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EXPLORING THE BENEFITS OF ARTIFICIAL INTELLIGENCE TOWARDS ENSURING A SUSTAINABLE AGRICULTURAL DEVELOPMENTS IN NIGERIA

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Abstract

This paper looks at the relationship between artificial intelligence (AI) and agricultural developments in Nigeria. The place of Agriculture in Nigeria's economy is of high premium. In Nigeria, agriculture has traditionally been a significant contributor to the livelihoods of its population. Over 60-70% of the population relies on agriculture directly or indirectly for their livelihoods. This percentage includes smallholder farmers, agricultural laborers, agribusiness workers, and those involved in related sectors such as food processing and distribution. As a nation keying into fast growing technology space. Nigeria stands to benefit immensely from the integration of AI technologies into its agricultural sector. The study focused on overview of the current state of agriculture in Nigeria, the trend of agriculture practice, the key challenges such as climate change, environmental degradation, limited access to finance, as well as consider the benefits of AI to the agricultural sector.

Keywords: AI, agriculture, Nigeria, economy, environment.

1. Introduction

Nigeria's primary economic driver prior to the 1956 discovery of crude oil was agriculture. The place of Agriculture in Nigeria's economy is of high premium. In Nigeria, agriculture has traditionally been a significant contributor to the livelihoods of its population. According to past statistics, approximately 60-70% of the population relies on agriculture directly or

indirectly for their livelihoods. This includes smallholder farmers, agricultural laborers, agribusiness workers, and those involved in related sectors such as food processing and distribution. However, the drop in the price of oil on the global market has resulted in a sharp loss in Nigeria's oil revenue. This has had a detrimental effect on the country's economy since the second quarter of 2016, which has led the Nigerian government to decide to diversify the country's economy to go beyond oil revenue. Agriculture emerged as the superior or next crucial option to gas and crude oil as long-term source of income, jobs, and wealth development that will promote further economic expansion. But Nigeria's agricultural practices are currently at a crossroads, with major obstacles to providing food security for the country's exponential population increase and mitigating the effects of climate change on traditional farming practices (Altieri & Nicholls 2017).

Ye (2023) notes that technology like mobile, blockchain, robotics, remote sensor technology, IoT, big data, analytics, and most notably AI and machine learning, among others, serve as game changers that represent a huge opportunity for Africa, particularly Nigeria, to take advantage of them to correct all the identified challenges and exploit for increased productivity and improved quality of agriculture produce that meets local and international standards in agriculture. Furthermore, more productive, efficient, sustainable, inclusive, transparent, and resilient food systems will be needed to meet the UN Sustainable Development Goals (SDGs) of a world with zero hunger by 2030 (FAO, 2017). This article navigates through potential, constraints, and the overall impact of artificial intelligence (AI) in creating sustainable agricultural growth throughout varied regions of Nigeria. AI is a cutting-edge precision farming tool that gives farmers real-time insights about crop health, soil conditions, when to harvest, rainfall measurements, and weather patterns.

The paper aims to examine the relationship between AI and agricultural developments in Nigeria. We note that with adaptation of AI-driving tools such as remote sensing, machine learning, and data analytics, Nigerian farmers can make informed decisions, optimize resource utilization, and enhance productivity. The study focused on overview of the current state of agriculture in Nigeria. We show the trend of agriculture practice, the key challenges such as climate change, environmental degradation, limited access to finance, pest and disease control outbreak and low productivity. We considered the benefits of AI to the agricultural sector as well as the global trend in the use of AI for agriculture development. The paper further looked at the institutional framework necessary to facilitate the adoption and integration of AI

technology into Nigeria agriculture by examining the previous studies in Nigeria and other countries, the paper illustrates the potential impact of AI on agricultural development, including increased yields, improved resource efficiency, and enhanced resilience to environmental stresses.

2. Literature Review

2.1. Agricultural development in Nigeria

The primary goal of agriculture is to provide food for plants, humans, and animals to eat. Land was used for the methodical growth and gathering of plants and animals thanks to agriculture. (Olorunfemi, 2008) identified agriculture as a profession for the organic simplicity of food webs and the rerouting of energy for planting by humans and the consumption of animals. Nigeria's economy was mostly reliant on agriculture until the 1980s, when crude oil exploitation started. Izuchukwu (2017) shows that the agricultural sector contributes to economic growth and discovered that there was a positive correlation between GDP and foreign direct investment, domestic saving, and government spending on agriculture.

Nonetheless, Nigerian agriculture can be essentially classified into four areas: cattle, forestry, agricultural production, and fisheries. comprised 87.6% of the sector's overall output, with forestry, fishery, and livestock coming in second with 1.1%, 3.2%, and 8.1%, respectively. Nigerian policymakers are primarily concerned with reshaping agriculture reform to increase productivity and competitiveness in order to guarantee food security and safety for long-term sustainability. (Pawlak & Kołodziejczak, 2020; Akinbamowo, 2013). Nigeria, which was considered to have the biggest economy in Africa in 2014, derived approximately 23.6% of its GDP from agriculture, 30.78 percent from industry, and 44.04 percent from services, according to data published by the Food and Agriculture Organization (FAO) in 2022 found that Nigeria's GDP was primarily derived from the agricultural sector - 23.6% came from agriculture, 30.78 percent came from industry, and 44.04 percent came from services.

2.2. Trend of Agriculture

Nigerian agriculture is classified into crop production, fishing, livestock, and forestry. The largest component of the agriculture sector's output, accounting for 87.6% of total output, is crop base production, followed by livestock, fishing, and forestry at 8.1%, 3.2%, and 1.1%, respectively. Nigeria's total land area is estimated to be 70.8 million hectares, with the main

crops grown there being rice, beans, millet, yam, cassava, and guinea corn. It was noted in 2017 that rice production increased to 3.7 million metrics tons in 2017 and 4.0 million metrics tons in 2018. Despite this historic rise, only 57% of the 6.7 million metric tons of rice consumed in the country was produced domestically; the remaining 3 million metric tons were either illegally imported or smuggled in. When it comes to cassava, a noteworthy milestone was reached in 2017 when over 59 million tons were produced, becoming Nigeria the world's top producer (Owolabi et al., 2016).

Furthermore, the potential role of animal production is persistently underutilized. Agricultural families in Nigeria raise small ruminants such as goats (18.4 million), sheep (43.4 million), and cattle (76 million). The northern region of the country is well-known for raising livestock due to its unique ecosystem. There are 180 million chickens in the world in addition to small and large ruminants (FMARD, 2017). Even if development partners have improved production and taken steps to protect against diseases, particularly transboundary animal diseases, domestic demand still exceeds supply in this instance as well.

The northern region of Nigeria presents favorable ecological conditions for livestock husbandry, establishing the area as a prominent center for such agricultural activities. The region supports both small and large ruminants, along with a thriving poultry population estimated at 180 million birds (FMARD, 2017). Despite collaborative efforts from development partners to enhance production and control diseases, including transboundary animal diseases, the demand for livestock products exceeds domestic production capacity.

Nigeria is the largest fish consumer in Africa and one of the top consumers globally, with an annual consumption of approximately 3.2 million metric tons. The fisheries and aquaculture sectors are among the fastest-growing segments of the economy. With an extensive coastline of 853 kilometers and over 14 million hectares of inland water resources, Nigeria produces nearly 1 million metric tons of fish annually, including 313,231 metric tons from aquaculture and 759,828 metric tons from fisheries. Fishing is vital for the livelihoods of impoverished communities and is crucial for household protein intake.

Aquaculture is recognized as a promising avenue to increase domestic fish production and address nutritional deficiencies. Additionally, the forestry sector significantly contributes to agricultural development and broader socio-economic progress. However, Nigeria's forests are increasingly threatened by rapid population growth and economic activities, with annual deforestation rates ranging from 0.72 to 2.38 percent (FAO, 2018). Factors such as agricultural

expansion, heavy reliance on firewood and charcoal for energy, unsustainable timber extraction, urbanization, grazing, bushfires, and infrastructure development intensify this issue. With the population projected to reach 400 million by 2050, enhancing agricultural productivity through the adoption of new technologies is crucial for ensuring food security.

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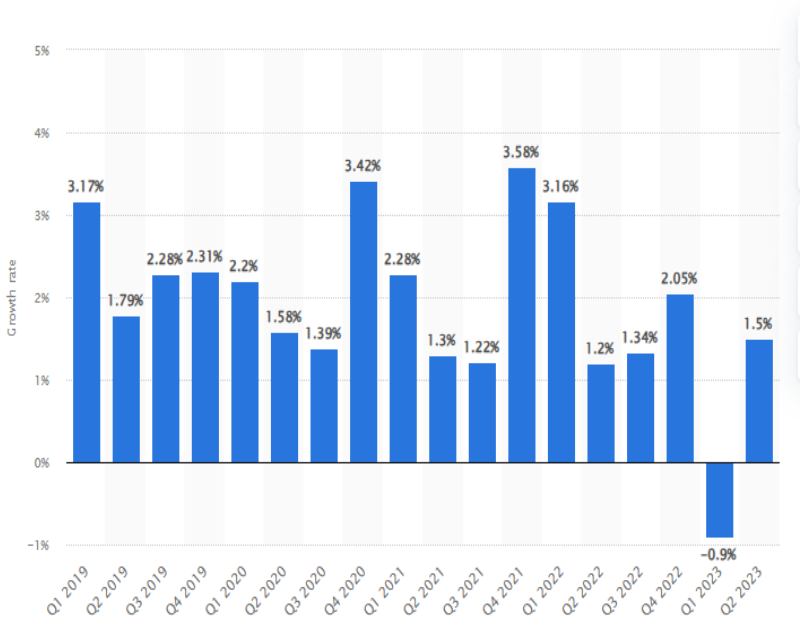

Figure 1: Agricultural contribution to GDP

Source: BNS, PWC Analysis

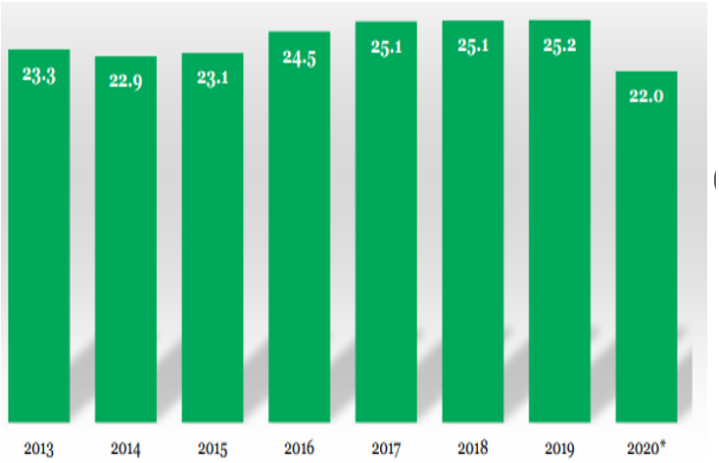

Figure 2: Agricultural contribution to GDP

Source: BNS, PWC Analysis

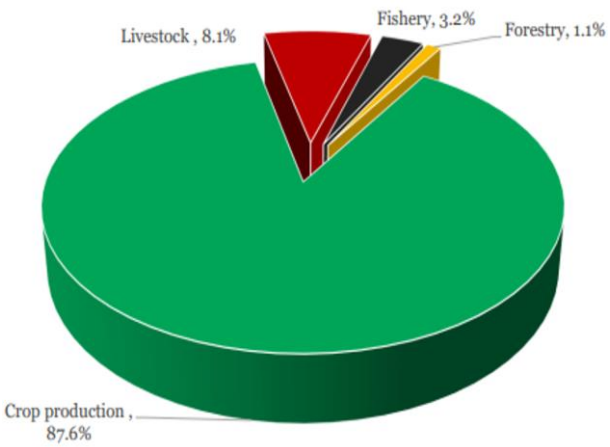

Figure 3: Size of Segment of Agricultural Sector

Source: BNS, PWC Analysis

2.3. Challenges of Agriculture in Nigeria

Over the years, the Nigerian government has implemented various initiatives and policies to boost agricultural output. When import substitution and export promotion strategies failed in the 1970s, the military regime of President Olusegun Obasanjo launched "Operation Feed the Nation" to address food challenges. This was followed by the "Green Revolution," inaugurated by President Shehu Shagari in 1980, aimed at increasing the production of food and raw materials to achieve food security and self-sufficiency in basic staples. Despite these efforts, food importation increased, and the programs ultimately failed.

Agricultural practices in Nigeria have faced numerous challenges, including inadequate implementation and monitoring mechanisms. Many initiatives have been plagued by corruption, fund mismanagement, and a disconnect between policymakers and farmers, leading to inefficiency and poor outcomes. Additionally, poor road networks, limited access to markets and infrastructure, and an unstable power supply have further hindered the agricultural sector's success. Climate change also significantly impacts Nigerian farmers, resulting in droughts, erratic weather patterns, and floods that negatively affect crop yields and livestock production. Despite these challenges, Nigeria has yet to effectively combat the effects of climate change. Moreover, the preference among youth for white-collar jobs has led to a decline in agricultural participation, further contributing to the sector's struggles.

2.4. AI and Agriculture Benefits

The use of AI in a variety of industries and services has significantly improved productivity in these fields. AI has revolutionized the global farming industry by providing food producers with far better access to operational data. These AI uses include precision farming, predictive analytics for weather and pest management, livestock monitoring, and crop monitoring and management, among others. Based on data on hunger and population by the United Nations (UN), there will be a 2 billion increase in the global population by 2050. The developments in AI and machine learning (ML) in agriculture are driving ideas that could enhance food production supply chains in more sustainable and cost-effective ways.

2.5. Recent Global Trend in use of AI for Agriculture development

Over the years, the trend of AI in both wealthy and developing nations has greatly improved. The development of AI started to progress scientific research in 2022. Numerous studies were conducted in 2023 to evaluate the effects of AI on various facets of life, with the expectation that advancements and integration of AI into services will enhance the quality of life. The recent year and the previous five years have seen a considerable improvement in the application of AI in the United States. There were only one AI-related rule in the United States in 2016; by 2023, there are expected to be 25. Regulating AI, however, increased by 56.3%. Nonetheless, agriculture is a fundamental component of human civilization and evidence of our capacity to use the natural world to our advantage. However, this ancient industry confronts numerous obstacles that reduce output, affect livelihoods, and jeopardize the security of the world's food supply.

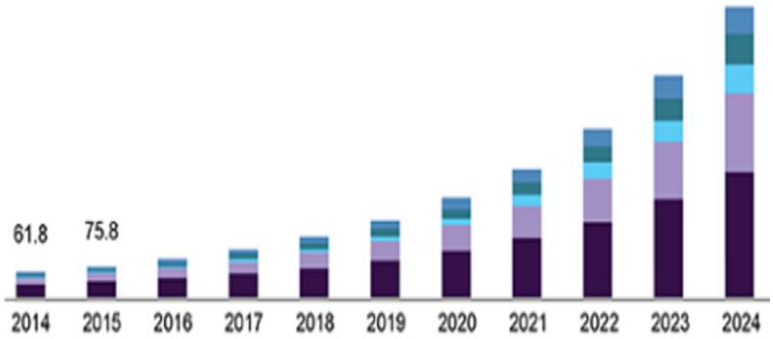

Figure 4: Asia Pacific AI in Agriculture Market ($Million)

Source: Grand View Research

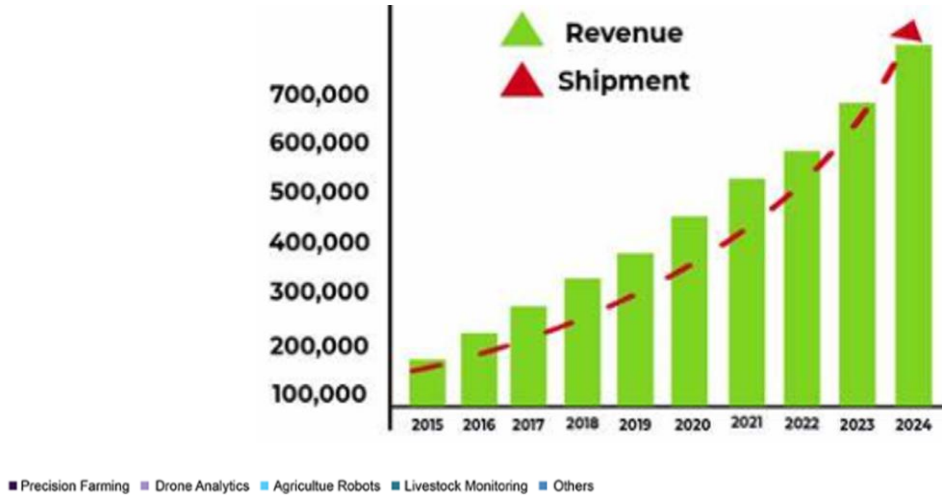

Figure 5: Impact of AI on Agricultural Sector ($Million)

Source: Grand View Research

3. AI and Agriculture Productivity

3.1. How AI Can Boost Agriculture in Nigeria

AI adoption in Nigeria agriculture sector could be a greatest instrumental that will boost agriculture output by helping organization cope with the complexity in modern agriculture practice. Moreover, in many countries of the world such as US, China, Netherland and Ukraine AI has proven to be a significant game changer in agriculture industry through many applications. For instance, AI can used Real-time monitoring of soil and crops allows for effective and robust supervision, enhancing overall agricultural management. Integrating advanced technologies can lead to efficient water use, conserving this valuable resource while maximizing crop yields (Nikolidakis et al., 2019). Furthermore, deploying robots and drones on farms can detect weeds, pests, and diseases, identify nutrient-deficient areas, monitor crop yield and quality, and perform various other applications. AI can continuously monitor climate conditions and provide localized, detailed data. This technology can significantly increase crop yields, improve workers' wellbeing, and enhance animal welfare.

3.2. Challenges on the Use of AI in Nigeria

In Nigeria, while the potential benefits of AI in agriculture are evident, there exist several challenges impeding its widespread adoption and effective implementation. One significant obstacle is the country's limited infrastructure, particularly in rural areas where much of the

agricultural activity takes place. Inadequate access to reliable electricity and internet connectivity hampers the deployment of AI-powered solutions, as these technologies often rely on real-time data and continuous connectivity for optimal performance. Without reliable infrastructure, farmers may struggle to fully leverage the benefits that AI offers in improving productivity and sustainability.

Moreover, a key challenge facing the use of AI in Nigeria's agriculture sector is the insufficient access to high-quality data. AI algorithms require large amounts of diverse and accurate data to train effectively and deliver meaningful insights. However, data collection and management systems in Nigeria are often fragmented and incomplete, limiting the availability of the data needed to develop robust AI solutions tailored to the country's specific agricultural challenges. Addressing this data gap is crucial for unlocking the full potential of AI in driving agricultural innovation and improving food security.

Additionally, the lack of skilled personnel proficient in both agricultural practices and AI technologies poses a significant challenge to the adoption of AI in Nigeria's agriculture sector. Building and maintaining AI-powered systems require specialized knowledge and expertise in data science, machine learning, and agricultural domain knowledge. However, there is a shortage of professionals with these interdisciplinary skills in the country, hindering the development and deployment of AI solutions tailored to the needs of Nigerian farmers.

Furthermore, concerns about the potential biases present in AI algorithms represent another challenge to the use of AI in Nigeria's agriculture. Biases in data collection, algorithm design, and decision-making processes can exacerbate existing inequalities and disadvantage marginalized communities, undermining the fairness and effectiveness of AI-powered solutions in agriculture. Addressing these biases requires careful attention to data quality, algorithm transparency, and ethical considerations throughout the AI development lifecycle.

Moreover, the affordability and accessibility of AI technologies remain significant barriers for many farmers in Nigeria. While AI has the potential to increase agricultural productivity and profitability, the upfront costs associated with implementing AI-powered solutions, such as purchasing hardware, software, and training personnel, can be prohibitive for small-holder farmers with limited financial resources. Additionally, ongoing maintenance and support expenses may further strain limited budgets, limiting the adoption of AI technologies among Nigerian farmers.

3.3. Framework for Adoption of AI for Agriculture in Nigeria

Establishing a framework for the adoption of AI in agriculture in Nigeria involves several key steps. First, it's essential to conduct a thorough assessment of the current agricultural landscape, including technological infrastructure, data availability, skill levels among stakeholders, and sector-specific challenges. Identifying priority areas where AI can make the most significant impact, such as crop production, livestock management, and supply chain optimization, helps focus efforts and resources effectively.

Investment in infrastructure development is crucial, including improving access to reliable electricity and internet connectivity, establishing data collection and management systems, and deploying necessary hardware and software infrastructure to support AI applications in agriculture. Additionally, mechanisms for collecting, storing, and sharing agricultural data must be developed, ensuring data privacy, security, and interoperability while leveraging IoT devices and sensors for real-time data collection.

Capacity building and training programs are vital to equip farmers, extension workers, researchers, and other stakeholders with the skills and knowledge needed to utilize AI technologies effectively. Collaboration with academic institutions, research organizations, and technology companies is essential for driving research and development efforts focused on adapting AI to local agricultural needs and challenges.

Regulatory frameworks and policies must be developed to govern the responsible and ethical use of AI in agriculture, addressing issues such as data privacy, algorithm transparency, and intellectual property rights. Public-private partnerships play a crucial role in driving innovation, investment, and knowledge sharing, leveraging resources, expertise, and networks to accelerate the adoption and scaling of AI technologies in the sector.

Implementing mechanisms for monitoring and evaluating the impact of AI adoption allows for continuous learning, adaptation, and improvement of the framework over time. Finally, successful pilot projects and initiatives should be scaled up for broader adoption across different regions and farming systems, with incentives and technical assistance provided to encourage widespread adoption and replication of AI-driven solutions in agriculture.

By following this structured approach to developing a framework for the adoption of AI in agriculture, Nigeria can harness the transformative potential of technology to improve

productivity, sustainability, and resilience in the sector, ultimately contributing to food security, economic development, and poverty reduction.

4. AI and the Future of Agriculture

AI holds immense promise for shaping the future of agriculture, offering innovative solutions to address key challenges faced by the sector. As global populations continue to grow, and climate change poses threats to food security, AI-powered technologies have the potential to revolutionize farming practices, increase productivity, and ensure sustainable food production. From precision farming and crop monitoring to predictive analytics and robotic automation, AI is poised to transform every aspect of agriculture, driving efficiency, resilience, and environmental stewardship.

One of the most significant ways AI is revolutionizing agriculture is through precision farming techniques. By integrating data from satellites, drones, sensors, and IoT devices, AI enables farmers to monitor crop health, soil conditions, and weather patterns with unprecedented accuracy. This data-driven approach allows for precise management of resources such as water, fertilizers, and pesticides, optimizing yields while minimizing environmental impact. Precision farming also facilitates site-specific management, enabling farmers to tailor cultivation practices to the unique needs of each field, ultimately enhancing productivity and profitability.

Predictive analytics powered by AI algorithms offer another powerful tool for farmers to make data-driven decisions. By analyzing vast amounts of historical and real-time data, AI can forecast crop yields, pest outbreaks, and market trends with remarkable accuracy. This predictive capability enables farmers to anticipate challenges and opportunities, optimize planting and harvesting schedules, and manage risks more effectively. By providing actionable insights in advance, AI empowers farmers to proactively address potential issues, improving efficiency and resilience in the face of uncertainty.

Robotic automation is another area where AI is transforming agriculture, revolutionizing labor-intensive tasks such as planting, weeding, and harvesting. AI-powered robots equipped with advanced sensors, computer vision, and machine learning algorithms can perform these tasks with precision and efficiency, reducing the need for manual labor and labor costs. Robotic automation also enables round-the-clock operations, allowing tasks to be performed at optimal times and under optimal conditions, further enhancing productivity and resource efficiency (Rao et al., 2018).

In addition to on-field applications, AI is driving innovation in supply chain management, market forecasting, and food traceability. By analyzing data from across the agricultural value chain, AI can optimize logistics, minimize food waste, and ensure the timely delivery of fresh produce to consumers. AI-powered market forecasting models can help farmers make informed decisions about pricing, marketing, and distribution, maximizing profitability and market competitiveness. Furthermore, AI-enabled traceability systems enhance food safety and quality assurance by tracking products from farm to fork, enabling swift identification and response to food safety incidents.

Overall, the future of agriculture is intricately linked with the continued advancement and adoption of AI technologies. By harnessing the power of AI for precision farming, predictive analytics, robotic automation, and supply chain optimization, farmers can overcome existing challenges, adapt to changing conditions, and unlock new opportunities for sustainable growth and development. As AI continues to evolve and mature, its transformative impact on agriculture is poised to revolutionize food production, improve livelihoods, and ensure a more resilient and sustainable future for generations to come.

5. Conclusions

The paper aims to examine the relationship between AI and agricultural developments. The study focused on overview of the current state of agriculture in Nigeria. As a nation keying into fast growing technology space, Nigeria stands to benefit immensely from the integration of AI technologies into its agricultural sector. We show the trend of agriculture practice, the key challenges such as climate change, environmental degradation, limited access to finance, pest and disease control outbreak and low productivity. We considered the benefits of AI to the agricultural sector as well as the global trend in the use of AI for agriculture development.

The paper further looked at the institutional framework necessary to facilitate the adoption and integration of AI technology into Nigeria agriculture by examining the previous studies in Nigeria and other countries, the paper illustrates the potential impact of AI on agricultural development, including increased yields, improved resource efficiency, and enhanced resilience to environmental stresses. Enhancing agricultural productivity through the adoption of new technologies is crucial for ensuring food security. Collaboration and support from various stakeholders are essential to supplement the efforts of federal and state governments in achieving this goal. We recommend that the government should prioritize AI for agricultural

development through supporting and financing AI research institutions, funding for pilot projects, testing new AI-driven tools, and adapting existing technologies to local contexts.

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