, economic development, and sustainability depend heavily on its agricultural industry. Therefore, Nigerian farmers will thus need to keep using and developing AI-driven solutions.

The integration of Artificial Intelligence (AI) into farm monitoring and security systems in Nigeria holds transformative potential for the agricultural sector. By leveraging AI technologies such as drone surveillance, IoT sensors, and machine learning algorithms, Nigerian farmers can significantly enhance their operational efficiency, crop yields, and security measures. AI-driven solutions enable real-time monitoring of farm conditions, precise resource management, and rapid response to threats, thus addressing some of the critical challenges faced by farmers.

The benefits of AI in agriculture are multifaceted, ranging from improved crop health and optimized irrigation to the reduction of theft and unauthorized access. These advancements contribute to sustainable farming practices and bolster food security, which are essential for Nigeria's economic stability and growth. However, the widespread adoption of AI in Nigerian agriculture is hindered by challenges including high implementation costs, limited rural connectivity, and a shortage of technical expertise among farmers.

To overcome these barriers, a collaborative approach involving government support, public-private partnerships, and educational initiatives is essential. Subsidies and incentives can make AI technologies more accessible to smallholder farmers, while capacity-building programs can equip them with the necessary skills to utilize these technologies effectively. Additionally, tailored AI solutions that consider the local agricultural context and resource constraints will ensure greater adaptability and success.

In conclusion, AI technology presents a promising avenue for revolutionizing farm monitoring and security in Nigeria. By addressing the existing challenges and fostering an environment conducive to technological innovation, Nigeria can pave the way for a more resilient and productive agricultural sector. Continued research and investment in AI-driven agricultural solutions will be pivotal in achieving these goals and ensuring the long-term sustainability of Nigeria's agriculture.

Research Directions

It comes as no surprise that an increasing number of farmers are implementing contemporary technology to make their operations more intelligent given the numerous benefits and tremendous potential that smart farming provides. Precision-programmed fruit and vegetable farming as well as greenhouses that autonomously manage all of the factors affecting plant development are already realities rather than futuristic ideas. If this development keeps on, it will not only make agriculture more effective over time but also continue to reduce carbon emissions thanks to the broad use of smart technology. Nigerian government will therefore need to embrace this new innovation and make necessary policies to actualize a farm that is truly smart.

The following are the important research directions that will help to provide an effective and efficient smart farming in Nigeria:

1. The training of a large pool of engineers, computer scientists, and agriculturalists to create various components of the technology will be the most crucial step in moving towards the provision of smart farms.

2. Nigeria won't be successful without outstanding human resources. Unfortunately, the majority of intelligent students desire to pursue careers in other fields of engineering and medicine, and ignorantly, agriculture is neglected. To create equipment like robots and drones, priority must be given to courses related to agricultural engineering, computer science, software development, mechatronics engineering in most of our universities. This can be aided by the development of a new field of engineering called agricultural mechatronics or robotics in our institutions.
3. Industries must take the initiative since they will build the machinery. Creating employment and encouraging more students to choose careers in these related fields will be of greater advantage.
4. Funding by government and non-governmental organizations alike will help to keep with new ideas and tools needed for an efficient smart agriculture.

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