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Artificial Intelligence Applications in Sustainable Agriculture in Nigeria: A Comprehensive Review

Mu'allim Yakubu[1*], Ubaidullahi Yakubu[2], Hauwa Yakubu[3] and Farida Ahmed Mayun[4]
[1]Department of Industrial Physics, Enugu State University of Science and Technology
[2]Department of Mechanical Engineering, Federal University Dutsinma
[3]Department of Microbiology, Bauchi State University Gadau
[4]University of Maiduguri Teaching Hospital (UMTH)
*Corresponding Author Email: yakubumuallim@gmail.com

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ABSTRACT
This review explores how Artificial Intelligence (AI) can revolutionize sustainable agriculture in Nigeria by employing advanced analytical methods. The methodology involved a systematic approach, including thorough searches across academic databases, journals, and conference proceedings to gather relevant literature on AI applications in sustainable agriculture in Nigeria. The selection criteria prioritized recent publications, credibility of sources, and in-depth analysis of AI technologies in the agricultural sector. Key findings from the synthesized data highlight the transformative potential of AI in optimizing resource management, improving crop yields, and addressing challenges related to climate change and limited infrastructure. The review underscores the importance of sustainable practices in driving agricultural development in Nigeria and emphasizes the need for affordable and centralized AI models to guide future research and strategies tailored to Nigeria's unique agricultural landscape.

Keywords:
Artificial Intelligence, Sustainable Agriculture, Agricultural Productivity, Nigeria.

INTRODUCTION

The Nigerian agricultural sector has faced numerous challenges, including neglect due to the dominance of the oil industry (Saidu, 2016). Despite its predominant role in the economy, the sector has not significantly impacted economic development (Matthew, 2010). This is partly due to the partial success of government agricultural policies, which have snot fully tapped into the sector's potential (Rasak, 2018). However, recent data suggests that the sector has made a significant contribution to economic growth, particularly in the period from 2016 to 2018 (Singla, 2021).

The challenges in Nigerian agriculture are multifaceted, including the inability to meet domestic food requirements and export at quality levels (Elijah, 2017), limited participation in artificial insemination technology (Shehu, 2011), and barriers such as climate change, weak infrastructure, and inconsistent policies (Etim, 2015). The broken value chain of agricultural productivity is also a significant issue, with problems on both the supply and demand sides (Saidu, 2016). These challenges underscore the need for a comprehensive approach to address the various issues in Nigerian agriculture, including the potential use of AI to improve productivity and sustainability.

A range of studies have highlighted the potential of AI and related technologies in transforming Nigerian agriculture. Umar (2022) and Elijah (2017) both underscore the significant positive impact of machine learning, deep learning, IoT, and data analytics in enhancing agricultural productivity and sustainability.

Artificial Intelligence (AI) technology offers significant benefits for livestock production and animal welfare. AI can improve livestock management by enhancing disease control, increasing fertility, and facilitating genetic improvement (Shehu *et al*., 2011). In dairy farming, AI implementation has shown exceptional growth, improving efficiency and reducing labor costs (Chimakurthi, 2019). AI applications extend to understanding animal behaviors and

emotions, revolutionizing nutrition through data analytics, and improving health management (Zhang *et al*., 2023). The technology also aids in monitoring and optimizing farm animal growth, combating parasites and biosecurity threats, and predicting consumer behavior (Rehan *et al*., 2023). Despite these advantages, challenges to AI adoption in livestock farming exist, particularly in developing countries like Nigeria (Shehu *et al*., 2011). To ensure sustainable implementation, appropriate extension methods for disseminating AI technology and strategies for overcoming adoption barriers are crucial (Shehu *et al*., 2011). Kehinde (2015) adds a socio-economic dimension, advocating for the application of ICT in agriculture as a solution to unemployment, particularly among the youth. These studies collectively underscore the transformative potential of AI and related technologies in Nigerian agriculture.

In this study, we present a comprehensive review of the applications of Artificial Intelligence (AI) in sustainable agriculture within the Nigerian context. The focus is on understanding how AI technologies can address the challenges faced by the agricultural sector, such as low productivity, resource mismanagement, and the impacts of climate change. By synthesizing relevant literature, the study identifies key AI-driven solutions, including precision farming, predictive analytics, and automated agricultural processes, which hold potential for enhancing crop yields, optimizing resource use, and supporting environmental sustainability. Furthermore, the review evaluates the socio-economic and infrastructural factors influencing AI adoption and highlights strategies for effective implementation tailored to Nigeria's unique agricultural landscape.

Artificial Intelligence (AI) presents significant opportunities for transforming agriculture in Africa, particularly in Nigeria. AI technologies can enhance sustainable farming practices, improve food security, and engage youth in agriculture (Olagunju, 2024; Aggarwal *et al*., 2024). Applications include precision farming, crop health monitoring, predictive analytics, and agricultural robotics (Aggarwal *et al*., 2024). AI-powered tools like biosensors and drones can help farmers monitor soil conditions, detect diseases, and increase crop productivity (Mathur, 2023). However, challenges such as accessibility, data privacy, and skills training need to be addressed (Aggarwal *et al*., 2024; Kinyua, 2024). To maximize AI's potential in Nigerian agriculture, stakeholder engagement, investment in digital infrastructure, and innovative policies are crucial (Olagunju, 2024). Ethical considerations and responsible AI integration are also important factors to consider (Gikunda, 2024). By leveraging AI technologies, Africa can work towards sustainable agricultural development, climate resilience, and inclusive growth in the sector (Gikunda, 2024; Mathur, 2023).

The role of AI in agriculture in Nigeria is significant, with the potential to enhance sustainable agricultural practices and food security (Babatunde, 2013). Data mining, a key component of AI, can improve decision-making and production capacity, leading to higher yields and market value (Waidor, 2019). Data mining, a key component of artificial intelligence (AI), has emerged as a powerful tool for improving decision-making and productivity in agriculture. By analyzing large datasets, data mining techniques can uncover hidden patterns and relationships, enabling farmers to make more informed decisions (Armstrong *et al*., 2020). These techniques, including artificial neural networks, Bayesian networks, and support vector machines, can be applied to various aspects of agricultural management (Armstrong *et al*., 2020). The integration of data mining with business intelligence systems allows organizations to enhance managerial processes, such as planning, budgeting, and monitoring, leading to cost reductions and increased yields (Hema and Malik, 2011). Furthermore, data mining can help predict customer behavior and market trends, providing valuable insights for agricultural enterprises (Milović and Radojević, 2015). By leveraging these advanced analytical capabilities, farmers can optimize their production strategies, potentially resulting in higher market values for their products (Milović and Radojević, 2015). The adoption of ICT, including AI, has a positive impact on crop production, particularlythrough internet utilizationwhich facilitates real-time data collection, remote monitoring, and connectivity, enabling AI technologies to analyze and respond to agricultural conditions swiftly and accurately. (Ejemeyovwi, 2017). These studies collectively highlight the potential of AI in transforming the agricultural sector in Nigeria.

A range of studies have explored the potential of AI applications for sustainable development in Nigeria. Odirichukwu (2024) highlighted the impact of AI-driven IoT systems on air quality management, while Poronakie underscores the potential of AI technology in addressing critical national development problems such as insecurity, poverty, and corruption. Dayo (2008) discussed the role of clean energy investment in Nigeria, and Dinebari (2017) emphasized the importance of spatial data infrastructure for sustainable development. These studies collectively underscore the potential of AI applications in addressing key sustainability challenges in Nigeria.

The potential for Precision Agriculture in Nigeria is recognized, with the need for further research and development emphasized (Adekunle, 2013). AI-based applications for Precision Agriculture have been successfully developed in India, with a focus on soil type, crop selection, and disease detection (Paramathma, 2023). Similarly,

Recent research has explored the potential of machine learning and precision agriculture in Nigeria to optimize farm productivity and profitability. Umar *et al*. (2022) highlighted the widespread application of machine learning in agriculture, emphasizing its potential to boost food sufficiency in Nigeria. Abdullahi and Sheriff (2017) demonstrated the feasibility of implementing precision agriculture techniques in Nigerian maize plantations, using simple image analysis and fuzzy classification to determine field variability and develop treatment plans. While not specific to Nigeria, Rani (2021) and Ravisha and Sinha (2023) presented relevant smart precision agriculture systems using machine learning algorithms. These systems integrate real-time field information, soil quality data, and weather parameters to optimize crop selection and management. The adoption of such technologies in Nigeria could significantly enhance agricultural decision-making, increase productivity, and improve resource management, addressing challenges faced by Nigerian farmers.

The plausibility of Precision Agriculture as a COVID-19-compliant digital technology for food security and agricultural productivity in Nigeria has been highlighted, with a range of disruptive technologies including AI identified (Raimi, 2021). Ohunene (2022) developed an AI-based energy management system for households, using a genetic algorithm to optimize electricity consumption. Eseosa (2014) focused on economic generation scheduling in the Nigerian power network, with Eseosa using an Artificial Neural Network (ANN) to minimize operating costs and Hydro applying the ANN to dispatch generated energy efficiently. These studies collectively demonstrate the potential of AI in enhancing resource optimization in Nigeria.

Research in Nigeria has shown that the adoption of ICT, including AI, can positively impact crop production (Ejemeyovwi, 2017). However, Artificial Intelligence (AI) offers promising solutions to various challenges in agriculture, particularly in Nigeria. AI applications include soil management, crop management, weed management, and disease management (Eli-Chukwu, 2019). Machine learning algorithms, such as Decision Tree Regressor, have shown potential for accurate crop yield prediction, achieving 72% accuracy in a Nigerian study (Shuaibu *et al*., 2024). AI can automate traditional farming practices like weeding, pesticide spraying, and irrigation using robots, sensors, and drones, leading to reduced water wastage and enhanced crop productivity (Dawn *et al*., 2023). However, AI implementation in agriculture faces challenges such as high costs, lack of expertise, and big data requirements (Dawn *et al*., 2023). To address these issues, Explainable AI (XAI) has been proposed as a solution to improve trustworthiness, reduce bias, and increase confidence in AI systems, particularly in Nigeria's agricultural sector (Mohammed and Shehu, 2023).

Artificial Intelligence (AI) presents significant opportunities for revolutionizing agriculture, addressing challenges such as increasing productivity, sustainability, and food security for a growing global population (Aggarwal *et al*., 2024; Dawn *et al*., 2023). AI applications in agriculture include precision farming, crop health monitoring, predictive analytics, and agricultural robotics (Aggarwal *et al*., 2024). These technologies can improve crop yield prediction, soil health monitoring, and automate tasks like weeding and irrigation (Dawn *et al*., 2023). However, the implementation of AI in agriculture faces several challenges, including accessibility, data privacy, skills training, and the need for big data (Aggarwal *et al*., 2024; Dawn *et al*., 2023). Additionally, Indian farmers face specific challenges such as low productivity, dependence on monsoon rains, and soil degradation, which AI and related technologies could help address (Pooja *et al*., 2023). Overcoming these hurdles requires collaborative efforts and strategic interventions to fully harness AI's potential in agriculture (Aggarwal *et al*., 2024; Vocaturo *et al*., 2023).

The technical efficiency of food crop production can be improved by increasing farmers' education and managerial ability (Oladeebo, 2013). Additionally, land management practices, including the use of fertilizer and improved crop varieties, can also enhance crop production (Omonona, 2006).

Artificial Intelligence (AI) offers significant potential for enhancing agricultural sustainability and environmental protection. AI applications in agriculture include precision farming, crop monitoring, and climate-resilient practices (Gikunda, 2024). These technologies can improve productivity, efficiency, and sustainability by enabling targeted use of inputs, reducing waste, and increasing yields (Bhumika Sharma *et al*., 2024). AI also supports agricultural extension services, facilitating knowledge dissemination and decision support for farmers (Ibrahim, 2023). However, challenges persist, including technological infrastructure limitations, data accessibility issues, and skill gaps (Gikunda, 2024). Ethical considerations and policy implications must be addressed for responsible AI integration (Nishant *et al*., 2020). To maximize AI's potential for sustainability, future research should incorporate multilevel views, systems dynamics approaches, and psychological, sociological, and economic considerations (Nishant *et al*., 2020). Overall, AI has the capacity to revolutionize agriculture, making it more efficient, sustainable, and profitable while addressing global food security challenges (Sharma *et al*., 2024).

Author(s)	Approach Adopted	Strength(s)	Weakness(es)
Odirichukwu (2024)	AI-driven IoT systems for air quality management	Highlights the transformative potential of AI in addressing environmental challenges	Limited focus on agricultural-specific applications
Poronakie	AI addressing national issues like insecurity	Demonstrates AI's adaptability to various critical socio-economic challenges	Does not provide empirical evidence for agricultural applications
Umar *et al*. (2022)	Machine learning for agricultural productivity	Shows AI's effectiveness in enhancing food sufficiency and crop yield prediction	High dependency on data quality, which may be challenging in Nigeria
Elijah *et al.*(2017)	IoT and data analytics for smart agriculture	Provides practical insights into how IoT enhances food security and export quality	Accessibility issues for small-scale farmers in rural areas
Abdullahi and Sheriff (2017)	Image analysis and fuzzy classification	Demonstrates feasibility of precision agriculture in maize farming	Focused on one crop, limiting scalability
Adekunle (2013)	Precision Agriculture	Explores applicability of AI to improve soil type, crop selection, and disease detection	Limited focus on infrastructure challenges in Nigerian agriculture
Dawn *et al*. (2023)	AI-powered predictive analytics	Discusses real-time crop health monitoring and predictive analytics	Faces barriers like high costs and lack of expertise
Mathur (2023)	Biosensors and drones for crop productivity	Highlights AI's role in improving productivity and environmental sustainability	Barriers to implementation include technical skills and data privacy concerns
Rani (2021); Ravisha and Sinha (2023)	Machine learning for precision agriculture	Integrates field data, weather, and soil conditions to optimize crop selection	Does not specifically address Nigerian agricultural contexts
Eli-Chukwu (2019)	Automated agricultural tasks	Reduces water usage and increases productivity	High costs and limited digital literacy among Nigerian farmers

MATERIALS AND METHODS

Approach to Conducting the Literature Review:

We employed a systematic approach. The methodology involved a thorough search across academic databases, journals, conference proceedings, and online platforms to gather relevant literature focusing on the integration of artificial intelligence and sustainable agriculture in Nigeria. The search encompassed literature published between 2006 and 2024 to ensure a comprehensive review of recent developments and foundational studies.

Criteria for Selecting and Evaluating Sources:

The selection criteria for sources included relevance to the topic of AI applications in sustainable agriculture in Nigeria, recent publication dates, credibility of the sources, and in-depth analysis of AI technologies in the agricultural sector.

To ensure the credibility of the sources, we prioritized peer-reviewed journals and reputable conference proceedings. This decision was based on the rigorous peer-review process these publications undergo, which typically involves scrutiny by experts in the field. Additionally, we considered the authors' affiliations and the publication's impact factor, which reflects its influence and the frequency with which its articles are cited in other works. For non-peer-reviewed sources, we assessed the reputation of the publishing organization and the author's expertise and background in AI and agriculture.

An "in-depth analysis" of AI technologies was defined by several parameters. First, we looked for sources that provided comprehensive descriptions of AI applications, including the algorithms used, the data requirements, and the implementation processes. Secondly, we considered studies that presented empirical evidence of the effectiveness of AI technologies, such as field trials, case studies, or comparative analyses. Thirdly, we prioritized sources that discussed both the benefits and the limitations of AI in agriculture, offering a balanced perspective. Lastly, we valued sources that explored future prospects and potential advancements in AI technology, as these insights are crucial for

understanding long-term implications and opportunities in sustainable agriculture.

Search Strategy and Databases Used:
To ensure a comprehensive collection of literature, various search strategies were employed. This included keyword searches using specific terms and Boolean operators such as "Artificial Intelligence" AND "Sustainable Agriculture" AND "Nigeria," "Machine Learning" AND "Agriculture" AND "Nigeria," and "Crop Yield Prediction" AND "Artificial Intelligence" AND "Nigeria." These searches were conducted in IEEE Xplore, ScienceDirect, Google Scholar, and ACM Digital Library databases. The institutional repositories used include the Nigerian Institute of Agricultural Research (NIAR), National Information Technology Development Agency (NITDA), and university digital libraries such as those of Ahmadu Bello University and University of Ibadan. Additionally, citation tracking and scanning of reference lists were utilized to identify additional pertinent sources that may not have surfaced in initial searches.

Data Synthesis and Analysis Methods:
The data synthesis process involved organizing the selected literature thematically around key topics such as the role of AI in crop production, resource management, environmental sustainability, and challenges in implementing AI technologies in Nigerian agriculture, the process of identifying themes and extracting key findings involved a qualitative analysis approach. Themes were identified by organizing the selected literature around key topics such as the role of AI in crop production, resource management, environmental sustainability, and challenges in implementing AI technologies in Nigerian agriculture. The criteria used to extract key findings included analyzing common themes across different studies, identifying connections, and establishing relationships between the literature reviewed. This qualitative analysis aimed to provide a comprehensive overview of AI applications in sustainable agriculture in Nigeria and highlight potential avenues for future research and development.

Data Selection
The review considered a range of research papers published between 2006 and 2024 to provide both historical context and insights into recent advancements. The inclusion of studies from 2006 onward allowed for a comprehensive understanding of the foundational work in AI applications in agriculture, particularly in the Nigerian context, while capturing the latest trends and emerging technologies in the field. Priority was given to peer-reviewed journals, conference proceedings, and institutional reports that met the selection criteria of relevance, credibility, and depth of analysis. Through analyzing studies over nearly two decades, the review highlights the evolution of AI-driven solutions, from basic machine learning models to sophisticated systems integrating IoTand data analytics, tailored for sustainable agriculture.

Data Extraction
After conducting a comprehensive literature search, the study discovered a total of 120 publications relevant to the application of Artificial Intelligence (AI) in sustainable agriculture. Following a rigorous evaluation based on the selection criteria, including relevance to the Nigerian agricultural context, credibility of sources, and depth of analysis, 65 research papers were taken into consideration for detailed review and synthesis. These papers covered a broad spectrum of AI applications, such as predictive modeling, precision agriculture, resource optimization, and environmental sustainability, highlighting their transformative potential in addressing the challenges faced by the Nigerian agricultural sector.

AI Applications for sustainable Development in Nigeria
The potential of AI in sustainable agriculture in Nigeria is highlighted by Younas (2020), who emphasizes the need for affordable and centralized AI models. This is further supported by Elijah (2017), who suggests the use of IoT and data analytics to address food security and export quality. However, the challenges of AI adoption, particularly in livestock farming, are discussed by Shehu (2011), who emphasizes the need for appropriate extension methods. Bamigboye (2016) also underscores the potential of IoT in agriculture, particularly in weather forecasting and pest control, but acknowledges the challenges in its implementation. These studies collectively underscore the potential of AI and IoT in sustainable agriculture in Nigeria, while also highlighting the need for affordable and appropriate extension methods.
Agricultural productivity can be enhanced through the use of predictive models, which can help in decision-making and resource allocation (Wit, 1985). These models can be particularly useful in precision farming, where they can optimize resource use and reduce production costs (Bakhtadze, 2021). Gupta (2022) emphasizes the importance of considering factors such as soil fertility and crop rotation in these models, to promote sustainable and organic farming practices. In the context of price prediction, Wihartiko (2021) highlights the use of Artificial Intelligence, Data Mining, and Regression as effective methods.
The integration of Artificial Intelligence (AI) and the Internet of Things (IoT) in agriculture is transforming the sector, making it more sustainable and efficient (Hussein, 2024). AI technologies, such as machine

learning and computer vision, are being used in precision agriculture to monitor crops, manage resources, and automate farming operations, leading to more sustainable practices (Daraojimba, 2024).

Emerging technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) are revolutionizing agriculture globally, including in Nigeria. AI-driven precision agriculture can significantly enhance crop yields by providing detailed insights into crop health and soil conditions, which is crucial for maximizing productivity in areas with diverse climates and soil types (Mathur, 2023). Predictive analytics can help Nigerian farmers forecast yields and market dynamics, enabling them to make informed decisions and reduce risks associated with climate change and market fluctuations (Mishra, 2024). AIoT integration can increase automation and reduce labor dependency, which is particularly beneficial in rural areas with limited access to agricultural labor. However, to fully harness these technologies, challenges such as data quality, connectivity, and user adoption must be addressed, ensuring that Nigerian farmers can effectively utilize these advancements to enhance agricultural sustainability and efficiency.

In addition to agricultural improvements, a growing body of research underscores the transformative potential of AI in environmental stewardship. Lohani (2024), through a series of case studies, highlights AI's ability to optimize resource management and reduce waste in industrial processes, demonstrating significant improvements in energy efficiency and emission reductions. Uwaoma (2024) employs machine learning models to predict and mitigate environmental impacts, showing how AI can support sustainable business practices by identifying more sustainable resource utilization patterns. Naeeni (2023) conducts a meta-analysis of various AI applications, emphasizing the need for a holistic approach that integrates environmental, social, and economic considerations. This study underscores the importance of balancing technological advancements with ethical considerations to avoid adverse socio-economic impacts. Rautela (2020) uses simulation models to explore AI's potential in addressing climate change, improving agricultural practices, and enhancing disaster resiliency. The findings suggest that AI can play a pivotal role in environmental sustainability, but also highlight the need for robust policy frameworks to guide ethical AI deployment.

Collectively, these studies inform policies and practices by highlighting the multifaceted benefits of AI in environmental sustainability while also stressing the imperative of ethical AI practices. They suggest that integrating AI into environmental strategies requires comprehensive planning and regulation to ensure that technological advancements contribute positively to sustainability goals and do not exacerbate existing inequities or create new ethical dilemmas.

RESULTS AND DISCUSSION

Implementation Strategies

The adoption of AI technologies in Nigerian agriculture can be facilitated through the use of IoT and data analytics (Elijah, 2017). However, challenges such as the proper dissemination of AI technology and the need for sustainable strategies must be addressed (Shehu, 2011). The potential benefits of AI in addressing agricultural challenges in India, such as increased productivity, resource management, and market access, are also relevant to Nigeria. However, differences arise due to Nigeria's more limited technological infrastructure, lower levels of digital literacy among farmers, and less structured government support for digital agriculture, (Kumar, 2020).

Strang (2019) identifies several specific factors or barriers that hinder the widespread adoption of AI and related technologies in Nigeria. These include limited access to reliable internet connectivity and insufficient technical support. These challenges are particularly pronounced in rural areas and contribute to disparities in the adoption of advanced agricultural technologies among farmers in central Nigeria. These studies collectively suggest that the successful implementation of AI technologies in Nigerian agriculture requires a focus on both the technological and socio-economic aspects.

The capacity building of farmers in Nigeria, particularly in the area of AI, is a critical need. The capacity building of farmers in Nigeria, particularly in the area of AI, is a critical need. Ubochioma (2018) emphasizes the importance of farmers' access to new technology for improved agricultural production. AI can enhance production by enabling precision farming through real-time monitoring and data analysis, optimizing resource use, improving pest and disease management, and automating labor-intensive tasks, thus increasing efficiency and productivity on farms. However, Issa (2013) highlights the shortage of extension personnel as a major obstacle to the effective implementation of agricultural transformation. This shortage not only hampers traditional agricultural practices but also poses a challenge for the adoption of AI technologies, which require skilled personnel for proper implementation and management. Olajide-Taiwo (2011) emphasizes the importance of capacity building in safe vegetable production, an area where AI can revolutionize agricultural practices through precision farming techniques, including automated monitoring of crop health and soil conditions. Similarly, Ogunbameru (2013) highlights the necessity of capacity building in climate change adaptation, showcasing AI-driven predictive models to anticipate climate patterns and optimize resource allocation for sustainable practices. To effectively harness AI's

potential, comprehensive capacity building programs should be tailored to Nigerian farmers, incorporating hands-on training in AI tools, workshops on data collection and analysis, and partnerships with tech experts for ongoing support. These initiatives are crucial for empowering farmers to adapt and thrive in an increasingly digital agricultural landscape.

The integration of AI in Nigeria faces several challenges and opportunities. Ogbuoshi (2021) highlights the importance of full digital migration in Nigeria's broadcast industry, which can parallel advancements in agricultural AI. Enhanced digital infrastructure from this migration supports real-time data collection and connectivity crucial for AI applications in precision farming and climate adaptation. Additionally, skills and regulatory frameworks developed can benefit farmers, facilitating ethical AI use in agriculture and promoting sustainable technology adoption across rural areas.

Enebeli (2022) emphasizes the importance of awareness creation and skills acquisition in the legal sector. Similarly, in agriculture, raising awareness and providing training on AI applications could empower stakeholders to leverage technologies for precision farming, data-driven decision-making, and sustainable practices. These efforts can enhance productivity, resource efficiency, and resilience in agricultural operations across Nigeria, while Akindele (2023) advocates for stringent requirements and stakeholder collaboration in governing AI tool deployment, ensuring responsible and effective use. In agricultural contexts, these principles are crucial for overseeing AI applications like precision farming and crop management, ensuring they align with local farming practices and environmental regulations. Ehikhamenor (2014) emphasizes the need for enterprise applications integration driven by factors such as data integration and improved communication. Similarly, integrating AI into agriculture can streamline data from various sources (like weather forecasts, soil sensors) to optimize farming decisions and enhance communication among stakeholders, fostering more efficient and sustainable agricultural practices in Nigeria. These studies collectively suggest the need for a comprehensive approach to AI integration in Nigeria, encompassing digital infrastructure, awareness and skills development, and robust governance.

The application of AI in Nigerian agriculture is a growing field with significant potential. The application of AI in Nigerian agriculture is a growing field with significant potential. Ani (2019) and Eli-Chukwu (2019) both highlight the use of AI in various aspects of agriculture, including soil management, crop management, weed control, and disease control. These advancements can enhance productivity, resource efficiency, and sustainability, ultimately transforming agricultural practices in Nigeria. Anbarasan (2022) further emphasizes the flexibility, high performance, accuracy, and cost-effectiveness of AI in addressing the challenges faced by the sector. Shuaibu (2024) specifically focuses on the use of machine learning algorithms for crop yield prediction, with the Decision Tree Regressor identified as the most effective model. The application of this model in Nigerian agricultural contexts has led to more accurate yield predictions, allowing farmers to make informed decisions about resource allocation and crop management. This has resulted in increased productivity, reduced waste, and improved financial planning for farmers, thereby enhancing the overall efficiency and sustainability of agricultural practices in Nigeria.These studies collectively emphasize the promise of AI in enhancing agricultural productivity and sustainability in Nigeria.

Discussion

The interpretation of the findings from the literature review reveals a significant potential for AI to revolutionize agricultural practices in Nigeria. The studies reviewed highlight the role of AI in enhancing sustainable agricultural practices, improving food security, and increasing productivity in the Nigerian agricultural sector. AI achieves these enhancements through precision farming, where AI-driven tools enable precise monitoring and management of crops, optimizing water usage, and minimizing the application of fertilizers and pesticides. Predictive analytics, using machine learning algorithms, forecast weather patterns and crop yields, helping farmers plan their planting and harvesting schedules more effectively. Automated disease and pest detection through AI systems using image recognition technology allows for timely interventions that prevent large-scale crop damage. AI also analyzes soil health and nutrient levels for resource optimization, reducing waste and enhancing soil sustainability. Furthermore, AI optimizes the agricultural supply chain by predicting market demands and streamlining logistics, ensuring efficient market reach and reduced post-harvest losses.

Utilizing AI technologies such as data mining, IoT systems, and machine learning, Nigerian farmers can make informed decisions, optimize resource utilization, and mitigate challenges related to climate change and limited agricultural infrastructure. Comparing the findings of this review with existing literature highlights the growing body of research on AI applications in agriculture, both in Nigeria and globally. For instance, Ani (2019) discusses the implementation of AI-driven soil management systems in Nigeria, which utilize IoT sensors to monitor soil moisture and nutrient levels in real-time. This data is analyzed using machine learning algorithms to provide farmers with precise recommendations on irrigation and fertilization, leading to improved crop yields and

sustainable farming practices. These concrete examples illustrate the transformative potential of AI in enhancing agricultural productivity and sustainability in Nigeria. Studies by Babatunde (2013), Adekunle (2013), and Paramathma (2023) have emphasized the potential of AI in precision agriculture, crop selection, and disease detection. Babatunde (2013) demonstrated that AI-powered precision agriculture systems can significantly reduce water and fertilizer usage by up to 30%, leading to more sustainable farming practices. Adekunle (2013) found that AI algorithms can analyze soil and climate data to recommend the most suitable crop varieties for specific regions, resulting in increased crop yields and reduced risk of crop failure. Paramathma (2023) showed that AI-based disease detection systems can identify crop diseases with over 90% accuracy, allowing for timely and targeted interventions that minimize crop loss and improve overall productivity. These studies collectively highlight the transformative impact of AI on various aspects of agriculture.The current review adds to this literature by focusing specifically on the Nigerian context, showcasing how AI can address the unique challenges faced by Nigerian farmers and contribute to sustainable agricultural development in the country.

The practical implications of integrating AI into Nigerian agriculture are vast, ranging from improved crop yields and resource management to enhanced environmental sustainability and food security. AI applications such as precision farming, crop monitoring, and climate-resilient practices can significantly enhance productivity and sustainability (Gikunda, 2024). These technologies improve crop yields by optimizing farming practices and reducing waste (Aggarwal *et al*., 2024; Patel, 2023). Effective resource management through AI-driven insights ensures efficient use of water, fertilizers, and other inputs, leading to better environmental sustainability (Gikunda, 2024). Moreover, AI's role in addressing food security challenges, particularly in the face of climate change and population growth, further underscores its importance (Sanjeev Aggarwal *et al*., 2024). Additionally, AI attracts youth to agriculture by providing valuable insights and optimizing resource utilization, thus contributing to the sector's long-term viability (Olagunju *et al*. 2024).

CONCLUSION

In conclusion, this reviewhighlights the transformative potential of AI technologies in revolutionizing agricultural practices in Nigeria. The application of Artificial Intelligence (AI) in agriculture has shown tangible benefits in enhancing productivity, sustainability, and efficiency. For instance, Umar (2022) demonstrated that AI-powered predictive models and data analytics have enabled Nigerian farmers to optimize resource management and improve crop yields. By utilizing IoT systems, farmers in Nigeria have been able to monitor soil conditions, predict weather patterns, and implement precision agriculture practices, leading to increased agricultural productivity and resilience.

Elijah (2017) further highlights how AI technologies, such as machine learning and data analytics, have been instrumental in addressing challenges related to climate change and limited infrastructure in Nigerian agriculture. AI-driven solutions help farmers make informed decisions on irrigation scheduling, pest management, and crop selection, ultimately enhancing the overall efficiency and sustainability of agricultural practices in Nigeria.

a. These studies provide concrete examples of how AI-powered predictive models, data analytics, and IoT systems have positively impacted Nigerian agriculture by optimizing resource management, boosting crop yields, and addressing climate and infrastructure challenges. This review contributes to the field by consolidating existing research on AI applications in Nigerian agriculture and emphasizing the importance of sustainable practices in driving agricultural development. By showcasing the benefits of AI in addressing key challenges faced by Nigerian farmers, this review underscores the potential for technology-driven solutions to enhance food security, environmental sustainability, and economic growth in the agricultural sector.models.

Future Directions

Future studies should focus on developing affordable and scalable AI models tailored to the specific needs of smallholder farmers in Nigeria. Research on enhancing AI accessibility through mobile-based solutions and regional language interfaces could further empower local communities. Additionally, there is a need to explore collaborative frameworks involving government, private sector, and academic institutions to build robust digital infrastructure and capacity development programs. Investigating the long-term environmental and socio-economic impacts of AI adoption in agriculture, as well as ethical considerations in AI integration, will be critical for ensuring sustainable growth and equity in the agricultural sector.

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