TITLE

REVOLUTIONIZING AGRITECH: INTEGRATING AUTOMATED MACHINERY FOR SUSTAINABLE FARMING PRACTICES

A Study of Mechanized Farming Adoption in Nigeria

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Keywords: Sustainable mechanized farming, Human-systems interaction (HSI), Technology adoption, Profitability, and Rural development.

This research opens doors for further collaboration with researchers and stakeholders invested in advancing the potential of mechanized farming in Nigeria.

ABSTRACT

This research investigates the potential of integrating automated machinery into Nigerian farming practices while prioritizing sustainable methods. Employing a human-centered design (HSD) approach in collaboration with Goldvest Nigeria Limited, the study bridged the gap between traditional farming and this innovative technology. Data collection spanned agricultural seasons across 2019, 2020, and 2021. A meticulously designed experimental-comparison study involving 30 farms evaluated the impact of introducing automated machinery. Key findings revealed cultural nuances, security concerns, and ongoing maintenance costs as significant hurdles to widespread adoption of this technology. Conversely, the traditional, non-mechanized approach to farming presented its own set of challenges, including labor scarcity, safety risks, and limited profitability. The study revealed a remarkable 32% average increase in net profits in 2021 for farms utilizing machinery, demonstrating its clear economic advantage. Additionally, farmers actively participated in shaping desired tractor design features, showcasing their receptiveness and adaptability to embracing new technologies. While initial apprehension was observed, the research revealed a positive shift in perception, particularly among younger generations, suggesting potential for long-term acceptance. This research underscores the critical role of HSI frameworks in fostering seamless integration of technology within rural Nigerian communities. By providing quantified data such as the observed profit increase, the study equips policymakers and manufacturers with valuable insights to inform strategic decision-making regarding purchasing models, machinery design, and educational initiatives aimed at promoting technology adoption. Ultimately, these findings pave the way for promoting sustainable and economically thriving agricultural practices in Nigeria, empowering farmers to embrace the transformative potential of agricultural technology.

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Chapter 1

INTRODUCTION

The Nigerian agricultural landscape stands poised for a transformative shift as automated machinery enters the field, promising a future brimming with increased efficiency, improved sustainability, and potential economic empowerment for rural communities. This trend mirrors a global rise in agricultural automation, driven by the urgent need to tackle food security challenges and enhance resource management (Mrema et al., 2014). However, successfully integrating these technological advancements requires a nuanced understanding of the human element - the farmers themselves. Their perspectives, concerns, and experiences are critical factors in ensuring seamless adoption and maximizing the benefits of this technological wave.

This research, completed in 2023 in close collaboration with Goldvest Nigeria Limited (Goldvest Nigeria Limited), delves into the specific case of Nigeria by exploring the impact of automated machinery on traditional farming practices. Employing a human-systems interaction (HSI) approach, the study acknowledges the critical role that human factors play in both embracing and successfully utilizing new technologies (Boy & Narkevicius, 2014). Building on this foundation, the research probes the perceptions, challenges, and opportunities associated with integrating automated machinery into the lives and practices of rural Nigerian farmers.

While the potential benefits of mechanized farming for boosting production, alleviating poverty, and empowering rural communities in developing economies are widely recognized (Alene & Coulibaly, 2009; Berhe, 2016), research often overlooks the nuanced experiences of farmers transitioning to this technology (Doss, 2001; Higgins et al., 2017). This study aims to bridge this gap by quantifying the impact of mechanized farming on various aspects of their lives, including labor requirements, profitability, and overall well-being. This provides

valuable insights into the real-world implications and challenges associated with technology adoption within the Nigerian agricultural context.

This research, guided by the principles of systems engineering, seeks to achieve two primary objectives:

- ***Unveiling seamless integration opportunities:*** This involves not only understanding the current state of technology adoption by Nigerian farmers but also identifying how automation can complement existing practices and expertise (Keil et al., 2016). This knowledge will be instrumental in enabling a smooth and sustainable transition for farmers, ensuring they reap the full potential of this technological shift.
- ***Developing strategies for long-term and sustainable use of machinery:*** By analyzing the findings through an HSI lens, the research aims to develop recommendations that address the specific challenges and needs of Nigerian farmers. This will ultimately foster a sustainable shift towards mechanized agriculture, ensuring long-term benefits for both farmers and the agricultural sector as a whole (Mottaleb et al., 2016).

The research findings presented in this paper are structured around three key themes:

- ***Evaluation of Traditional Farming Practices:*** This section explores the prevailing farming methods employed by traditional Nigerian farmers, identifying the factors that shape their decision-making processes (Doss, 2001). This understanding serves as a foundation for designing sustainable solutions that resonate with their existing practices and address their specific needs.
- ***Impact of Mechanized Farming:*** This section delves into the consequences of introducing automated machinery into the lives of Nigerian farmers. It analyzes their initial perceptions and attitudes towards the technology, identifies barriers obstructing adoption (Kasirye, 2013), and assesses the transformative impact on their livelihoods, including labor demands, profitability, and safety (Friedrich, 2013). Furthermore, it

evaluates the impact on crop production, providing evidence of the potential benefits of mechanized farming in the Nigerian context.

- ***Requirements of Automated Farming Machinery:*** This section focuses on understanding the specific needs and preferences of Nigerian farmers regarding automated machinery (Gregg et al., 2020). It analyzes the desired features and functionalities (Bechar & Vigneault, 2016), assesses financial considerations and their willingness to invest (Mottaleb et al., 2017), and ultimately proposes optimal automated machinery solutions tailored to the unique context of Nigerian agriculture.

This research aims to bridge the gap between technological advancements and the human element within the agricultural sector. By analyzing the findings through an HSI lens, it sheds light on the intricate dynamics surrounding technology adoption in rural Nigeria. This knowledge can inform the development of adaptive solutions that address the needs of farmers, fostering enduring and sustainable technology use within the Nigerian agricultural landscape, ultimately contributing to a more efficient, profitable, and sustainable agricultural sector for the nation.

Chapter 2

LITERATURE REVIEW

This chapter delves into the existing body of knowledge surrounding the adoption of agricultural machinery, specifically focusing on traditional farming across various traditions. This includes crops such as maize, cassava, guinea corn, yam soybeans, and rice, as well as the use of animals, and the incorporation of machinery in farming processes in developing economies. While previous studies have emphasized the critical role of agriculture in enhancing food security and rural livelihoods in these contexts (e.g., Mrema et al., 2014), the relationship between humans and machinery within the agricultural sector in Nigeria remains underexplored. More importantly, strategies to enhance trust and acceptance between humans and machinery have received limited attention. This chapter aims to address this gap by focusing on the crucial role of Human-Systems Interaction (HSI) in facilitating the successful adoption of agricultural technology by traditional farmers in developing economies, with a specific focus on Nigeria.

2.1 Human-Systems Interaction Overview

The successful adoption of agricultural machinery in developing economies requires a nuanced approach that goes beyond simply introducing new technology. This section delves into the critical role of Human-Systems Interaction (HSI) in bridging the gap between humans and machines within the agricultural sector.

HSI is an interdisciplinary field that focuses on understanding the interaction between humans and technology within a system (Ahram et al., 2009). It emphasizes the importance of integrating human considerations throughout the design, development, and implementation of any system, ensuring compatibility and seamless interaction between humans and technology. This human-centered approach is fundamental to successful system engineering

and plays a vital role in the adoption and effective utilization of agricultural technology (Boy & Narkevicius, 2014).

However, previous studies on farming technology adoption in developing economies often lack a strong HSI perspective. The focus has primarily been on the technical feasibility and potential benefits of the technology, overlooking the human element (Bechar & Vigneault, 2016; Charlton et al., 2019).

This approach has several shortcomings:

- **Neglecting user needs and preferences:** Failing to consider factors such as education level, digital literacy, cultural context, and local practices can lead to technologies that are unsuitable for the intended users.
- **Ignoring cultural influences:** Ignoring existing cultural beliefs and practices can create resistance to adoption and hinder the successful integration of technology.
- **Overlooking implementation challenges:** Focusing solely on the potential benefits overlooks the practical challenges faced by farmers during implementation, such as lack of training, limited technical skills, and financial constraints.
- **Neglecting Socioeconomic Dynamics:** A lack of consideration for socioeconomic factors, such as income disparities and resource availability, can result in technologies that exacerbate existing inequalities and hinder widespread acceptance.
- **Underestimating Environmental Impact:** Overlooking the environmental repercussions of technology implementation can lead to unintended ecological consequences, affecting not only the farming community but the broader ecosystem.
- **Minimizing Stakeholder Involvement:** Inadequate engagement with local communities, farmers, and other stakeholders may result in a disconnect between technological solutions and the diverse needs and realities on the ground.

- **Overemphasizing Short-Term Gains:** A nearsighted focus on immediate benefits may disregard the long-term sustainability of technological interventions, potentially leading to unforeseen challenges and diminishing the overall impact.

Through adoption an HSI perspective, we can address these shortcomings and ensure that agricultural technology is designed, implemented, and utilized in a way that supports and empowers traditional farmers in developing economies. This requires a shift in focus, emphasizing understanding user needs, addressing cultural context, and providing adequate support mechanisms to facilitate the seamless integration of technology into existing farming practices.

2.2 Importance of Agricultural Technology

Traditionally, farming practices have sustained communities for centuries. However, the adoption of agricultural technology presents substantial potential for positive transformations in the agricultural sector of developing economies, including Nigeria (Yusuf & Malomo, 2007). This section explores the significance of agricultural technology and its documented benefits in these regions.

While farming machinery has a long history (Wilkins, 2008), research highlights knowledge gaps regarding the factors influencing its adoption by traditional farmers (Yusuf & Malomo, 2007). Addressing these gaps is essential, as studies have shown that mechanized farming plays a critical role in poverty reduction within developing economies (Sugiardi, 2021). By targeting resource-constrained farmers, this technology can contribute to pro-poor growth and enhance livelihoods.

Research suggests that agricultural technology offers a range of significant benefits for various aspects of farming:

- **Improved soil cultivation and water management:** Technology can enhance efficiency in preparing land for planting and utilizing water resources (Sugiardi, 2021).

- **Increased crop yields:** By optimizing various farming processes, technology can contribute to significantly higher crop yields (Martin-Clouaire & Duru, 2013).
- **Reduced post-harvest losses:** Leveraging advancements in technology, improved storage and transport systems can significantly reduce post-harvest losses.
- **Enhanced resource efficiency:** Technology can contribute to the sustainable utilization of resources like water, fertilizer, and energy (Sugiardi, 2021).
- **Streamlined processes:** From pre-planting stages to final distribution, technology can streamline various farming activities, leading to increased efficiency and productivity (Martin-Clouaire & Duru, 2013).

As highlighted in the literature (Martin-Clouaire & Duru, 2013; Sugiardi, 2021), the impact of agricultural technology extends across the entire agricultural value chain. This underscores its potential for improving food security and rural livelihoods in developing economies. Addressing the factors influencing technology adoption remains a crucial area of focus for future research.

2.3 Benefits of Agricultural Technology

The adoption of agricultural technology in developing economies offers a range of potential benefits at both individual and societal levels. This section explores these benefits, focusing on their impact on poverty reduction, economic growth, food security, and farmer well-being.

- **Individual-level benefits:** Improved livelihoods and reduced poverty: Studies indicate that agricultural technology can enhance agricultural production, leading to increased income and reduced poverty for traditional farmers (Alene & Coulibaly, 2009; Muzari et al., 2012).
- **Enhanced food security and nutrition:** Technology can contribute to improved food security and nutrition by increasing food production and reducing post-harvest losses (Kasirye, 2013). Increased efficiency and reduced drudgery: Farming machinery can

significantly improve efficiency and reduce labor drudgery, making agriculture a more attractive profession, especially for younger generations (Kienzle et al., 2013a; Gartaula et al., 2012).

- **Societal-level benefits:** Economic growth and transformation: The adoption of agricultural technology can contribute to sustained agricultural growth and economic transformation in developing economies (Sheahan & Barrett, 2017). By stimulating pro-poor growth, it can benefit low-income individuals and communities (Pamuk et al., 2014).
- **Improved resource efficiency and reduced costs:** Technology can lead to more efficient use of resources such as water, labor, and time, ultimately reducing costs (Gonzales, 1993; Biggs et al., 2011).
- **Climate resilience:** Certain technologies can enhance farmers' resilience to climate change and extreme weather events.

Economic viability and environmental sustainability:

It is crucial to acknowledge that the balanced utilization of agricultural technology is essential for long-term economic viability and environmental sustainability. While technology can increase productivity and income for farming families (Yadav et al., 2013), it is necessary to implement practices that minimize negative environmental impacts.

Further research:

While the potential benefits of agricultural technology are substantial, it is important to note that further research is needed to understand the specific context-dependent factors that influence successful adoption and to ensure that these benefits are realized in a sustainable and equitable manner.

2.4 Factors Influencing Adoption of Agricultural Technology

Previous research has identified several crucial factors influencing the adoption of agricultural technology by traditional farmers in developing economies. Drawing on the work

of Tey & Brindal (2012), this section categorizes these factors and emphasizes their importance in understanding the adoption process.

Table 1: summarizes the key factors influencing technology adoption, classified into three categories:

Table 1: Factors Influencing Adoption of Agricultural Technology

Categories	Factors
Individual farmer considerations	Age, education, risk attitude, innovativeness, and access to resources (e.g., credit, information)
Farm characteristics	Farm size, income, location, and existing infrastructure
Technology attributes	Compatibility with existing practices, complexity of use, observability (ability to see others using it), and trialability (opportunity to experiment before full adoption)

Understanding these interconnected factors is crucial for designing effective strategies to promote the successful adoption and integration of agricultural technology into traditional farming practices. By addressing the specific needs and limitations faced by farmers in various contexts, these strategies can ensure that technology supports rather than hinders their agricultural endeavors.

2.5 HSI Considerations in Designing Agricultural Technology for Developing Economies

Human-Systems Interaction (HSI) principles play a vital role in designing and implementing agricultural technology that is effective and sustainable for developing economies. Similar to consumer products, agricultural technology needs to address the specific needs and capabilities of its users, the farmers, to achieve successful adoption and utilization.

In developing economies, meeting the diverse needs of farmers is often complicated by competitive pressures within the agricultural sector, making it challenging to understand and fulfill their specific requirements. This complexity is further compounded by additional challenges faced by farmers in these regions, such as labor shortages and the need to revitalize rural economies.

Therefore, it is crucial for manufacturers of agricultural technology to actively engage with farmers in developing economies to:

- Grasp the specific needs and constraints faced by farmers within their local context.
- Integrate these user requirements into the design and development process to ensure compatibility with existing practices and operational capabilities.

While recent efforts in farm mechanization have focused on improving technical aspects such as engine power, capacity, and cost-efficiency, a more holistic approach is necessary. Overemphasis on technical specifications, without considering the human element and the needs of small-scale farmers in developing economies, can exacerbate existing challenges.

By incorporating HSI principles, manufacturers can design technology that is user-centered, culturally appropriate, and readily integrable into existing farming practices. This, in turn, can lead to increased adoption rates, improved efficiency, and sustainable agricultural development in these regions.

2.6 Strategies to Facilitate the Adoption of Agricultural Technology with a Focus on HSI

Promoting successful adoption of agricultural technology in developing economies requires a nuanced approach that goes beyond simply introducing new technologies. This section outlines key strategies that incorporate Human-Systems Interaction (HSI) principles to ensure user-centered and sustainable technology integration.

1. **User-Centered Design:** Employing user-centered design methodologies is fundamental. This involves actively engaging farmers throughout the design process, from identifying needs and challenges to testing and iterating prototypes. This ensures the technology aligns with their cultural context, operational capabilities, and resource constraints.
2. **Training and Capacity Building:** Providing comprehensive training programs is crucial. This equips farmers with the knowledge and skills necessary to operate, maintain, and troubleshoot the technology effectively. Training should be culturally appropriate,

delivered in both English and local languages, and consider the varying literacy levels of farmers.

3. **Accessibility and Affordability:** Addressing affordability and accessibility concerns is essential for widespread adoption. This can involve exploring options like subsidies, microloans, and leasing arrangements to make technology financially accessible. Additionally, considering local manufacturing and maintenance capabilities can enhance accessibility and sustainability.
4. **Building Trust and Addressing Concerns:** Actively engaging with communities, addressing potential concerns, and fostering trust in the technology are crucial. This includes transparent communication about potential risks and benefits and ensuring cultural sensitivity throughout the adoption process.
5. **Long-term Support and Maintenance:** Providing ongoing support and maintenance services is essential for sustained technology utilization. This can involve establishing local repair and service networks, offering technical assistance hotlines, and ensuring the availability of spare parts.

Implementing these HSI-focused strategies, we can promote equitable and sustainable adoption of agricultural technology to combat the disenfranchisement plaguing my native Nigeria and other emerging economies. This can empower farmers, improve agricultural productivity and efficiency, and ultimately contribute to enhanced food security and rural livelihoods.

2.7 Considerations for Selecting Appropriate Technology

Selecting appropriate agricultural technology for developing economies requires careful consideration of factors beyond mere functionality. While various common farming

machinery types exist, generalized solutions might not be suitable due to the unique socio-economic and environmental contexts of these regions.

Key aspects to consider when selecting technology for adoption in developing economies:

- **Complexity and user-friendliness:** Technology should be simple to operate and maintain, taking into account potential limitations in literacy, technical skills, and access to repair facilities.
- **Affordability and accessibility:** The technology should be financially accessible to small-scale farmers, potentially through subsidies, microloans, or leasing arrangements. Additionally, considering local manufacturing and maintenance capabilities can enhance sustainability.
- **Compatibility with existing practices:** The technology should be compatible with existing farming practices and cultural norms to minimize disruption and encourage adoption. This might involve adapting existing machinery or introducing technologies that complement traditional methods in Nigeria.
- **Sustainability and environmental impact:** The technology's environmental impact should be carefully evaluated, with a focus on minimizing resource consumption and pollution. This aligns with the need for sustainable development in these regions (Yadav et al., 2013).

Through carefully considering these factors, we can ensure that the adoption of agricultural technology in developing economies contributes to improved livelihoods, increased efficiency, and sustainable agricultural development.

2.8 Traditional Farming Practices and Challenges

Developing economies often rely on traditional farming practices, employing simple tools and equipment for various tasks like planting, fertilizing, and harvesting (Hassan, 2015).

These traditional methods, while culturally ingrained and requiring minimal maintenance, are often labor-intensive and less efficient compared to modern technologies.

Transitioning from traditional practices to modern technology presents several challenges in developing economies. These challenges might include:

- **Limited access to resources:** Affordability and financing options might limit access to advanced technologies for small-scale farmers.
- **Skill development:** Shifting to new technologies might require training and skill development for farmers accustomed to traditional methods.
- **Cultural considerations:** Integrating new technologies should be done sensitively and consider the cultural context of traditional practices.

Understanding these challenges and developing appropriate strategies, we can facilitate a smoother transition towards sustainable and efficient agricultural practices in developing economies.

Chapter 3

METHODOLOGY

This section outlines the methods utilized in the study focusing on the integration of automated machinery for sustainable farming practices.

3.1 Ethical Considerations

- The research followed ethical guidelines to ensure participant well-being and informed consent.
- Participants were briefed about the study's purpose, procedures, and their right to withdraw.
- Measures were taken to protect participant privacy.

3.2 Participant Selection and Farming Equipment

3.2.1 Participant Selection

The study focused on 30 farms located within the North Central region of Nigeria. The selection criteria ensured that the participating farms shared several key characteristics and perspective:

- **Traditional Farming Practices:** Farms employed traditional farming methods as their primary means of cultivation/farming. This ensured a common baseline for comparing the impact of automated machinery introduced to the experimental group.
- **Farm Size:** Farms encompassed a variety of sizes to capture the diverse landscape of agricultural operations within the region. Specific size ranges or details are withheld to maintain anonymity.

- **Crop Types:** Farms cultivated a range of crops commonly grown in the North Central region. Specific crop information is excluded to avoid indirectly identifying individual participants.

3.2.2 Sample Selection Method

To ensure representativeness and unbiased selection, farms were chosen through a random sampling technique. This technique involved assigning each eligible farm within the defined sampling frame (North Central region, farms practicing traditional methods) a unique identifier. Subsequently, a random selection process was implemented, utilizing software or a random number generator, to choose the 30 participating farms.

3.2.3 Farming Equipment (Experimental Group Only)

Goldvest Nigeria Limited provided the following automated farming machinery to the experimental group for the 2019, 2020 and 2021 farming seasons, at no cost to the participating farms:

- Tractor
- Cultivator
- Planter
- Harvester

Each region had a shared set of machinery conveniently located within the same village to facilitate efficient utilization. Additionally, the experimental group received comprehensive training, fuel, and equipment support throughout the study period. This ensured proper use and maintenance of the machinery.

3.3 Data Collection Methods

This section details the methods used to gather data from the participating farms.

3.2.1 Interviews

a) Participants: All 30 farmers, from both the experimental and comparison groups, were interviewed.

b) Language: Interviews were conducted in English. For participants who spoke Hausa, Fulani, Tiv, Igala, or other local languages, a qualified translator fluent in both English and the respective language was present to facilitate communication. The translator ensured accurate and culturally sensitive relaying of questions and responses.

c) Interview Schedule: The table below outlines the structure of the interviews for both groups across the study period.

This table outlines the interview structure for the research study

Table 2. Structure of Interviews for Experimental and Comparison Groups in the Nigerian Farming Study

Activity	Experimental Group	Comparison Group	Time Period	Data Collected
Baseline	Conducted	Conducted	January 2020 (2019 Season)	• Farming practices employed (traditional methods) • Farm size and layout • Types of crops cultivated • Expected impact of automated machinery (experimental group only) • Perceptions and expectations regarding automated machinery (experimental group only)
Land Preparation	Conducted	Conducted	March/April 2020 (2020 Season)	• Costs associated with land preparation (labor, fuel, etc.) • Experience using provided machinery (experimental group only)
Planting (rice & Maize) / Weeding & Sowing (Cassava)	Conducted	Conducted	May/June 2020 (2020 Season)	• Costs associated with planting/weeding activities (seeds, fertilizer, labor, etc.) • Experience using provided machinery (experimental group only)
Weeding (Maize &	Conducted	Conducted	July/August 2020 (2020	• Costs associated with weeding activities (labor,

Rice) / Weeding & Mounding (Cassava)			Season)	herbicides, etc.) • Experience using provided machinery (experimental group only)
Harvesting (First Maize Harvest)	Conducted	Conducted	August 2020 (2020 Season)	• Costs associated with harvesting activities (labor, transportation, etc.) • Revenue generated from first maize harvest
Harvesting (second Rice Harvest)	Conducted	Conducted	October 2020 (2020 Season)	• Costs associated with harvesting activities (labor, transportation, etc.) • Revenue generated from first maize harvest
Before Second Planting	Conducted	N/A	March 2021 (2021 Season)	• Expectations and concerns regarding second planting season • Costs associated with preparing land for second planting
Planting (Second Soybeans, Guinea Corn & Yam)	Conducted	N/A	May 2021 (2021 Season)	• Costs associated with planting activities (seeds, fertilizer, labor, etc.) • Experience using provided machinery (experimental group only)
Second Weeding & Top Dressing (Soybeans, Guinea Corn & Yam) / Weeding & Mounding (Cassava)	Conducted	Conducted	July 2021 (2021 Season)	• Costs associated with weeding and top dressing activities (labor, fertilizer, etc.) • Experience using provided machinery (experimental group only)
Final Harvesting (Soybeans, Guinea Corn, Yam & Cassava)	Conducted	Conducted	November 2021 (2021 Season)	• Costs associated with harvesting activities (labor, transportation, etc.) • Revenue generated from final harvest (maize & cassava)
End of Study	Conducted	N/A	December 2021 (2021	• Perceived impact of automated machinery on

			Season)	farming practices and efficiency (experimental group only) • Suggestions for improvement in machinery design or training (experimental group only)

3.4 Data Cleaning and Analysis Approaches

The research outcomes, presented in Chapters 4, 5, and 6, each employ a slightly different analytical approach tailored to their specific research objectives. These individual approaches are detailed within their respective chapters.

However, some commonalities exist in the data analysis methods used throughout the study:

Data Cleaning:

- Interviews, originally conducted in local languages (Hausa, Fulani, Tiv, Igala, etc.), were translated into English by a team member fluent in both the respective local language and English, ensuring accurate conversion and data integrity. This process ensured consistent communication and data comprehension across participants and researchers.
- Data cleaning and analysis were primarily conducted using R Studio, a statistical software environment. Excel was utilized for initial data organization and visualization tasks.

Statistical Analysis:

- Statistical significance was evaluated at a level of $\alpha = 0.05$.
- The analyses employed a variety of techniques, including:
  - **Hypothesis testing:** t-tests and Mann-Whitney U-tests were used to compare group means for quantitative data.
  - **Non-parametric testing:** Chi-square tests were used to analyze categorical data.
  - **Analysis of variance (ANOVA):** This method was used to compare group means across multiple categories, with post-hoc tests (Tukey's HSD) employed for further comparisons.

Qualitative Analysis:

- Content analysis was used to analyze the interview data, identifying recurring themes and patterns.

Cost Modeling:

- While not employed in this specific study, cost modeling techniques could be used in future research to analyze the economic impact of interventions like automated machinery on farm operations.

Chapter 4

FARMERS' PERCEPTIONS OF ADOPTING AUTOMATED MACHINERY

4.1 Overview

The integration of automated farming machinery has emerged as a potential driver of agricultural transformation in various regions. However, understanding the perceptions and experiences of farmers regarding the adoption of this novel technology is crucial for its successful implementation and long-term sustainability. This chapter delves into the qualitative insights gleaned from interviews conducted with farmers in the experimental group during the 2019, 2020, and 2021 farming seasons. It aims to provide a comprehensive understanding of farmers' initial perceptions of and concerns about adopting automated machinery, alongside the perceived benefits, challenges, and adaptations encountered throughout the mechanized farming process. Additionally, the chapter explores the evolution of these perceptions throughout the study period, culminating in an analysis of farmers' overall impressions of the implemented machinery at the study's conclusion.

4.2 Methods

4.2.1 Sample and Setting

This chapter focuses on the qualitative analysis of data obtained from the 15 farmers who participated in the experimental group of the study. These farmers were located within the North Central region of Nigeria and primarily employed traditional farming practices prior to the intervention. The selection process for the entire study, involving 30 farms (15 experimental, 15 comparison), ensured that participating farms shared key characteristics, including farm size and crop types, to enhance internal validity and facilitate comparisons.

This chapter specifically explores the experiences and perceptions of the experimental group related to the introduction and use of automated machinery.

4.2.2 Data Collection

Semi-structured interviews were conducted with all 15 farmers in the experimental group throughout the study period. This approach allowed for in-depth exploration of their perceptions and experiences with automated machinery. Interviews were conducted in English, with qualified translators present for participants who spoke other local languages. This ensured accurate and culturally sensitive communication, minimizing any potential misunderstandings during the data collection process.

The interview schedule, outlined in Table 2 of Chapter 3, served as a guide to ensure consistency while allowing flexibility to explore emerging themes and individual experiences. By capturing farmers' perspectives at various stages of the agricultural cycle, this approach enabled a comprehensive examination of their evolving perceptions regarding automated machinery adoption.

4.2.3 Data Analysis

As the interview questions were open-ended, generating qualitative data, content analysis was employed as the primary method for data analysis. This approach involves a systematic process of:

1. **Coding:** Transcripts are read and assigned codes based on recurring themes, keywords, or concepts.
2. **Categorization:** Codes are grouped into broader categories based on similarities and relationships.
3. **Analysis:** The identified categories and their relationships are analyzed to understand the underlying meanings, patterns, and insights related to farmers' perceptions and experiences with automated machinery.

This detailed explanation clarifies the specific steps involved in the content analysis process, adding value to the description of the methodology.

4.2.4 Ethical Considerations

Ethical considerations are paramount in any research involving human subjects. This study adhered to the following principles:

- Informed consent: All participants provided written informed consent before participating in the interviews. This ensured they understood the nature and purpose of the study, potential risks and benefits, and their right to withdraw at any point.
- Anonymity and confidentiality: The identities of all participants were anonymized. Interview data was stored securely, and any publications or presentations based on the findings omitted any information that could identify individual participants.
- Right to withdraw: Participants were informed of their right to withdraw from the study at any point, without any penalty or repercussions.

By adhering to these ethical principles, the study ensured the protection of participants' rights and well-being.

4.3 Experimental Group Demographics

Table 3 summarizes the key characteristics of the 15 farmers participating in the experimental group. The farmers were primarily male with an average age of 52 years (SD 4.3 years) and led families with an average of seven members (SD 1.3 people). The farms, categorized as small to medium household farms, ranged in size from 35 to 40 acres. All farmers relied on hiring additional laborers for planting and harvesting due to the limited size of their families. The table also showcases the location and diversity of crop types cultivated by each farmer, reflecting variations based on regional factors such as weather, water resources, and local traditions.

3. Farm Characteristics for Experimental Group in Nigerian Agriculture

Farmer ID	Age	Family Size	Land Size (acres)	Labor Involvement	Location	Crop Types
1	52	5	40	Mixed (Male/Female)	North Central, Nigeria (Benue State)	Diverse
2	40	5	35	Male Only	North Central Nigeria, (Niger State)	Various
3	49	5	38	Mixed (Male/Female)	North Central Nigeria, (Kogi State)	Varied

4.4 Traditional Farming Practices and Challenges

4.4.1 Deeply Rooted Traditions and Commitment to the Land

Across all participating Nigerian farmers, there was a strong emphasis on the deep-rooted nature of their traditional farming methods, deeply intertwined with cultural heritage and passed down through generations. This translates to a powerful connection to the land, nurtured through family history.

While all participants expressed unwavering commitment to their farming practices and land, concerns emerged regarding the future generation. Two farmers acknowledged their sons' desire to move to urban areas seeking alternative opportunities, echoing similar sentiments shared by a neighbor of another farmer. Notably, none of the participants currently utilize modern technology in their agricultural practices. They rely on tried-and-true methods, using simple tools like hoes, cutlasses, and sticks for tilling the land. To support themselves, they raise animals for various purposes, including transportation.

For further insights, refer to Table 4, which summarizes key themes related to these practices, the farmers' unwavering commitment to their land, and the factors contributing to their resistance to change:

Table 4. Themes for Traditional Farming Practices in Nigeria

Theme	Primary Focus	Representative Quotes
Cultural Heritage & Generational Learning	Upholding traditions and passing knowledge to future generations	"Deep-rooted traditions shape our farming practices, a way of life passed down from our ancestors."
Firm Commitment to Land	Deep emotional connection and dedication to their land	"Our land is deeply rooted in our identity, an inseparable part of who we are."
No Machinery Currently Used	Concerns about cost, maintenance, and access	"The high cost of machinery, limited access to repairs, uncertainty and rising cost about fuel and its availability deter us from using it."
Reliance on Animals and Traditional Method	Established methods utilizing animals for various tasks	"We've relied on time-honored methods for generations, using simple tools like hoes and cutlasses for tilling and raising various animals for both farm work and transportation. These methods have served us well."
Challenges Faced	Potential hurdles impacting their practices	"It's hard to see young people leaving for the city, however access to improved resources could help us be more productive."

However, signs of potential shift in attitudes were observed. While the current participants, aged 40-52, remained committed to traditional practices, mentions of younger generations expressing interest in machinery suggest a positive development. This interest in improved resources, including technology, could lead to a more productive and potentially more attractive future for farming.

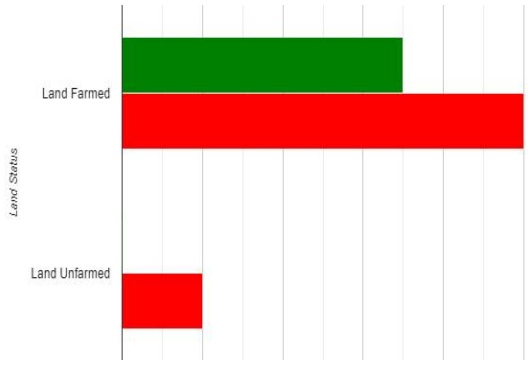
4.5 Challenges Faced with Traditional Farming

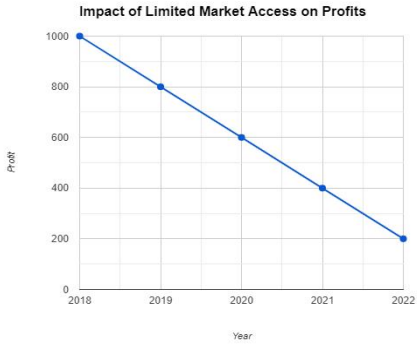
Despite their dedication to traditional methods, the participants faced several common challenges:

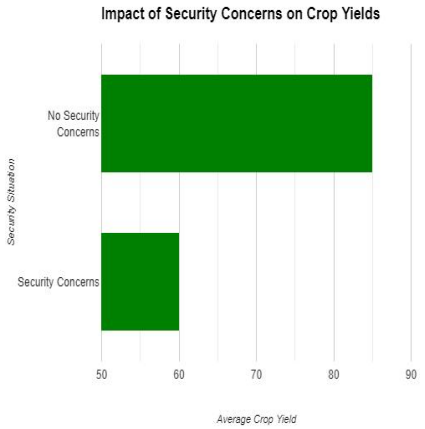
- **Rising Costs:** Traditional practices incurred escalating costs, primarily related to labor, which often exceeded returns on crops, significantly impacting their livelihood.

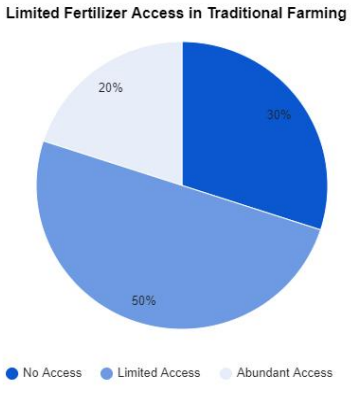
- **Labor Scarcity:** Difficulty finding or affording labor led to untimely harvesting, resulting in crop losses and reduced yields.
- **Limited Fertilizer Access:** Limited access to, or the high cost of, fertilizers forced some farmers to adopt alternative practices with negative long-term effects.
- **Security Concerns:** Farmers faced threats from Fulani herdsmen during the harvesting season, leading to looting and crop losses.
- **Limited Market Access:** Lack of access forced selling produce to brokers at low prices, limiting profit margins.

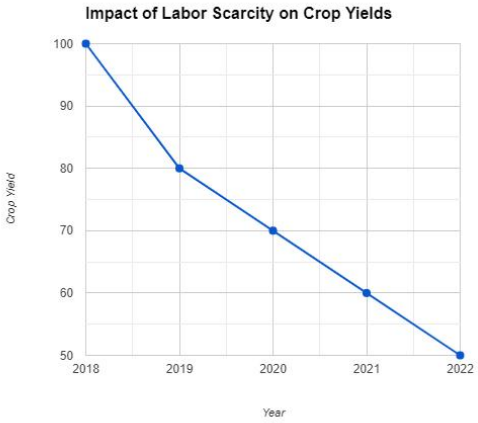
Figure 1: Challenges Faced in Traditional Farming

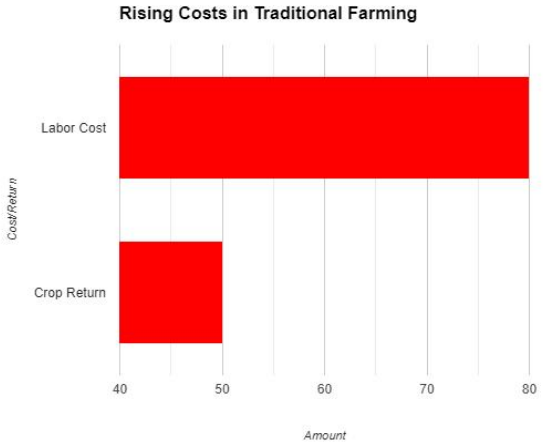












While some challenges were mentioned by a smaller number of participants, all farmers expressed concern about rising costs, particularly labor, which surged by 1800% from 2003 to 2019 according to this study. This financial strain, compounded by inconsistent crop returns, contributed to their difficulty in consistently breaking even financially. The rising cost of labor, particularly an 1800% increase from 2003 to 2019 as reported in this study, along with inconsistent crop returns, made it difficult for farmers to consistently break even financially. As a result, the adoption of automated machinery emerged as a potential solution, especially by reducing reliance on labor.

Table 5 combines information from the original Tables 4, presenting key challenges and their impact on the farmers' agricultural operations.

Table 5. Challenges Faced in Traditional Farming

Challenge	Number of Farmers Mentioned	Supporting Quotes	Impact on Operations
Rising Costs (Labor)	15 (100%)	"Production was wasted due to untimely harvesting."	Reduced profits, difficulty breaking even financially.
Limited Fertilizer Access	3 (55%)	"Sometimes we burn the land to fertilize it with carbon."	Reduced crop yields in the long term.
Security Concerns (Fulani Herdsmen)	2 (46.3%)	"Fulani herdsmen attack during harvesting, disrupting production."	Crop losses, decreased production.
Limited Market Access	2 (35.3%)	"To sell, we often have to lower prices."	Reduced profits, financial difficulties.

4.6 Willingness to Adopt New Technology

Initial Hesitation:

Farmers initially displayed limited familiarity with modern farming technologies and were hesitant about their potential benefits, as summarized in Table 6. When asked about their interest in new farming practices, their responses reflected two key themes:

Table 6: Themes for Interest in New Technology Adoption in Nigerian Agriculture

Question	Key Themes	Supporting Quotes
Are there any farming technologies you would like to use?	Not familiar with technology (N = 5) Content with current farming practices (N = 5)	"Though I've heard about new farming machinery, I'm not familiar with its specifics. As experienced farmers, we're content with our current methods for now."
Can you afford to buy any farming machinery?	No (N = 5) Owning machinery comes with	“While I don't see a need for farming machinery in my current practices, even if it were readily available, I doubt I could afford it. Additionally, some models seem to include features that are unnecessary for my needs”.

Similarly, their responses regarding affordability of machinery (Table 7) reflected this initial hesitation:

Table 7: Themes for Willingness to Adopt Technology Given the Opportunity

Question	Key Themes	Supporting Quotes
• "Would you be interested in learning about new agricultural technologies that could potentially improve farming practices?" • "Some farmers have adopted new technologies to enhance their operations. Would you consider exploring such options in the future?"	(N = 5) Willing to try only if it truly improved the process	"I'm open to trying new approaches to improve my farming operation, but any suggestions must demonstrably benefit the process without disrupting the season or causing unintended negative consequences."
• "What are some of the potential challenges you see in adopting automated machinery for your farming practices?" • "If you were able to overcome the challenges you mentioned, would you be interested in trying out automated machinery?"	(N = 5) Willing to try, but skeptical	• "Well, I might try, but I will not make it the way of my farming process forever. I will still continue to use my method. Because I like my culture, and I don't want to give up my culture for modern machines. A peaceful life is very important to us." • "I am open to trying new things as long as it is going to help. So, it's yes, I will accept it. But I am afraid that these militias will hear that I am using machinery, and then they will think I am a rich person, then I will be targeted by them."
We are planning to provide you with machinery, will you accept it?	Open to new things if they enhance the process (N = 5)	If "it helps and doesn't harm our farming season, I am open to trying."

Several factors contributed to this initial resistance:

- Lack of knowledge: Limited exposure to new technologies resulted in uncertainty about their functionality and potential benefits.
- Contentment with existing practices: Generations of success with traditional methods fostered satisfaction and reluctance to change.

- Cultural and environmental considerations: Traditional methods might hold cultural significance or be perceived as more environmentally sound.
- Concerns about complications: Operating and maintaining machinery was seen as potentially complex.
- Security concerns: Owning valuable machinery could attract unwanted attention from such as fulani Herdsmen and bokoharam militias.

These findings as described by Bello (2014), highlights a common challenge faced in many regions where these services are crucial for enhancing food production and introducing farming innovations like machinery. This limitation underscores the importance of expanding the coverage and effectiveness of extension services to ensure that more farmers can benefit from modern agricultural practices and technologies, ultimately contributing to increased food production and sustainability in the agricultural sector.

Willingness to Try:

Despite the initial hesitation, a willingness to explore new possibilities emerged when presented with the opportunity:

- **Open to new things if they enhance the process (N = 5):** "If it helps and doesn't harm our farming season, I am open to trying." (Table 7)
- **Willing to try but skeptical (N = 5):** "I might try, but won't abandon my traditional methods entirely." (Table 7)
- **Willing to try for Improvement (N = 5):** I want to try if it improve our farming operations and do harm our farm season

This suggests that while initially hesitant, they were open to learning about and potentially adopting new technologies if they demonstrably improved their farming practices.

Addressing the Hesitation:

To overcome these hurdles and promote technology adoption, it is crucial to:

- **Provide education and training:** Offer accessible and targeted information about modern farm machinery, addressing concerns and highlighting potential benefits. This could include demonstrations, workshops, and training programs tailored to the specific needs and learning styles of the farmers.
- **Showcase success stories:** Share positive experiences from other farmers who have successfully adopted new technologies. This can help to build trust and confidence in the potential benefits.
- **Address cultural and environmental concerns:** Ensure that new technologies complement existing practices and align with the local environment. This could involve finding solutions that are culturally sensitive and do not have a negative impact on the environment.
- **Offer support and resources:** Provide assistance with acquisition, maintenance, and troubleshooting of new equipment. This could involve financing options, technical support personnel, and readily available spare parts.

By addressing these concerns and building trust, we can encourage farmers to embrace new technologies and improve their livelihoods.

4.7 Chapter Summary and Discussion

This chapter focused on the willingness of farmers in the study to adopt new technologies, specifically farm machinery. Here are the key takeaways:

1. **Deep-Rooted Traditions:** Farmers emphasized the long-standing, culturally ingrained nature of traditional practices. While changing ingrained behavior is challenging, a potential generational shift emerged with the younger generation showing more openness to technology.
2. **Financial Challenges:** Profit margin recovery was a universal concern. Labor costs, accounting for 40% and 65% of planting and harvesting, were the primary contributor.

Labor scarcity led to wasted crops, and farm machinery was identified as a potential solution to reduce labor dependence and improve financial outcomes.

3. **Market Access Limitations:** Farmers faced difficulties selling their produce at fair prices due to limited access to end-users and reliance on local brokers. This highlights the need for interventions to improve market accessibility. While machinery could reduce production costs, vulnerability to controlled prices set by brokers remains a concern.

Initial Resistance to Machinery: Initially, farmers exhibited concerns regarding:

- Lack of knowledge about modern machinery and its functionalities.
- Cultural significance of traditional practices.
- Complications associated with machinery ownership: Concerns included learning to operate and maintain the equipment, as well as potential breakdowns and the availability of spare parts.
- Security risks from militias targeting wealthy farmers: Owning valuable machinery could increase their vulnerability to theft or extortion.

Positive Experiences with Machinery:

Despite initial resistance, farmers who received machinery during the 2020 season reported positive experiences:

- Reduced costs: Machinery helped to decrease production costs, particularly related to labor.
- Increased efficiency: It improved time management and land utilization, allowing them to cultivate more land and potentially increase yields.
- Enhanced safety: Owning machinery provided a sense of security against theft and damage to crops and equipment.

Barriers to Long-Term Adoption:

However, long-term adoption remained contingent on addressing concerns regarding:

- **Security:** Ongoing security risks from militias particularly this regions posed a threat to owning valuable equipment.
- **Financial sustainability:** Affordability of machinery, fuel, and spare parts in the long term remained a significant concern.

Recommendations:

To facilitate technology adoption and address rural poverty, the following are crucial:

- Education: Providing accessible and targeted information about modern farm machinery, addressing concerns and highlighting potential benefits. This could include demonstrations, workshops, and training programs tailored to the specific needs and learning styles of the farmers.
- Post-adoption support: Offering ongoing support to farmers who have adopted new technologies, including assistance with maintenance, fuel provision, and troubleshooting. This could involve establishing service centers, providing access to financing for spare parts and repairs, and creating communication channels to address any challenges they encounter.
- Addressing security concerns: Collaborating with local authorities and communities to develop strategies to mitigate security risks associated with owning farm machinery. This could involve increased security presence in rural areas and initiatives to address the root causes of conflict and crime.
- Improving market access: Investing in infrastructure and initiatives that connect farmers directly to markets and fair pricing mechanisms. This could involve establishing farmers' markets, cooperatives, and partnerships with larger agricultural businesses.

Conclusion:

This chapter highlights the initial resistance to change, gradual shift in attitude towards adopting new technologies, and the importance of addressing knowledge gaps and providing

ongoing support to promote sustainable agricultural development. By addressing the concerns and barriers faced by farmers, we can empower them to embrace new technologies and improve their livelihoods, contributing to rural economic growth and poverty reduction.

Chapter 5

ECONOMIC IMPACT OF AGRICULTURAL MACHINERY IN NIGERIA

5.1 Overview

This chapter delves into the economic implications of integrating agricultural machinery into farming practices in Nigeria. It aims to assess the comparative profitability and sustainability of traditional versus mechanized farming, while identifying potential improvements in farmer productivity, income, and overall quality of life. The analysis addresses two key research questions:

1. What are the major factors influencing farming costs and revenues in Nigeria?
2. How does the use of agricultural machinery impact cost, revenue, net profit, return on investment (ROI), and farm sustainability for Nigerian farmers?

5.2 Methods

The economic evaluation is based on a three-year longitudinal study conducted during the 2019-2021 farming seasons. Data on costs and revenues were collected from Nigerian farmers participating in the study. Costs, encompassing labor, materials, and fuel, were expressed in USD per acre, mirroring the approach for revenue and net profit calculations. The local currency, the Nigerian Naira (NGN), was used initially for data collection before conversion to USD for analysis. The investigation utilized rigorous statistical techniques, such as T-tests and Analysis of Variance (ANOVA), and potentially linear regressions to compare the experimental and comparison groups in 2019, and to assess the impact of both

farming year and machinery adoption on net profit, ROI, and farm sustainability for the period 2019-2021. Farm sustainability was assessed based on various environmental, economic, and social indicators, such as soil health, resource use efficiency, and farmer well-being.

5.3 Similarities in Farm Characteristics

The study encompassed farms from diverse regions throughout Nigeria, reflecting the variety of crops cultivated based on regional climates. Each farm grew at least two different crops, adhering to established local cultivation and harvest schedules. In the absence of modern machinery, traditional methods relying on animal and human labor were prevalent. Transportation practices varied, ranging from animal-drawn carts used for direct local sales to reliance on brokers for larger market access.

Initially, both the comparison and experimental groups reported utilizing hired labor throughout the past three seasons. Additionally, family involvement in farming activities remained consistent between both groups. While farms in the experimental group were slightly larger in size, subsequent analyses focused on cost, revenue, and net profit per acre to minimize potential size-related biases in the overall findings.

5.4 Factors Affecting Farming Net-Profits

Responses from the 30 Nigerian farmers who participated highlighted a substantial impact of economic factors on their net profits. Challenges related to labor scarcity and the consequent high costs were recurrent, leading to delayed harvests and subsequent crop losses. Moreover, the farmers faced constraints due to limited availability or the elevated costs of essential inputs like seeds and fertilizers, compelling some to turn to less efficient local alternatives. Additionally, elements such as unpredictable weather patterns, market fluctuations, and constrained access to financial resources were recognized as key determinants affecting the overall profitability and sustainability of farming practices in Nigeria.

5.5 Expected Outcomes

This chapter is expected to provide valuable insights into the economic and sustainability implications of agricultural machinery adoption in Nigeria.

The analysis aims to:

- Identify cost-saving opportunities and potential increases in agricultural output and farm income associated with machinery use.
- Assess the impact of machinery adoption on labor requirements, farm efficiency, and environmental sustainability.
- Provide recommendations for policymakers, agricultural development agencies, and farmers regarding the potential benefits and challenges of agricultural mechanization in the Nigerian context.

Chapter 6

NEEDS AND REQUIREMENTS ANALYSIS ON TRACTOR DESIGN

6.1 Overview

This chapter aims to employs a human-systems interaction approach for developing and integrating farming machinery that aligns with the needs and expectations of users. Three primary research objectives guide this endeavor: (1) identify the needs and perceptions of traditional farmers in Nigeria regarding tractor machinery; (2) determine general tractor design requirements to meet these needs; and (3) establish payback models for tractor adoption by these farmers.

6.2 Methods

Responses from 30 farmers were analyzed to identify shared needs and expectations. A comparative analysis was conducted between farmers with and without prior machinery experience. Common themes were categorized from the raw responses, such as the preference for owning tractors over renting due to factors like full control. Statistical methods, including t-tests and chi-square tests, were employed to compare the two groups. Two payback models are presented for viable farming machinery that addresses identified needs.

6.3 Farm Sizes

The study encompassed 30 farms, averaging 40 acres in size (SD 19.37 acres). Participants were questioned about the minimum farm size deemed suitable for adopting tractor machinery. Notably, no statistically significant difference was observed between the groups

concerning the minimum required farm size ($p > .05$). This suggests that preferences for tractor adoption remained relatively consistent irrespective of prior experience.

6.4 Tractor Preference: Ownership vs. Rental

A significant majority (88.9%, N_no experience = 25, N_experience = 5) expressed a preference for owning tractors over renting. Insights from their responses revealed three key motivations:

1. **Unrestricted Control (N = 30: P_no experience = 83.3%, P_experience = 100%):** Nearly all participants emphasized the benefits of ownership, such as flexibility in usage, maintenance, and the ability to sell, lend, or rent the tractor as needed. Ownership offered autonomy, freedom from rental fees, and the assurance that equipment-related issues wouldn't incur external consequences.
2. **Asset Value for the Farmer (N = 5: P_no experience = 13.3%, P_experience = 16.7%):** Some participants viewed owning a tractor as an investment, considering it a valuable asset. The option to sell it at any time was seen as an advantage compared to the limitations of a leasing agreement.
3. **Economic Prudence (N = 2: P_no experience = 3.3%, P_experience = 16.7%):** Two participants believed that owning machinery was a more economical choice in the long run, potentially offering cost savings compared to potential hidden surcharges in rental agreements.

These findings highlight a strong preference for tractor ownership among traditional farmers, driven by considerations of autonomy, asset value, and perceived economic advantages.

Alternatively, all four participants that preferred renting explained that they preferred not to be liable for repairs and not be locked into a potentially outdated tractor, but rather have the opportunity to upgrade.

6.5 Rental Preference: Reasons for Opting Against Ownership

The minority of participants who favored renting (N = 4) articulated distinct reasons for their preference:

1. ***Liability Avoidance (N = 4: P_no experience = 100%, P_experience = 0%):*** All participants who preferred renting highlighted their desire to avoid liabilities associated with tractor repairs. Renting provided a sense of relief from the financial burden and responsibilities of maintenance, ensuring that upkeep costs and unforeseen damages wouldn't fall on them.
2. ***Avoidance of Outdated Equipment (N = 4: P_no experience = 100%, P_experience = 0%):*** Renting appealed to these participants because it afforded them the flexibility to avoid potentially owning outdated machinery. The prospect of upgrading to more advanced models without being tethered to a single unit was a driving factor in their choice.

The preference for renting stemmed from a desire for financial security and the ability to embrace technological advancements without the constraints of ownership.

6.6 Discussion and Summary

This chapter complements the net-profit analysis from Chapter 5 by incorporating findings from design needs interviews. The analysis distinguished between farmers with and without experience, but no significant statistical differences emerged in their preferences ($p > .05$).

An overwhelming majority (88.9%, N_no experience = 25, N_experience = 5) favored tractor ownership, driven by the desire for unrestricted control, the value of the tractor as an asset, and perceived cost-effectiveness. Participants envisioned an ideal tractor as simple, inexpensive, fuel-efficient, easy to repair, and versatile for various farming tasks. While simple and utilitarian designs were preferred, a nuanced desire for a balance between basic and advanced features was also evident.

Interestingly, safety features were not explicitly mentioned by participants, which contradicts existing literature emphasizing their importance in agricultural machinery design. This gap highlights an opportunity.

Chapter 7

GENERAL CONCLUSIONS & SUGGESTIONS

7.1 Overall Findings

This independent research employed the Systems Engineering framework to thoroughly explore opportunities for Human-Systems Interaction (HSI) within the intricate landscape of Nigerian agricultural practices. The extensive study spanned three agricultural seasons, closely observing 30 farms scattered across the North Central Region of Nigeria. The participant pool was meticulously divided between mechanized (N = 15) and non-mechanized (N = 15) settings, ensuring a nuanced understanding of diverse farming practices. Key findings from the research include:

1. **Initial Resistance and Subsequent Adoption:** In the initial season, a discernible resistance to the integration of agricultural machinery surfaced among both mechanized and non-mechanized farmers. This resistance, however, transformed over time as positive experiences with mechanized farming practices fostered a notable shift in attitude. Farmers, initially hesitant, gradually became more open to the idea of long-term adoption, highlighting the pivotal role of positive experiences in shaping perceptions.
2. **Labor Challenges and Comparative Advantages:** The study illuminated the challenges faced by non-mechanized farmers, particularly those related to labor scarcity and the subsequent escalation of labor costs. These challenges significantly impacted the efficiency and productivity of non-mechanized farming. In stark contrast, mechanized farming showcased distinct advantages, even after accounting for fuel expenses. This

suggests that the initial investment in machinery translated into long-term benefits, effectively mitigating challenges associated with labor dynamics.

3. **Financial Analysis (2019-2021):** A thorough financial analysis covering the years 2019 to 2021 uncovered compelling insights. Mechanized farming, as revealed by the data, not only significantly increased net profits but also demonstrated superior returns on investment (ROI) when compared to traditional non-mechanized practices. The financial gains underscored the economic viability and sustainability of adopting mechanized farming approaches, presenting a promising avenue for transforming the agricultural sector.

4. **Operational Efficiency and Environmental Impact:** Beyond the financial realm, the study delved into the operational efficiency of mechanized farming practices. It was found that mechanized farms exhibited greater operational efficiency, enabling timely planting, harvesting, and overall farm management. Additionally, a qualitative assessment of environmental impact suggested potential sustainability benefits associated with reduced resource use and emissions in mechanized farming.

These comprehensive findings collectively highlight the intricate dynamics surrounding technology adoption, labor considerations, financial outcomes, operational efficiency, and environmental implications within the context of Nigerian agriculture. The study advocates for a holistic approach to modernizing agricultural practices, emphasizing the multifaceted benefits of embracing mechanized farming.

7.2 Recommendations

Based on the research findings, several recommendations are proposed:

1. Collaborative policy development: Involving local communities, authorities, and governments in policy formulation is crucial to encourage technology adoption among

traditional farmers. This fosters sustainable machinery adoption and overall economic improvement.

2. Education and accessibility initiatives: To address technology adoption challenges and reduce rural poverty, educational programs on modern equipment are crucial. Additionally, exploring alternative ownership models (e.g., cooperatives) and improving access to equipment maintenance services are vital aspects.
3. Post-purchase support: Providing post-purchase care, including maintenance services and readily accessible fuel stations, is essential for convincing traditional farmers to adopt machinery. Local authorities or private sectors can offer these services, making investments more attractive.
4. Knowledge dissemination: Essential education on contemporary farming technology is needed, emphasizing its potential to improve farmers' livelihoods. Farming groups and extension services can play a key role in disseminating knowledge about advancements in the field.
5. Financial inclusion: Enhancing financial inclusion for traditional farmers necessitates improved access to loans and financial services. Long-term commitments and adjustments in operational methods by Microfinance Institutions (MFIs) and banks are crucial.
6. Improved security environment: Creating a secure environment is pivotal for encouraging farmers to invest in improved farming practices. Establishing connections with local police or security services can enhance farmers' confidence and willingness to invest.
7. Culturally sensitive machinery design: Manufacturers should strive to tailor machinery to diverse user needs by considering cultural, educational, and financial variations. This

approach can boost business for manufacturers while promoting machinery adoption among traditional farmers.

7.3 Contributions

This research contributes to the field in three main ways:

1. **Applying the Systems Engineering framework:** This research demonstrates the application of the Systems Engineering framework for HSI in Nigerian agriculture, utilizing quantitative evidence to guide the adaptation of technology for sustainable use in developing economies.
2. **Economic evaluation of farming systems:** The study provides an economic comparison of traditional and modern farming systems in Nigeria, highlighting the potential of agricultural machinery to improve the financial situation of traditional farmers.
3. **Addressing farmers' needs in machinery design:** By exploring the views of Nigerian farmers on available machinery, the research identifies design preferences that align with their needs. This knowledge can contribute to increased income, poverty reduction, and job creation through improved agricultural practices.

7.4 Limitations and Future Research

The study acknowledges limitations concerning its duration, sample size, and potential mismatch between increased production and demand. Future research should:

- Explore the long-term impact of machinery adoption on the food supply-demand balance.
- Consider additional costs like fuel and equipment servicing.
- Conduct a survey to directly measure the economic and quality-of-life impact of adopting different machinery designs among traditional farmers in Nigeria.

- Investigate the impact of consolidating small family farms and factor in associated costs to gain a more comprehensive understanding specific to the socio-economic context of Nigeria.

7.5 Conclusion

This research employed a Human-Systems Interaction framework to explore and address the challenges and opportunities associated with adopting agricultural machinery in developing economies. The findings highlight the potential for significant improvements in efficiency, profitability, and overall quality of life for traditional farmers in Nigeria. While challenges exist, the proposed recommendations offer a roadmap for collaborative efforts among stakeholders to ensure sustainable and responsible adoption of agricultural technology. This research contributes valuable empirical data and insights to the ongoing dialogue on modernizing agricultural practices in developing economies, paving the way for further research and practical implementation.

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APPENDIX: TRANSLATED INTERVIEW QUESTIONS

This appendix presents the translated interview questions utilized in the research conducted in collaboration with Goldvest Nigeria Limited, focusing on the economic and user-centered aspects of agricultural machinery adoption in Nigeria.

A. Farmer Interviews:

1. **Pre-intervention (June 2020):**

- **Demographics:** Age, gender, education level, years of farming experience, farm size (hectares)
- **Current farming practices:** Primary crops cultivated, traditional farming methods employed, labor requirements, sources of income
- **Perceptions of technology adoption:** Awareness of agricultural machinery, initial concerns or hesitations regarding adopting new technologies, expectations for potential benefits and challenges

2. **Post-planting (October 2020):**

- **Initial experiences with machinery:** Ease of use, perceived effectiveness in planting tasks, comparison to traditional methods (time, effort, quality)
- **Initial concerns addressed:** Have initial concerns regarding machinery adoption been addressed or alleviated? If yes, how?

3. Post-harvest (December 2020):

- Impact on harvesting process: Changes in efficiency, labor requirements, crop yield compared to traditional methods
- Overall satisfaction: Level of satisfaction with using machinery, perceived impact on livelihood and farm income

4. **Pre-planting (February 2021):**

- **Continued use of machinery:** Intentions for using machinery in the upcoming planting season, reasons for continued use or potential hesitation
- **Emerging concerns or challenges:** New challenges or concerns encountered with machinery use, suggestions for improvement

5. **Post-planting (July 2021):**

- Second planting season experiences: Comparison of experiences with the first planting season, identification of any recurring challenges

6. **Post-harvest (September 2021):**

- **Long-term impact:** Changes in farm profitability, labor requirements, and overall well-being since adopting machinery
- **Challenges and future intentions:** Ongoing challenges faced with machinery use, plans for future use of the technology

B. Machinery Design Survey:

This survey, administered either through interviews or standalone questionnaires, focused on understanding farmer preferences and needs regarding agricultural machinery design:

- **Functionality:** Prioritization of specific functionalities and features in agricultural machinery (e.g., ease of operation, compatibility with local soil conditions, fuel efficiency)
- **Affordability:** Preferences for pricing models (e.g., one-time purchase, leasing options) and willingness to pay for specific features

- **Accessibility:** Preferred sources for acquiring machinery (e.g., local dealerships, cooperatives) and desired availability of maintenance services
- **Safety:** Awareness of and importance placed on safety features in agricultural machinery