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AI SENSORS FOR CROP MONITORING AND FARM SECURITY IN SMALLHOLDER FARMS IN NIGERIA

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ABSTRACT
Agriculture is the largest sector in Nigeria, employing about 70% of the workforce, yet farmers continue to face numerous challenges, such as low crop yield and farm insecurity. With Artificial Intelligence (AI) gaining global popularity, its potential can be used to create effective systems to address these issues. This paper proposes the integration of AI-powered sensors for farm and crop monitoring in smallholder farms in Nigeria to improve productivity and strengthen food security. The proposed system will use low-cost IoT sensors and trained AI models to monitor soil moisture, crop health, and unauthorized movement around the farm, and provide real-time insights and alerts, helping farmers make data-driven decisions. Ultimately, this approach aims to improve productivity and contribute to food security.

KEYWORDS: Artificial Intelligence, Agriculture, real-time data processing, smallholder farms, Internet of Things (IoT).

1. INTRODUCTION

Nigeria relies heavily on the agricultural sector for its local economy. Smallholder farmers, who cultivate their crops on small plots of land, typically in rural areas, play a large role in food production in Nigeria. With more than 80% of Nigerian farmers being smallholder farmers, smallholder farms produce about 90% of Nigeria's agricultural products **[1]**. Despite their critical role in ensuring food security, these farmers face various challenges, including farm insecurity, poor infrastructure, low yield, and inefficient use of technology.

The effective adoption of agricultural innovations could potentially address these problems, rather than relying solely on indigenous knowledge, which often fails to meet the rising food demands. For instance, precision agriculture, which uses AI sensors and Internet of Things (IoT) technologies to monitor crops and determine their specific needs, can enhance agricultural production while minimizing human effort **[2].**

To make this transformation possible, government investment in rural digital infrastructural development, public-private partnerships for tool development, affordable financing, and farmer-focused training programs are essential. This also calls for data protection frameworks and inclusive policies that tackle general insecurity to safeguard users. Furthermore, integrating digital marketing with data-driven farming can transform smallholder farming, improve livelihoods, and promote sustainable agricultural development **[3]**.

This paper explores how integrating AI sensors can address these challenges by enabling data-driven decision-making, thus improving food and farm security in Nigeria. By adopting AI-powered sensor technologies, smallholder farmers in Nigeria can transition from traditional methods to a more efficient and technology-driven system capable of meeting the nation’s growing food demands.

2. BRIEF OVERVIEW OF SENSORS

The main aim of these sensors is for farmers to make data-driven farming decisions. Using IoT sensors, real-time data on crop health, soil temperature, or weather can be collected. Furthermore, AI systems analyze this data to predict outcomes and speed up decision-making processes.

In Precision agriculture, smart sensors play a crucial role. There are different types of sensors used for technological farming systems. For example, soil moisture sensors help farmers measure the water content in the soil, allowing them to determine the amount and time of irrigation needed. Also, nutrient sensors determine and recommend the precise amount of fertilizer needed. pH sensors, temperature sensors, pest sensors, and motion sensors all provide real-time, targeted data that helps reduce costs from wasted resources and promotes efficiency **[4]**.

In Nigeria, implementing sensor-based systems can address the challenges smallholder farmers regularly face. By monitoring soil and crop conditions, smallholder farming transforms into a more efficient and sustainable practice **[1].**

3. BENEFITS

1. Data-driven farming decisions: The sensors produce real-time data, which enables accurate and targeted decision-making processes for the farmer **[4]**. This ensures efficient use of resources, allowing farmers to maximize yield while minimizing wastage.
2. Early Disease and Pest Detection: Traditional methods for detecting plant diseases and pests were time-consuming and less effective, as those problems were not known until damage had been done. However, through machine learning algorithms and computer vision, diseases and pests could be detected at an early stage, enabling fast intervention and reducing excess pesticide usage, which can harm the environment.
3. Reduced Human Error: Human error is unavoidable, especially in labor-intensive tasks. However, automated data collection ensures higher degrees of accuracy and reliability while analyzing crop conditions.
4. Increased productivity: This system helps to improve yield as fewer crops are lost to diseases or other adverse conditions.
5. Resource Efficiency: By targeting specific problem areas, farmers can implement focused control measures, thereby minimizing the excessive use of resources on certain areas such as chemical pesticides **[4]**.

4. CHALLENGES

1. Lack of Technical Knowledge: In general, there is an insufficient population of adequately skilled labor, with the technical know-how to build, manage and maintain AI sensors, presently in Nigeria. This is also a challenge for most African countries as demonstrated in some cases in South Africa **[6].**
2. Insecurity: Examines vandalism, theft, and general insecurity affecting smallholder farmers' productivity and resilience. This is a call to action for government security bodies to prioritize protecting AI machinery investments **[7]**.
3. Superstitious or limiting beliefs as a result of low digital literacy and adoption barriers: Some related studies find that cultural factors, including respect for local values, communal land tenure, and some traditions, significantly influence acceptance of agricultural innovations **[8]**. The lack of digital literacy is a significant barrier to adoption, especially among older farmers

and rural communities. There is limited access to ICT training programs for most **[5]-[10]**. *Due to the gap in literature regarding superstitions and AI sensor technology in Nigeria, these are works in some related areas in Africa justifying this part of the research contribution.*

4. Lack of machine parts at affordable prices: This makes for low accessibility to innovative solutions like AI sensors for smallholder farmers in rural areas. Exploring government policies made to solve market barriers to cheaper machinery, parts availability, and maintenance, shows a major challenge in affordability for effective implementation **[12]**.

5. SUGGESTIONS

In light of the earlier stated challenges, the need to prioritize specialized training opportunities as well as general sensitization programs, locally build the required software (hence creating job opportunities), and tackle insecurity, places a heavy responsibility on the Nigerian government. These measures will ensure an increase in technically skilled labor, higher receptivity among locals, and prevent losses for the farmers as a result of theft or vandalism. Government subsidies on machine parts will also encourage efficient integration of the AI sensors, especially for smallholder farms, as is the main focus here. This may necessitate strong future international collaborations with agriculturally advanced countries like India. It is known that digital agriculture has enabled the optimization of agricultural processes globally. For example, countries such as China and Germany have integrated unmanned aerial vehicle (UAVs) based weed detection and robotics in livestock management, respectively **[6].** The Adamawa state government can strategically take action towards such collaborations by leveraging the diplomatic connections formed through the American Space and the Indian Corner here at the American University of Nigeria, Yola, in order to solve security issues that lead to food crises.

6. IMPLEMENTATION PLAN

Phase 1 – Infrastructure and Capacity Building: as a solution to some issues explored in "The neglected governance challenges of agricultural mechanization in Africa – insights from Ghana" by M. Adu-Benin (2017) **[12].**

- Conducting digital literacy and technical training for workers and local farmers.
- Introducing international investors and collaborators to the project for progressive growth.
- Establishment of a pilot demonstration farms in some localities equipped with soil and crop sensors to test project feasibility before open launching.
- Establishment of government-owned factories for software development and building machine parts to facilitate supply.

Phase 2 – System Deployment:

- Installation of AI-powered sensors for soil moisture, temperature, pest monitoring, and security surveillance in more farms after gathering positive results from pilot farms **[4]**.
- Development of a mobile applications to display real-time data and alerts in local languages for easy management by smallholder farmers.

Phase 3 – Monitoring and Optimization (Months 13–18):

- Evaluation of system efficiency and farmer adoption in several regions over time.

- Fine-tuning AI models using locally gathered data for improved accuracy.

Phase 4 – Expansion and Policy Integration (Months 24 and above):

- Scaled implementation to other regions based on pilot success and available technical resources.
- Collaborations with government agencies to integrate AI farming strategies into state agricultural development policies based on smallholder farms' results.

7. CONCLUSION

The concept of implementing AI-powered sensor systems represents a transformative opportunity for solving food crises through smallholder farming in Nigeria. By integrating low-cost IoT devices and AI analytics, farmers can monitor soil conditions, detect threats early, and enhance productivity in yield and the local economy. However, successful adoption depends on digital literacy, improved physical and online infrastructure, and strong policy support for security and market availability/affordability.

Nigeria stands at a pivotal moment. Embracing AI in agriculture will significantly improve food security, reduce poverty, and empower rural communities; the major arrowheads of agriculture presently. Policymakers, researchers, private stakeholders, and skilled professionals, must act collaboratively to make this vision a reality toward confronting security and food crises. The time to digitize Nigeria's farms is now. For a future with smarter, more secure, and sustainable agricultural development.

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