Readiness Of Agribusinesses To Adopt Internet Of Things (IoT) For Smart Farming Systems In Ebonyi State, Nigeria

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ABSTRACT:
This study investigates the adoption of Internet of Things (IoT) devices for smart farming systems among agribusinesses in Ebonyi State, Nigeria. Despite some awareness (38.3%), actual usage remains low (10%). Limited understanding, technological infrastructure challenges (poor connectivity), and cost constraints hinder adoption. However, early adopters (10%) exist, and agribusinesses are receptive to incentives. A positive correlation between education and willingness to adopt suggests the value of training programs. To promote broader adoption, we recommend (1) raising awareness and educating stakeholders, (2) addressing infrastructure challenges, (3) facilitating adoption through incentives and training, and (4) prioritizing relevant applications like water conservation solutions. By creating a more supportive environment, stakeholders can empower agribusinesses to leverage the potential of IoT for a more efficient, productive, and sustainable agricultural sector.

KEYWORDS: *Agribusinesses; Adoption; Internet of Things (IoT); smart farming systems; Ebonyi State; Nigeria*

INTRODUCTION

Agriculture remains the backbone of the Nigerian economy, employing a significant portion of the workforce and contributing substantially to the Gross Domestic Product (GDP) (Korgbeelo, 2022). However, the sector faces numerous challenges that hinder its productivity and growth. These challenges include fragmented landholdings, reliance on rain-fed agriculture, limited access to improved inputs and financing, and rudimentary post-harvest handling practices (Özkan&Fawole, 2021).

In recent years, a growing interest has been in leveraging digital technologies to transform the agricultural sector and address these challenges (FAO. 2022; Dayioglu&Turker, 2021; Shamin *et al.,* 2019). The Internet of Things (IoT) has emerged as a promising technology with the potential to revolutionize farming practices by enabling the collection and analysis of real-time data on various farm parameters such as soil moisture, temperature, and crop health (Kshetri, 2020; Jayaraman*et al.,* 2019).

IoT-based smart farming systems integrate sensors, actuators, and connectivity devices that collect and transmit data to a central platform for monitoring and analysis (Hassan, 2018). This data can then inform decision-making on various aspects of farm operations, such as irrigation scheduling, fertilizer application, and pest control (Setiaji*et al.,* 2021).

Adopting IoT technologies in agriculture can improve resource use efficiency, optimize crop yields, and enhance farm productivity (Ali et al., 2023; John *et al.,* 2021). Studies conducted in developed countries have shown that IoT-based smart farming systems can significantly improve water use efficiency, reduce fertilizer application, and increase crop yields (Tombe, 2020; Puranik*et al.,* 2019).

Ebonyi State, located in south-eastern Nigeria, is a major producer of rice, cassava, and yam (Nigerian Tribune, 2021). The state government has identified agriculture as a key driver of economic development. It has implemented various initiatives to promote agricultural modernization (Ebonyi State Government, 2023). However, smallholder farmers' adoption of new technologies in Ebonyi, as in many parts of Nigeria, remains limited due to factors such as lack of awareness, affordability concerns, and limited digital literacy skills (Eze&Obikeze, 2017; Ajani, 2012).

Despite the potential benefits of IoT for smart farming, agribusinesses' successful adoption of these technologies in Ebonyi State, Nigeria, is not guaranteed. There is a limited understanding of the state's current readiness to adopt IoT devices for smart farming systems.

This research aims to address this gap by investigating the following key questions:
What is the level of awareness among agribusinesses in Ebonyi State regarding IoT technologies and their potential applications in agriculture?
What are the perceived benefits and challenges of adopting IoT devices for smart farming systems?
What are the key factors influencing the readiness of agribusinesses in Ebonyi State to adopt IoT-based smart farming solutions?

By addressing these questions, this study will provide valuable insights into the current state of IoT adoption for smart farming in Ebonyi State. The findings will inform stakeholders, including policymakers, technology developers, and extension service providers, in designing targeted interventions and capacity-building programs to facilitate agribusinesses' successful adoption of IoT technologies in the state.

METHODOLOGY
The study was conducted in Ebonyi state, Nigeria, located in the country's south-eastern region. Ebonyi state was selected as the study area due to its significant agricultural activities and the relevance of understanding the adoption potentials of Internet of Things (IoT) devices for smart farming systems in the context of the state's agricultural sector.

Data collection for this study involved both primary and secondary source using a multistage sampling technique was employed to select participants for the survey and interviews. The procedures involved - **Stage 1:** Selection of Local Government Areas (LGAs): LGAs in Ebonyi state were stratified based on geographical location and agricultural productivity. Two LGAs (Abakaliki and Afikpo) representing different agro-ecological zones were randomly selected for inclusion in the study.
Stage 2: Selection of Communities: Within each selected LGA, communities with a high concentration of agribusinesses and agricultural activities were purposively chosen for data collection.
Stage 3, which is the selection of participants involves using a combination of convenience and systematic random sampling. Agribusiness owners, farmers, and stakeholders involved in agricultural activities within the selected communities were approached and invited to participate in the study. A total of sixty (60) participants were used for the study.

Analytically, the collected data were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were computed to summarize the demographic characteristics of the participants and their responses to survey questions related to IoT adoption, benefits, challenges, and factors influencing adoption decisions. And inferential statistics, such as Pearson's Correlation coefficient, were employed to examine variables' associations and assess the significance of relationships.

RESULTSAND DISCUSSIONS
Socio-Economic Characteristics of Respondents

Table1: **Socio-Economic Characteristics of Respondents**

Type of Agribusiness	Frequency	%
Crop Farming	15	25.0
Livestock Farming	12	20.0
Mix Farming	33	55.0
Total	**60**	**100.**
Experience		
1	3	5.0
2	16	26.7
3	10	16.7
4	4	6.7
5	9	15.0
6	4	6.7
7	8	13.3
8	3	5.0
9	3	5.0
Total	**60**	**100.0**
Education		
Primary	1	1.7
Secondary	33	55.0
Vocational Training	17	28.3
College/University	9	15.0
Total	**60**	**100.0**

Source: Field Survey, 2024

The result shows that most of the respondents (55.0%) were involved in mixed farming, indicating that many agribusinesses in Ebonyi State are involved in multiple farming activities. Crop farming accounted for 25.0% of the respondents, while livestock farming accounted for 20.0%. It further revealed that the respondents had varying levels of experience in agriculture, with an average of 4.38 years, indicating that, on average, the agribusiness owners/workers in Ebonyi State have gained a significant amount of practical knowledge and expertise in agricultural practices. This suggests that the study captured insights from individuals at different stages of their agricultural careers, ranging from newcomers to more seasoned farmers.

The respondents had different educational backgrounds. Most of the respondents (55.0%) had a secondary education, indicating that a significant proportion of agribusiness owners/workers in Ebonyi State have completed secondary school. Vocational training accounted for 28.3% of the respondents, suggesting that a considerable number of individuals have received specialized training related to agriculture. College/university education was reported by 15.0% of the respondents, indicating a smaller but notable proportion of respondents with higher education qualifications. Only a small percentage (1.7%) had primary education.

Awareness and Understanding of IoT Devices
Table 2: Awareness and Understanding of IoT Devices

Awareness	Frequency	%
Not Aware at All	2	3.3
Not Very Aware	16	26.7
Neutral	14	23.3
Somewhat Aware	23	38.3
Very Aware	5	8.3
Total	**60**	**100.0**

Source: Field Survey, 2024

Table 2 reveals a mixed level of awareness regarding Internet of Things (IoT) devices among agribusinesses in Ebonyi State, Nigeria. While a significant portion (38.3%) demonstrates some level of awareness ("Somewhat Aware"), a concerning number (26.7%) are "Not Very Aware" and a small group (3.3%) are entirely "Not Aware at All" This finding aligns with research conducted in other developing countries, where studies have shown limited awareness of IoT technologies among smallholder farmers (Mapiye*et al.,* 2021; Zulu et al., 2023).

Use of IoT Devices
Table 3: Use of IoT Devices

Ever-Used IoT Device	Frequency	%
No	54	90.0
Yes	6	10.0
Total	**60**	**100.0**

Source: Field Survey, 2024

The study reveals a limited adoption rate of Internet of Things (IoT) devices among agribusiness enterprises in Ebonyi State, Nigeria. Only 10% of respondents reported having ever used an IoT device. This finding aligns with the low awareness levels observed in Table 2 and suggests a significant gap between knowledge and application. The low usage rate of IoT devices reflects the challenges of translating awareness into action. This aligns with studies by Bayih*et al.* (2022) and Pillai and Sivathanu (2020), highlighting the various barriers smallholder farmers face in adopting new technologies face. While the current usage rate is low, the existence of some users (10%) indicates a potential for wider adoption with appropriate support mechanisms.

IoT Devices Used
Table 4: Use of IoT Devices

IoT Device Used	Frequency	%
None	54	90.0
automated feed system	3	5.0
smart irrigation system	3	5.0

Source: Field Survey, 2024

The result on IoT usage details the specific types of IoT devices currently used by agribusinesses in Ebonyi State, Nigeria. While the overall adoption rate remains low (10%), it reveals interesting insights into the limited applications explored. Only two types of IoT devices, automated feed systems, and smart irrigation systems, have been reported to be in use. This suggests a narrow understanding or prioritization of potential applications. Both reported devices (automated feed systems and smart irrigation systems) address resource management and efficiency, potentially reflecting concerns about resource scarcity or optimization efforts. While specific device usage details may vary, the limited variety observed aligns with research on precision agriculture in developing countries, where basic applications like irrigation management are often the initial focus (Saranya*et al.,*2023). More so, using smart irrigation systems resonates with studies highlighting water scarcity as a major challenge in Nigerian agriculture (Daniel &Tajudeen, 2023).

Technological Infrastructure and Readiness
Table 5: Technological Infrastructure and Readiness

Access to Reliable Internet Connectivity	Frequency	%
No	43	71.7
Yes	17	28.3
Total	**60**	**100.0**
Challenges in Implementing IoT Devices due to Limited Internet Connectivity		
No	50	83.3
Yes	10	16.7
Total	**60**	**100.0**
Tech Infrastructure for Agribusiness		
Poor	51	85.0
Below Average	4	6.7
Average	5	8.3
Total	**60**	**100.0**

Source: Field Survey, 2024

The results of ttechnological iinfrastructure and readiness paint a concerning picture regarding the technological infrastructure and readiness for adopting IoT devices among agribusinesses in Ebonyi State, Nigeria. From the result, a significant majority (71.7%) lack access to reliable internet connectivity (Table 5). This is a critical barrier to implementing IoT devices, as most rely on internet connections to transmit data. Also, over 16% of respondents acknowledge limited internet connectivity as a challenge for implementing

IoT devices, highlighting the real-world implications of this gap. The overall perception of the existing technological infrastructure for agribusinesses is concerning, with 85% rating it as poor or below average. This suggests a lack of essential hardware, software, and technical expertise to support advanced technologies like IoT. These findings resonate with challenges identified in other developing countries (Pathmud i*et al.,*2023; Villa-Henriksen *et al.,*2020).

Relationship between the level of education/training and willingness to adopt IoT Devices for Smart Farming Systems
Table 6 presents the result of the relationship between the level of education/training of agribusiness owners/workers and their willingness to adopt IoT devices for smart farming systems in Ebonyi state, Nigeria.

Table 6. Relationship between the level of Education/Training and their Willingness to Adopt IoT Devices for Smart Farming Systems

		Education	Willingness to Adopt IoT Devices
Education	Pearson Correlation	1	.548**
	Sig. (2-tailed)		.000
	N	60	60
Willingness to adopt IoT devices for smart farming systems	Pearson Correlation	.548**	1
	Sig. (2-tailed)	.000	
	N	60	60
**. Correlation is significant at the 0.01 level (2-tailed).			

Source: Field Survey, 2024

The result of the relationship between the level of education/training and their willingness to adopt IoT for smart farming systems(Table 6) reveals a statistically significant positive correlation (0.548) between the level of education/training and the willingness to adopt IoT devices for smart farming systems in Ebonyi State, Nigeria (p-value = 0.000). This indicates that agribusinesses with higher levels of education/training are more likely to be open to adopting these technologies. The positive correlation suggests that education/training equips agribusinesses with the knowledge and confidence to understand and utilize IoT technologies for agricultural purposes. This finding highlights the potential of educational programs and training workshops to address the knowledge gap identified earlier and encourage the adoption of IoT devices. This finding aligns with research on digital transformation in Nigerian agriculture, which emphasizes the importance of building capacity through training programs (Daniel &Tajudeen, 2023). It also resonates with studies on the challenges faced by smallholder farmers, where a lack of knowledge and skills was identified as a barrier to adopting new technologies (Ikoyo-Eweto, 2022).

Barriers and Enablers for the Widespread Adoption of IoT Devices for Smart Farming Systems in Ebonyi State

Table 7 presents the barriers and enablers to the widespread adoption of IoT devices for smart farming systems in Ebonyi state.

Table 7: Barriers to the Widespread Adoption of IoT Devices for Smart Farming Systems in Ebonyi State

Barriers	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)	Total	Mean Score	Remark
Cost of IoT Devices.	0	0	0	30 (120)	30 (150)	270	4.50	Significant
Internet connection.	0	0	0	30 (120)	30 (150)	270	4.50	Significant
Technical expertise and knowledge.	0	0	0	33 (132)	27 (135)	267	4.45	Significant
Data privacy and security.	0	3 (6)	31 (93)	21 (84)	5 (25)	208	3.47	Significant
Government support and incentives.	0	0	0	14 (56)	46 (230)	286	4.77	Significant
Limited awareness and understanding.	0	0	0	24 (96)	36 (180)	276	4.60	Significant
Grand Mean	**4.38**							

Source: Field Survey, 2024

The study reveals several significant barriers hindering the widespread adoption of IoT devices for smart farming systems in Ebonyi State, Nigeria. The findings are based on a survey where respondents rated their level of agreement with each barrier using a scale of 1 (strongly disagree) to 5 (strongly agree). All listed barriers except Data privacy and security received a mean score above 4, indicating a high level of agreement among respondents. This suggests that multiple factors are impeding IoT adoption. Government support and incentives, Limited awareness and understanding, the cost of IoT devices, internet connectivity, and technical expertise emerged as the top concerns, with mean scores ranging from 4.45 – to 4.77. These factors likely pose significant challenges for agribusinesses, particularly considering the limited technological infrastructure discussed in Table 5. While less prominent than the top three, data privacy and security concerns (mean score 3.47) also warrant attention. Addressing these concerns will be crucial for long-term adoption as agribusinesses become more comfortable with the technology. The high agreement on the importance of government support and incentives (mean score 4.77) highlights the potential role of government policies in promoting IoT adoption.

These findings align with research on barriers to adopting new agricultural technologies, particularly in developing countries. Studies highlight affordability, access to resources, and technical expertise as key challenges faced by smallholder farmers (Curry*et al.,* 2021; Pathmudi*et al.,*2023). The concerns about internet connectivity in Ebonyi State echo findings on digital transformation in Nigerian agriculture (Elijah *et al.,* 2021).

Incentives that would encourage more Agribusinesses to Adopt IoT Devices
Table 8: Incentives that would encourage more Agribusinesses to Adopt IoT Devices

Incentives	Frequency	%
None	21	35.0
Financial incentives	14	23.3
Government support	18	30.0
Inventory management	1	1.7
Reduced cost of the devices	1	1.7
Risk management	1	1.7
Traceability	1	1.7
Training and Education	1	1.7
Water conservation	2	3.3
Total	**60**	**100.0**

Source: Field Survey, 2024

The study results on the incentives that would encourage more agribusinesses to adopt IoT devices **(**Table 8) explore the incentives that agribusinesses in Ebonyi State, Nigeria, perceive as most encouraging for adopting IoT devices. While a significant portion (35%) indicated "None" of the listed options, the remaining responses reveal valuable insights. The lack of a clear majority response suggests that agribusinesses may require a combination of incentives or have varying priorities when considering IoT adoption. Financial incentives (23.3%) and government support (30.0%) emerged as the most preferred options. This aligns with research on technology adoption in developing countries, highlighting the importance of economic considerations and government intervention (Özkan & Fawole, 2021; Kshetri, 2020). These findings resonate with studies emphasizing the role of economic factors and government initiatives in promoting technology adoption (AbuBakar*et al.,* 2020). The desire for government support in Ebonyi State reflects similar trends observed in these studies (Elijah *et al.,* 2021; Daniel &Tajudeen, 2023).

While financial incentives and government support are crucial, the result also reveals interest in Training and Education (1.7%). This aligns with findings from Table 6, highlighting the perceived value of knowledge and skills development for successful IoT adoption. Water Conservation (3.3%): Considering the challenges with access to reliable internet connectivity (Table 5), exploring low-power, water-focused IoT solutions might be beneficial.

CONCLUSION AND RECOMMENDATIONS
This research reveals a mixed picture regarding adopting Internet of Things (IoT) devices for smart farming systems among Ebonyi State, Nigeria agribusinesses. While a significant portion (38.3%) demonstrates some level of awareness (Table 2), the actual usage rate remains low (10% - Table 3). The limited adoption can be attributed to several key factors:
    i   Limited Awareness and Understanding: Many agribusinesses lack a clear understanding of IoT technologies' potential benefits and applications in agriculture (Tables 2 & 6).
    ii   Technological Infrastructure Challenges: Poor internet connectivity and inadequate technological infrastructure create significant hurdles for implementing IoT devices (Tables 5 & 7).
    iii   Cost and Resource Constraints: The cost of IoT devices and the need for technical expertise pose challenges, particularly for smaller agribusinesses (Tables 7 & 8).

However, the research also identifies promising aspects:
    i   Early adopters exist (10%), and their experiences can provide valuable insights for broader adoption (Tables 3 & 4).
    ii   Agribusinesses are receptive to incentives, particularly financial aid and government support (Table 8).
    iii   There is a positive correlation between education and willingness to adopt (Table 6), suggesting the value of training programs.

Based on these findings, the following recommendations were made to promote the adoption of IoT devices in Ebonyi State:

1. Raise Awareness and Educate Stakeholders:
   - Develop targeted educational campaigns and training programs tailored to different levels of existing awareness.
   - Showcase successful case studies and highlight the potential benefits of IoT for improved agricultural productivity, resource management, and decision-making.
   - Collaborate with agricultural extension services and universities to create a comprehensive training infrastructure.

2. Address Infrastructure Challenges:
   - Invest in expanding reliable internet connectivity, particularly in rural areas.
   - Explore alternative data transmission technologies like Low Power Wide Area Networks (LPWANs) for areas with limited internet access.
   - Partner with public and private stakeholders to develop the necessary technological infrastructure for supporting IoT adoption.

3. Facilitate Adoption:
   - Explore financial incentives such as subsidies, tax breaks, or cost-sharing models to make IoT devices more accessible for agribusinesses.
   - Develop government policies that incentivize IoT adoption, such as grants or tax breaks.
   - Offer training programs that equip agribusinesses with the technical knowledge and skills to install, operate, and maintain IoT devices.

4. Prioritize Initial Applications:
   - Considering the focus on resource management among early adopters (automated feed systems and smart irrigation), other relevant applications like soil monitoring and crop health tracking should be promoted.
   - Explore low-power IoT solutions specifically designed for water conservation efforts, addressing a key regional concern.

By implementing these recommendations, stakeholders can create a more supportive environment for adopting IoT technologies in Ebonyi State. This will empower agribusinesses to leverage the potential of smart farming systems for increased efficiency, productivity, and sustainability in the agricultural sector.

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