Integrating Artificial Intelligence and Internet of Things in Smart Farming: A Technological Revolution in Agricultural Sustainability

Dr. Kizzy Nkem Elliot[1*] Dr. Anasuodei Bemoifie Moko[2] Dr. Damingo Levi Adawari[3]

1. Department of Computer Science and Informatics, and Cybersecurity, Federal University Otuoke, Yenegoa, Nigeria
2. Department of Computer Science and Informatics, and Cybersecurity, Federal University Otuoke, Yenegoa, Nigeria
3. Department of Computer Science, Ignatius Ajuru University of Education, Port Harcourt, Nigeria

* E-mail of the corresponding author: elliotnk@fuotuoke.edu.ng, mokoaa@fuotuoke.edu.ng levi.damingo@iaue.edu.ng

Abstract

The Internet of Things and artificial intelligence have advanced to the point that they have impacted every field of human endeavor with novel and ground-breaking solutions that promise increased data security and productivity. This integration has introduced innovative solutions that enhance data security, operational efficiency, and productivity across the agricultural value chain. Implementing AI and IoT technologies has demonstrated substantial returns on investment by improving real-time monitoring capabilities, operational safety protocols, resource optimization, and overall agricultural management processes. The agricultural sector has witnessed comprehensive technological integration throughout its entire value chain, from pre-cultivation land preparation to post-harvest market distribution. Modern smart farming applications encompass various critical areas, including precision crop monitoring systems, automated irrigation management, intelligent harvesting mechanisms, and sophisticated supply chain optimization. These technological implementations are designed to maintain product quality and integrity throughout the agricultural cycle. This technological transformation has produced a new agricultural paradigm, called "smart agriculture," which addresses multiple contemporary challenges. These challenges include managing increasing crop yield demands due to population growth, adapting to climate change impacts, creating sustainable employment opportunities, and ensuring food security. This paper presents a critical analysis of AI and IoT applications in smart agriculture, examining their conceptual frameworks and implementation dimensions, focusing on crop production optimization under adverse climatic conditions, aiming to address food security challenges, promote employment generation, enhance the green economy, and ensure sustainable agricultural productivity.

Keywords: Smart Agriculture, AI-IoT Integration, Agricultural Sustainability, Food Security, Agricultural Value Chain

DOI: 10.7176/CEIS/16-1-04

Publication date: May 30th 2025

1. Introduction

Throughout human history, farming has played a significant role in providing food for the growing population as well as in producing fuel, fibre, and medicine. All of these procedures were carried out using a manual, conventional manner; but, throughout the course of the last several years, farming has been witness to various technological revolutions, which have led to an increase in industrialization and reliance on technology [1]. Farmers now have a better degree of control over the production of their crops as a consequence of the implementation of intelligent agricultural technology, which has led to increased profitability and predictability [2]. The agricultural revolution of the 21st century is the incorporation of intelligent agricultural methods that are aimed at boosting production. This is motivated by the growing demand from customers for farm output and the need to provide food security.

The global proliferation and advancement in information technology to enhance service delivery across different domains such as agriculture has given rise to the concept of smart agricultural practices. This effort is dependent on the cooperation of a wide variety of digital technologies, including but not limited to artificial intelligence, the Internet of Things, big data, cloud computing, and others [1]. An approach to agricultural operations that is both dynamic and inventive is created via the collaborative efforts of these technical components, which in turn fosters efficacy in the accomplishment of its objectives. As a consequence of this, the data-driven approach gives farmers the capacity to optimize their agricultural operations, which ultimately results in an increase in total production while simultaneously assuring sustainability and environmental stewardship [3].

By the year 2050, the Food and Agriculture Organization (FAO) projects that the world population would have reached 9.73 billion, and by the year 2100, it is anticipated that the population will have increased even more to reach 11.2 billion [4]. This scenario has been made worse by the problems posed by climate change, which have resulted in rising temperatures, floods, and longer droughts, all of which have had a significant influence on agricultural output and yields [5]. Food shortages and population increase are the most significant hurdles to global sustainable development. As a result of industrialization, urbanization, and climate variables that are caused by human activity, crop farming, which has continued to be a significant source of food for humanity, has witnessed a decrease in yields because of these factors. This study thus takes a thorough assessment of the role that artificial intelligence (AI) and the Internet of Things (IoT) play in boosting agricultural production and sustainable environmental development in the face of these imminent global food crises, as well as difficulties related to climate change and the environment.

2. Literature Review

IoT and artificial intelligence working together produces a dynamic, data-driven agricultural economy. IoT guarantees real-time connectivity and data collecting, and AI uses data from IoT devices to enable intelligent decision-making. Precision farming depends on this type of integration.

2.1 ICT in Agricultural Development

Information and communication technology (ICT) is a term that encompasses advancements in software, systems, and methods that enable the collection, organization, processing, and dissemination of data in all its forms. This includes, but is not limited to, electronic mail, the Internet, and computer programs [6]. The term "information and communications technology" (ICT) refers to new media devices that are utilized to facilitate the administration of information. This encompasses the collection, organization, retrieval, dissemination, and safeguarding of information. Information and communication technology (ICT) is an essential component of contemporary existence. The utilization of telecommunications to obtain information is referred to as "information and communication technology" (ICT). It is primarily reliant on a variety of communication technologies. It encompasses an audio/video display, the Internet, and a computer or mobile device. Information and communication technology is perceived as a driving force behind innovation, creativity, and change, as per Suleiman et al. [7]. Technology has progressed to the extent that it is now an integral part of all aspects of life. In the course of time, the utilization of information and communication technology has resulted in a fundamental transformation in the procedures and processes of a wide range of organizational achievements.

The promotion of sustainable agricultural development is one of the most significant benefits of the utilization of information and communication technology (ICT) tools in agricultural contexts. In order to guarantee the long-term productivity of agriculture, it is imperative that the agricultural sector incorporate state-of-the-art technology, including artificial intelligence (AI) and the Internet of Things (IoT), as well as the applications that are associated with these technologies. The potential of these technologies to enhance global food security is derived from their capacity to reduce crop production deficits, mitigate inefficiencies in resource usage, and reduce food waste [8]. In order to forecast yields using sophisticated yield prediction models developed through machine learning and to accomplish predictive decision-making capabilities in smart agriculture, these information and communication technology (ICT) tools that are deployed in agricultural production are indispensable. The process of data collection and analysis of big data from a variety of sources, particularly in situ and mobile sensors, is facilitated by these instruments.

2.2 Artificial Intelligence

Artificial intelligence (AI) is a subfield of computer science that allows computers to replicate human behavior in order to help individuals enhance their performance in the disciplines of science and technology. The individual objectives of artificial intelligence (AI) include the replication of human intellect, the resolution of knowledge-intensive problems, the construction of computers that can execute activities that require human intelligence, and the development of a system that is capable of self-learning [9]. Artificial intelligence facilitates the development of systems that are more interpretable, explicable, and visible, thereby enhancing their capacity to function as intelligent agents. The concept of trusting a machine as a human counterpart was established by the Turing test. The computer is assessed in this test as if it were a human, and if it passes, it is deemed sentient, irrespective of the examiner's comprehension of the instructions. It is unsurprising that artificial intelligence has significantly impacted a variety of facets of life and has initiated a new era in the context of the digital revolution [10].

Ahemad et al. [11] assert that artificial intelligence (AI) technologies have advanced to the extent that they now provide genuine and practical advantages in a diverse array of applications. Neural computing, architecture, finance, software and gaming industries, speech understanding, robotics and sensory systems, computer vision and scene recognition, intelligent computer-aided instruction, expert systems to address unforeseen challenges in various scientific and technological domains, aerospace, drugs, and climate prediction are among the most significant applications of AI.

2.3 The Internet of Things (IoT)

The term "Internet of Things" is gaining traction as a term that is used to describe a wide range of Internet-connected devices, appliances, sensors, and everyday objects [12]. Recent research suggests that the Internet of Things will have approximately 30 billion devices implemented by the end of this decade. However, the development and deployment of the Internet of Things (IoT) are accompanied by a variety of management challenges, such as seamless integration, heterogeneity, scalability, mobility, security, and a myriad of other issues [13]. The primary advantage of the Internet of Things is its capacity to facilitate communication between an infinite number of devices that are integrated into a large-scale wireless network. These automated devices and sensors enable the implementation of a wide range of applications by generating and transmitting information in real time [14].

Automation and augmentation are two methods by which the Internet of Things (IoT) can enhance the quality of our existence. The Internet of Things (IoT) has the potential to enhance decision-making and outcomes across a wide variety of application areas, while simultaneously saving individuals and enterprises significant quantities of time and financial resources [15]. The driving force and explanation for the creation of this new trend are the IoT applications and usage in a broad variety of industries, which ultimately lead to its present acceptability on a global scale [16]. The Internet of Things (IoT) is capable of generating information from a single item and transmitting it to another item on a daily basis, as per Elliot et al. [13]. This facilitates object communication and broadens the potential applications of the Internet of Things. Currently, the internet of things (IoT) is widely used in the following sectors: healthcare, the environment, smart cities, commercial, industrial, and infrastructure, smart automation, and agriculture.

The term "Internet of Things" (IoT) denotes a network that is composed of a variety of mechanical apparatus, computational equipment, and objects that are all interconnected. Each of these objects is endowed with a distinctive identification and the ability to transmit data. This enables the effective prevention of encounters between humans or between humans and computers. The Internet of Things (IoT) is a technological advancement that is based on a variety of existing technologies, including wireless sensor networks (WSNs), databases, and radio frequency identification (RF). The components that are present, as well as the processes that are performed on the insight data and the necessary actions, are all incorporated into a hybrid Internet of Things design [17]. One of its advantages is its ability to incorporate a substantial number of subsystem architectures [18]. Figure 1 illustrates the functions of each component in a conventional Internet of Things design.

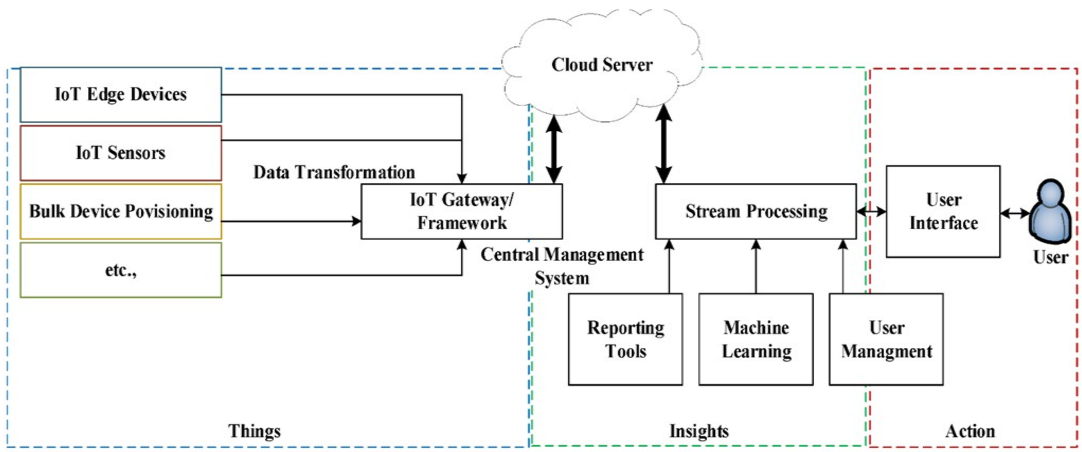

Figure 1. Basic IoT Architecture (Source: Hassan et al., 2020)]

The components of the basic Internet of Things architecture depicted in Figure 1 include:

1) IoT Edge Devices: Edge devices are essential in an Internet of Things environment because they gather raw data from sensors, process and analyze them locally, and then send only the most pertinent data to the cloud. This lowers network latency and bandwidth consumption and allows for quicker real-time decision-making; in other words, they serve as a bridge between the physical sensors and the cloud-based data processing systems. Since IoT Edge devices can perform some processing on their own, they make up the smart IoT actuator.

2) IoT Sensors: These are connected to the cloud, and designed to receive and transmit data. According to Olanrewaju et al. [19] sensors are devices that collect data from their surroundings. Sensors come in a variety of designs, including proximity sensors, temperature sensors, gas sensors, and light sensors. These sensors are used to build smart gadgets or systems like tablets and smartphones, but they can also be used to predict the weather and perform other intelligent tasks. For example, smartphones make great use of sensors, therefore they are named smartphones [20].

3) Device Provision: IoT device provision is the initial interaction a user has with a new smart IoT device and how they connect or configure it to their Wi-Fi for later device administration and control through the vendor-specific mobile app. It involves giving a new IoT device a unique identity, authenticating it, and setting up the settings it needs to send and receive data. In other words, it involves "enrolling" the device into the IoT platform and preparing it to operate safely within the network [21].

4) IoT Gateway/Framework: IoT devices communicate to the Internet via access communication protocols such as Wi-Fi, LoraWAN, Bluetooth, Ethernet, or ZigBee. Sensor data can be delivered to Internet-connected servers (or actuators). An IoT gateway is essential for aggregating and processing sensor data before it is transmitted over the Internet [22]. This transmission model provides the best-effort service but does not guarantee transmission quality. In other words, the IoT Gateway serves as a cloud hub for the IoT devices, providing command, management, and control over them.

5) Stream Processing: The new paradigm of stream processing has developed into a significant facilitator of applications that fall under the category of time-critical Internet of Things applications. In addition to providing the ability to collect, integrate, analyze, and display continuous data streams in real time, it also gives the capability to maintain a fault-tolerant, highly available, and scalable architecture. Stream processing is primarily beneficial because it acts as a bridge between the application layer and the service and middleware layers. This bridge enables the top logic to make appropriate use of the general-purpose services and infrastructure that are underneath the application layer [23].

6) Machine Learning: Machine learning is an area of artificial intelligence that enables computers to learn and improve from enormous datasets without being explicitly programmed. This is accomplished through the technique of machine learning. In order to do this, it is necessary to design algorithms that are capable of analyzing data patterns and producing models for certain activities. This enables accurate predictions and intelligent behavior [24]. IoT environments that make use of machine learning techniques make it possible for those algorithms to be anticipated and implemented on extremely large amounts of data. In addition to this, it

does predictive maintenance based on a number of different scenarios and assesses them. In order to improve the effectiveness of the Internet of Things (IoT), new machine learning algorithms and methods have made it simpler to analyze massive volumes of data. Devices and gadgets are able to recognize patterns and make judgments based on data analysis thanks to the application of specialized machine learning techniques such as decision trees, clustering, neural networks, and Bayesian networks [25].

7) Reporting: IoT analysis involves the analysis of enormous volumes of data generated by IoT devices at high velocities, typically in real-time. This is the seventh and final phase in the aforementioned process. In order to extract timely insights from the inexhaustible stream of data that is being collected, real-time or near-real-time processing is necessary. Furthermore, data from the Internet of Things (IoT) can be quite diverse, encompassing structured, semi-structured, and unstructured data types. Sensor readings, text data, photographs, and other categories of data are among the data types that complicate data integration and analysis. This is why reports are of paramount importance, as they enable the making of informed decisions, which would be impossible to achieve if they were conducted manually. In the agricultural sector, crucial information regarding crop health, soil conditions, and weather patterns is obtained through an in-depth examination of the Internet of Things (IoT). This study will enable producers to make informed decisions that will increase agricultural output, safeguard critical resources, and contribute to environmental sustainability. Reporting tools for the Internet of Things are designed to retain and organize data, as well as to provide the necessary tools for bulk processing. [26]

8) User Management: it has the capacity to restrict and authorize specific individuals or organizations to perform specific actions on the device. The procedure is executed by utilizing the program's capabilities that each user possesses.

Monitoring, precision agriculture, tracking and tracing, greenhouse production, and agricultural apparatus manufacturers are among the numerous applications of the Internet of Things. For example, agricultural product chain tracking and tracing requires the ability to input information (including the entire product life cycle and the transportation process), store the information for an extended period, and transfer, process, and output the data. Agricultural enterprises are able to make more informed decisions, discover new business partners, and save both time and money as a result of being able to view the entire history of the product. Commercial objectives may be achieved by utilizing the monitoring and tracing of the product chain, particularly to foster trust between the supplier and the client. Data analysis is performed by Internet of Things (IoT) systems using a variety of methods, including sensor data, audio, photographs, and videos. Prediction, storage management, decision-making, agricultural management, precise application, and insurance are among the numerous applications for which data analysis is indispensable [27].

The Internet of Things (IoT), an extensive network of interconnected devices and technologies, is a critical element in the advancement of smart farming. The Internet of Things (IoT) architecture in agriculture is comprised of agricultural sensors, information and communication technology (ICT), and unmanned aerial vehicles (UAVs). This architecture simplifies the process of gathering essential data for precision farming [28]. The increasing prevalence of mobile data and the Internet of Things is of paramount significance when examining the context of the fourth industrial revolution [29].

2.4 The Integration of the Internet of Things (IoT) and Artificial Intelligence in Smart Farming

Although machines are not intended to replace humans, they can help individuals reduce the amount of labor they must perform. It is imperative that the human civilization maintain its control over machines. AI is most effective when it functions in conjunction with human intellect, rather than as a replacement for it. It underscores the notion that computers and humans possess distinct capabilities in the vast domain of excellence: computers are significantly more efficient at arithmetic and calculating, while humans are particularly adept at logic and thought. This is a significant distinction between the two. The various levels of intelligence are not mutually exclusive; rather, they are complementary. As a result, artificial intelligence is the technology that will allow us to construct "things" that are capable of "thinking" [30]. Moreover, Elliot et al. [13] suggest that the Internet of Things (IoT) can be utilized to develop intelligent machines that can replicate intelligent behavior and aid in decision-making with minimal or no human involvement. Both the general public and individual audiences with specific interests benefit from the convergence of these two strands. In contrast to the Internet of Things, which involves items communicating with one another over the internet, artificial intelligence allows devices to learn from their data and experiences.

As Sharma and Shivandu [29] have stated, the integration of the Internet of Things (IoT) and artificial intelligence (AI) into smart farming leads to the development of cyber-physical systems that are capable of overseeing agricultural operations as a whole. Agricultural health monitoring, disease identification, vegetation control, and soil management are among the applications of artificial intelligence. ANN-GIS, computer vision systems, Management-Oriented Modeling (MOM), SRCDSS (a fuzzy logic-based soil risk characterization decision support system), CALEX, PROLOGUE, and SVMs are among the most prominent examples [31].

It is crucial to recognize that mobile expert systems are a form of artificial intelligence. These systems allow farmers to utilize their cellphones to perform tasks such as disease diagnosis, species identification, and soil health analysis by utilizing mobile applications. Artificial intelligence also enables the real-time analysis of satellite images, which can be used to monitor agricultural progress. These technologies provide a scientific foundation for smart agriculture, thereby enabling the optimization of agricultural outputs and enhancing the efficiency of smart agriculture. The promise of smart agriculture is found in the integration of cyber-physical systems, unmanned aerial vehicles (UAVs), the internet of things, and artificial intelligence in agricultural management. The autonomous operation of these interconnected devices enables the collection and analysis of data in a timely and efficient manner. There is a potential for this combination of new technology to alter agricultural practices, thereby allowing producers to optimize their operations and achieve increased productivity and sustainability. In addition, smart agriculture addresses a diverse array of obstacles related to crop production by monitoring soil moisture, soil characteristics, and climatic factors. In order to link remote sensors such as drones, ground sensors, and robotics in a straightforward manner, it is imperative to have Internet of Things technology.

The operation of autonomous systems (RAS) and robotics is contingent upon artificial intelligence (AI). It is feasible to generate data streams on an ongoing basis due to its interface with the Internet of Things. The utilization of data mining techniques is essential for the conversion of agricultural data into insights that can be applied to decision-making [32]. In large-scale data repositories, artificial intelligence (AI) analyzes a diverse array of environmental data and prior agricultural records. This analysis exposes concealed patterns that are critical for the optimization of fertilizer regimens, the diagnosis of diseases, the calculation of yields, and the identification of parasites in agricultural decision support systems. The utilization of these insights is crucial for the improvement of the precision and efficacy of agricultural processes, which in turn enables the formulation of well-informed decisions that are founded on a comprehensive analysis of statistics. The integration of artificial intelligence (AI) and the Internet of Things (IoT) in the process of improving smart farming is illustrated in Figure 2. It commences with the acquisition of data and progresses through the categorization processes implemented by AI-machine learning algorithms,

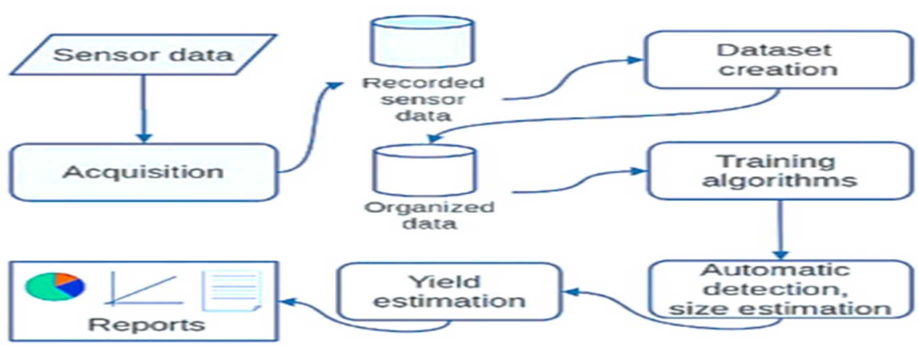

Figure 2. . AI-IoT Smart Farming Integration Model (Source: Sharma & Shivandu, 2024)]

3. Evaluating the Contributions of AI and IoT in Smart Farming

This study uses a qualitative, multi-case study and comparative analysis design to critically examine the integration of Artificial Intelligence (AI) and the Internet of Things (IoT) in smart farming.

3.1 Advantages of AI-IoT Integration in Smart Farming

The advancement of AI and IoT has resulted in continuous data streaming [33]. In order to transform agricultural data into pertinent information for decision-making purposes, data mining techniques are essential. Various environmental data and agricultural historical records in big data have been analyzed using AI, thereby revealing patterns that would otherwise remain concealed [34]. The significance of these discoveries is that they are essential for the development of agricultural decision support systems, which include insect identification, disease detection, yield prediction, and fertilization strategies [35]. The potential of AI to reduce food waste, enhance production hygiene, and monitor machines at various stages of agriculture, including the supply chain, agricultural production pattern, and agricultural production process, which encompasses soil, crop, and water management, as well as disease and pest control, is substantial [36], [37]. Artificial intelligence (AI) can then resolve challenges associated with conventional farming [33]. An overview of the different areas where smart farming can be applied, its contributions as well as the challenges it faces are summarized in Table 1. The enabling technologies for smart agriculture with AI-IoT integration are illustrated in Table 2.

Table 1: Summary of Evaluating the Contributions of AI and IoT in Smart Agriculture

Dimension	Contributions	Challenges
Food Security	Better crop yields, fewer losses, timely advice for farmers	Not everyone can access the technology, some farmers lack training
Job Creation	New jobs in technology and farming, more chances for young people and small businesses	Some people don't have the skills or education to benefit
Green Economy	Saves water, cuts waste, reduces pollution and energy use	e-waste management issues, Environmental data could be misused
Sustainable Farming	Helps grow more food using fewer resources, supports long-term farming practices	Needs strong support from government and long-term investment

Table 2: Advantages of AI-IoT Integration in Smart Farming

N	TECHNOLOGY	ADVANTAGES	APPLICATION AREA
1	IoT	i. Real-time surveillance, ii. Promotion of data-informed decision-making, iii. Enhancement of resource use, iv. Prompt identification of problems	i. Intelligent Agriculture, ii. Advanced Irrigation Systems, iii. Livestock Surveillance, iv. Environmental Monitoring, v. Aquaculture Management, vi. Remote Agricultural Oversight
2	AI	i. Automation and predictive analytics in decision support systems, ii. Improvement of crop management, disease identification, and yield maximization	i. Crop yield forecasting ii. Disease identification iii. Pest control iv. Visual recognition v. Mobile expert systems vi. Plant anomaly identification
3	ML	i. Facilitates pattern recognition ii. Predictive modeling iii. Data analysis iv. Aids in crop disease diagnosis v. Crop yield forecasting vi. Recommendation systems	i. Diagnosis of crop diseases, ii. Prediction of yield, iii. Analysis of soil, iv. Optimization of yield, v. Optimization of breeding, and vi. Systems for farm management

3.2 Limitations to AI-IoT-Driven Smart Farming

The implementation of advanced technology from the fourth industrial revolution can revolutionize the agricultural sector, facilitating enhanced efficiency and sustainability, while augmenting production and minimizing resource wastage. The implementation of advanced technologies like AI and IoT in smart farming and agricultural production remains nascent, necessitating the resolution of several challenges to facilitate the transition to smart agriculture. It is essential to meticulously assess the specific requirements, challenges, and implementation concerns associated with each technology within the context of the agricultural enterprise in question. The primary obstacles and constraints of integrating AI-IoT in smart farming and the agricultural revolution in Nigeria and other developing nations include:

- Insufficient Skilled Workforce: A primary challenge hindering the advancement and implementation of smart farming in developing and emerging economies is the deficiency of interdisciplinary expertise. Big data engineers, data analysts, and data scientists often lack agricultural knowledge, whereas experienced farmers possess practical skills but lack the education required to manage advanced technologies such as artificial intelligence (AI) and the Internet of Things (IoT) [37]. The expenses associated with the production and development of high-tech applications, along with the capital necessary for their implementation in practical agriculture, are substantial, potentially rendering modern technologies prohibitively expensive for small-scale farmers lacking sufficient financial resources for investment.
- Insufficient Affordable Technologies for Smallholder Farmers: In numerous developing agricultural nations, including Nigeria, the adoption of AI and IoT in smart agriculture has proven to be a formidable challenge due to inadequate funding, lack of trust in the technologies, insufficient

infrastructure, and limited resources. The absence of inexpensive technology for smallholder farmers may engender a digital gap, wherein only large-scale, educated farmers can capitalize on such technologies [41]. In a society characterized by unequal resource distribution, certain people find it challenging to access new technical innovations.

- Insufficient Energy Supply: The persistent issue of inadequate energy in rural areas, where agriculture is prevalent, hinders the implementation of new technologies, despite scientific advancements in wireless power transfer systems and localized energy generation methods [37]. The provision of electricity continues to be a major limitation in the execution of smart agriculture, especially concerning irrigation, heating, machinery, and monitoring systems. The treatment and storage of water need supplementary energy, which may result in energy limitations within the agricultural sector [42].
- Lack of Digital Literacy: Digital literacy, akin to information literacy, is the capacity to obtain and process information utilizing critical thinking abilities. Digital literacy encompasses the comprehension of digital tools and their application in communicative and collaborative manners through social contact. As to Martin [43], a digitally literate individual is one who can identify, access, manage, integrate, evaluate, analyze, and synthesize digital resources. He observed that digital literacy may be categorized into three levels. He posited that digital literacy included three components: digital competence, digital consumption, and digital transformation. Conversely, restricted digital literacy and uneven access to digital technologies in rural regions, along with connection issues, provide significant obstacles to the long-term integration of intelligent technology in agricultural practices [44], [45].
- Insufficient Computing Power: Constraints in computational capability, storage availability, processing velocity, and excessive battery energy consumption provide significant technological hurdles in smart agriculture technology, especially when managing substantial data volumes [46]. In several agricultural areas within developing and rising nations, reliable internet access, essential for data collection, transmission, and analysis, may be lacking, hence hindering the adoption of new technology [47].
- Privacy and Confidentiality Issues: The gathering and examination of data from agricultural activities may provide privacy and security problems [36]. The data is varied, necessitating private-sector software platforms for extensive transport and storage. This highlights issues related to data ownership. Farmers are hesitant to share data with third-party service providers due to persistent challenges in precision agriculture, including blockchain interoperability, privacy concerns, data leakage, cyber terrorism, and nonrepudiation issues associated with large data [38].

4. Conclusion

The integration of AI and IoT in smart agriculture, as demonstrated by several studies, reveals a landscape abundant with prospects and challenges. This assessment has underscored the essential attributes of these technologies as they transform farming and agricultural practices. The conclusion synthesizes key results from the evaluated papers, providing a thorough understanding of the present state and future potential of smart agricultural agriculture. This review presents the subsequent findings:
The amalgamation of AI, IoT, and contemporary technologies, including drones and sensors, has significantly augmented agricultural efficiency and production. These technologies provide accurate monitoring and control of crops, leading to enhanced production and resource optimization. This connection ensures a substantial return on investment for agricultural endeavors by minimizing waste, since the system precisely monitors all actions and accurately forecasts future occurrences using time series analytics.
The integration of AI with IoT enhances the data-driven decision-making process. The utilization of machine learning algorithms and predictive analytics in agriculture has transformed decision-making processes. Agriculturists today possess insights derived from extensive data, enabling them to make educated and timely decisions that enhance crop management and mitigate risks. The utilization of machine learning algorithms for analyzing agricultural big data provides practitioners with insights to make educated agro-business decisions that favorably affect the farm and enhance productivity across the value chain.
The combination of AI and IoT enhances sustainability and resource conservation. The use of AI-IoT smart farming technology enhances sustainable agriculture by optimizing resource use, particularly in water and soil management. This mitigates the environmental impacts of the agricultural technique and fosters long-term sustainability.

Obstacles to the execution of AI-IoT Smart Agriculture: Notwithstanding their advantages, these technologies encounter implementation challenges, including elevated prices, integration complexities, data security concerns, and the necessity for specialized operation and maintenance. Moreover, challenges in accessibility and connectivity arise due to discrepancies in technological access, particularly in rural and underdeveloped regions, presenting a significant obstacle. The inadequate infrastructure, including the absence of broadband internet networks and connection, hinders smart agriculture from achieving its full potential.

References

[1] S. De Alwis, Z. Hou, Y. Zhang, M. H. Na, B. Ofoghi, and A. Sajjanhar, "A survey on smart farming data, applications and techniques," Computers in Industry, vol. 138, no. 2, pp. 34-45, 2022.

[2] M. Javaid, A. Haleem, R. P. Singh, and R. Suman, "Enhancing smart farming through the applications of Agriculture 4.0 technologies," International Journal of Intelligent Networks, vol. 3, no. 1, pp. 150-164, 2022.

[3] P. Thongnim, V. Yuvanatemiya, and P. Srinil, "Smart Agriculture: Transforming Agriculture with Technology," in Methods and Applications for Modeling and Simulation of Complex Systems, F. Hassan, N. Sunar, M. Mohd Basri, and M. Mahmud, Eds., 2024, pp. 362-376.

[4] Food and Agriculture Organization [FAO], The future of food and agriculture -- Trends and challenges, Food and Agriculture Organization of the United Nations, 2017. [Online]. Available: https://openknowledge.fao.org/server/api/core/bitstreams/2e90c833-8e84-46f2-a675-ea2d7afa4e24/content

[5] I. Charania and X. Li, "Smart farming: Agriculture's shift from a labor intensive to technology native industry," Internet of Things, vol. 9, no. 2, pp. 566-579, 2020.

[6] T. O. Owolabi, B. K. Oyewole, and J. O. Oke, "Teacher Education, Information and Communication Technology: Prospects and Challenges of E-Teaching Profession in Nigeria," American Journal of Humanities and Social Sciences, vol. 2, no. 1, pp. 87-91, 2013.

[7] M. M. Suleiman, T. Kaur, M. Kuliya, and A. Sarki, "Impact of ICT for the 21st Century: A Change Driving Tools for Tertiary Education in Nigeria," Tsinghua Science & Technology, vol. 4, no. 10, pp. 42-49, 2020.

[8] T. Alahmad, M. Neményi, and A. Nyéki, "Applying IoT Sensors and Big Data to Improve Precision Crop Production: A Review," Agronomy, vol. 13, no. 1, pp. 1-20, 2023.

[9] R. Kamble and D. Shah, "Applications of artificial intelligence in human life," International Journal of Research, vol. 6, no. 6, pp. 178-188, 2018.

[10] M. Ghosh and A. Thirugnanam, "Introduction to Artificial Intelligence," in Artificial Intelligence for Information Management: A Healthcare Perspective, K. G. Srinivasa and S. Sekhar, Eds., 2021, pp. 23-44.

[11] M. M. Ahemad, I. Ahmad, J. Ashraf, S. Tanweer, and A. R. Nasir, "Applications of Artificial Intelligence in Human Life," Middle East Journal of Applied Science & Technology (MEJAST), vol. 3, no. 3, pp. 28-38, 2020.

[12] V. Kebande, "Industrial internet of things (iiot) forensics: The forgotten concept in the race towards industry 4.0," Forensic Science International: Reports, vol. 5, p. 100257, 2022.

[13] K. N. Elliot, L. Damingo, B. Luckyn, and W. Nwankwo, "Big Data and Internet of Things (IoT) in Autonomous Navigation," International Journal of Technology and Engineering Studies, vol. 9, pp. 45-50, 2023.

[14] R. Hassan, F. Qamar, M. K. Hasan, A. H. M. Aman, and A. S. Ahmed, "Internet of things and its applications: A comprehensive survey," Symmetry, vol. 12, no. 10, p. 1674, 2020.

[15] C. Cheng, J. Dou, and Z. Zheng, "Energy-efficient for internet of things in smart city," Internet of Things and Cyber-Physical Systems, vol. 2, pp. 145-158, 2022.

[16] L. Chettri and R. Bera, "A comprehensive survey on internet of things (IoT) toward 5G wireless systems," IEEE Internet of Things Journal, vol. 7, no. 1, pp. 16-32, 2019.

[17] R. Stackowiak, "Azure IoT Solutions Overview," in *Azure Internet of Things Revealed*, 2019, pp. 29-54.

[18] G. Mojib, A. H. M. Aman, M. Khalaf, and R. Hassan, "Simulation analysis for QoS in Internet Of Things wireless network," *3C Tecnología*, pp. 77-83, 2019.

[19] R. F. Olanrewaju, B. U. I. Khan, A. H. A. Hashim, K. A. Sidek, Z. I. Khan, and H. Daniyal, "The Internet of Things Vision: A Comprehensive Review of Architecture, Enabling Technologies, Adoption Challenges, Research Open Issues and Contemporary Applications," Journal of Advanced Research in Applied Sciences and Engineering Technology, vol. 26, no. 1, pp. 51-77, 2022.

[20] M. J. McGrath and C. N. Scanaill, "Key sensor technology components: hardware and software overview," in Sensor Technologies: Healthcare, Wellness and Environmental Applications, 2013, pp. 51-77.

[21] R. A. K. Fezeu, T. J. Salo, A. Zhang, and Z. Zhang, "Dissecting IoT Device Provisioning Process," *arXiv Preprint*, pp. 1-7, 2023.

[22] O. Brun, Y. Yin, and E. Gelenbe, "Deep learning with dense random neural networks for detecting attacks against IoT-connected home environments," *Procedia Computer Science*, vol. 134, no. 3, pp. 458-463, 2018.

[23] X. Liu, A. V. Dastjerdi, and R. Buyya, "Stream processing in IoT: Foundations, state-of-the-art, and future direction," in Internet of things: Principles and Paradigms, R. Buyya and A. V. Dastjerdi, Eds., 2016, pp. 145-161.

[24] P. F. Reinaldo, A. C. B. Monteiro, R. Arthur, and Y. Iano, "An overview of deep learning in big data, image, and signal processing in the modern digital age," in Hybrid Intelligene in Pattern Analysis: Trends in Deep Learning Methodologies, P. Vincenzo, R. Sandeep, G. Angelo, and S. Rajshree, Eds., 2021, pp. 63-87.

[25] S. Mishra and A. K. Tyagi, "The Role of Machine Learning Techniques in Internet of Things-Based Cloud Applications," in Artificial Intelligence-based Internet of Things Systems, S. Pal, D. De, and R. Buyya, Eds., 2022, pp. 105-135.

[26] J. Gopalakrishnan, IOT Analytics and Reporting -- A Comprehensive Guide, 2024. [Online]. Available: https://www.knowi.com/blog/iot-analytics-and-reporting-a-comprehensive-guide/

[27] O. Elijah, T. A. Rahman, I. Orikumhi, C. Y. Leow, and M. N. Hindia, "An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits.