FACTORS INFLUENCING THE ADOPTION OF TECHNOLOGIES, INNOVATIONS AND MANAGEMENT PRACTICES AMONG BANANA FARMERS IN VIHIGA COUNTY

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DECLARATION

Student Declaration

This dissertation is solely my creation and has not been submitted to any other reviewing entity before. Any replication of this dissertation in whole or in part requires my authorization or that of the Strathmore University Business School.

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APPROVAL

In my capacity as supervisor at Strathmore University Business School, I endorse this dissertation for examination.

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DEDICATION

I dedicate this dissertation to my sons; Aiden Migaili and Akim Migaili, my parents, family, friends and all those who have been part of academic journey.

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ABSTRACT

This study investigates the factors influencing the adoption of technologies, innovations, and management practices (TIMPs) among banana farmers in Vihiga County, Kenya. With the global emphasis on sustainable agriculture to meet the rising food demands, understanding these factors is crucial for enhancing agricultural productivity and ensuring food security. The research adopted a quantitative descriptive design, analyzing data from 392 banana farmers across the county. The study was grounded in the Unified Theory of Acceptance and Use of Technology (UTAUT) and the Innovation Diffusion Theory, providing a robust theoretical framework for understanding adoption behaviors. A Multivariate Probit (MVP) model was employed to analyze the relationships between adoption and key variables, including awareness, cost, market demand, and climate change. The findings revealed that awareness and affordability significantly drive the adoption of tissue culture banana seedlings, integrated pest and disease management, and climate-smart irrigation technologies. Market demand was found to enhance the adoption of productivity-enhancing technologies, while climate change motivated the uptake of climate-smart innovations. However, post-harvest technologies exhibited low adoption rates, highlighting the need for targeted interventions. The study concludes that a comprehensive strategy addressing affordability, accessibility, and market support is essential to enhance the adoption of TIMPs, improving productivity and sustainability in the banana value chain. The study's findings provide valuable insights for policymakers, researchers, and agricultural stakeholders to develop targeted strategies that promote sustainable farming practices and improve the livelihoods of banana farmers in Vihiga County.

Keywords: Adoption, Technology, Innovation, Management Practices, Banana Farmers, Vihiga County

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LIST OF ABBREVIATIONS

CIAT: International Center for Tropical Agriculture

CIDP: County Integrated Development Plan

FAO: Food and Agriculture Organization of the United Nations

FGD: Focused Group Discussion

HCD: Horticultural Crops Directorate

IPDM: Integrated Pest and Disease Management

ISFM: Integrated Soil Fertility Management

ITC: International Trade Centre

KII: Key informant interview

SBS: Strathmore University Business School

SDG: Sustainable Development Goal

SME: Small and Medium Enterprises

SSA: Sub-Saharan Africa

TC: Tissue Culture

TIMPs: Technologies, Innovations, and Management Practices

UTAUT: Unified Theory of Acceptance and Use of Technology

DEFINITION OF TERMS

Adoption refers to the choices people make when they contemplate embracing an innovation/technology or decide to utilize an innovation as the most suitable option. Adoption is not finalized until the innovation or technology is consistently used.

Biotechnology refers to a diverse field that employs living organisms or their elements to create products and processes for the betterment of human society. It incorporates various scientific fields such as molecular biology, genetics, biochemistry, and engineering, and has experienced notable advancements in recent times.

Innovation refers to altering existing technology to serve a different purpose than its original intended use.

Management practices are guidelines for actions deemed essential to ensure technology reaches its maximum effectiveness. These practices might encompass various methods related to crop and livestock management, such as fertilizer application rates, seeding rates, planting schedules, spatial arrangements, watering routines, land preparation, and other crop management techniques.

Post-harvest losses refer to the loss of food quantity and quality from harvest to consumption.

Sustainable agricultural practices refer to methods and techniques employed in farming that aim to optimize the long-term health and productivity of the ecosystem, while minimizing negative impacts on the environment.

Technology refers to techniques, systems, and apparatus developed through the application of scientific knowledge for practical use. This can include outcomes from research such as tools, machinery, genetic resources, animal breeds, agricultural and pastoral methods, harvesting practices, laboratory procedures, models, and so forth.

Value chain refers to the complete set of activities involved in the creation, manufacturing, distribution, and disposal of a product or service. This includes the physical transformation of materials, input from different producer services, and the ultimate delivery to consumers.

CHAPTER 1: INTRODUCTION TO THE STUDY

This chapter presents the background details of the study, including the definition of words and variables. It also offers an overview of the banana value chain on a worldwide scale, as well as specific information regarding its presence in Kenya and Vihiga County. The chapter then presents the technological advancements and managerial strategies employed in the banana value chain. The chapter thereafter presents the research objectives, and research questions, and provides an overview of the study's scope, importance, and limits.

1.1 Background of the Study

Agriculture is the backbone of many economies, especially in developing nations because it greatly contributes to GDP, employment, and food security. However, Pawlak & Kołodziejczak (2020) argue that developing countries, despite being agricultural countries also have higher levels of food insecurity because they fail to properly invest in agricultural infrastructure. With increasing global demand for food, innovations such as tissue culture, precision farming, and farm automation where farmers are expected to embrace relevant technological advancements and effective management practices to enhance agricultural productivity, profitability, and sustainability. In addition, Steensland & Zeigler (2020) explain that innovative agricultural technologies and practices, such as advanced seed technologies and mechanization, drive productivity growth and contribute to sustainable food and agriculture systems.

According to Vuppalapati et al. (2023), banana farming plays a critical role in rural livelihoods, providing income, nutrition, and employment opportunities. In addition, banana farming contributes to 75% of income in developing countries such as Ecuador (Vuppalapati et al., 2023). In Kenya, banana farming is widely practiced by smallholder farmers in counties such as Kirinyaga, Embu, and Vihiga, where a large portion of the population depends on agriculture for subsistence and commercial purposes (Simiyu et al., 2021). Banana production is done in many African countries. However, over-reliance on traditional methods of production lowers the sustainability and productivity of their lands and the performance of their cultivars due to limited access to improved technologies, lack of innovative farming approaches, and weak management practices (Tumaini et al., 2024). In addition, integrating pest and disease management and value-addition techniques improves yield and profitability, but with limited farmer training and resource constraints, banana farmers in Vihiga are yet to embrace these changes (Lawrence & Omuse, 2021). In addition, Vihiga County has low innovation adoption rates due to a lack of awareness, a perception of banana farming as a traditional way of life, and high costs of innovative strategies and technology.

1.1.1 Global Outlook

Considering the rising need to provide food for the world's swiftly expanding population, it is imperative and essential to secure sustainable advancements in agriculture. This is particularly crucial as the growth in crop production does not keep up with the escalating demand for food. In 2018, agriculture generated 4% of the global GDP and up to 25% in some developing nations, considerably impacting economic development (World Bank, 2023). In many emerging economies, agriculture is crucial for earning foreign exchange, growing exports, and creating jobs (Nugroho et al., 2021). Moreover, most rural communities in developing countries still rely heavily on agriculture for their livelihood and often need financial resources to scale productivity and diversify livelihoods (Qiu-Bin et al., 2023). According to IFAD, (2023), more than 3 billion people in developing countries live in rural areas and rely on farming for food and livelihood.

According to Statista (2025), bananas are a major agricultural product grown worldwide in over 135 countries, with India leading in production with 36,614 thousand metric tons, China with 11,702, and Indonesia with 9,335 thousand tons. While only a small portion (less than 15%) of the massive 145 million tons produced annually gets exported, these exported bananas bring in significant foreign income (over US$8.9 billion) for many producer countries (FAO, 2024). In addition, the Banana Market Review report (2023) indicates that global banana exports have increased by 0.3% from 2022. According to Voora et al. (2020), in 2017, a staggering 22.7 million tons of bananas, not including plantains, were exchanged, constituting nearly 20% of the world's total production for that year. This trade amounted to a value of USD 11 billion, surpassing the export worth of any other fruit (Voora et al., 2020). The report reveals that this significant consumption of bananas grown locally is observed in several African nations like Uganda, Rwanda, and Cameroon. In these countries, individuals can consume over 200 kg of bananas per year on average, particularly in rural regions where this tropical fruit can contribute up to a quarter of a person's daily calorie intake (Voora et al., 2020). While the global Banana export from Africa is around 0.7% (FAO, 2024), bananas are globally recognized and widely distributed, playing a crucial role in ensuring food security, particularly in developing regions

Banana demand is increasing as consumers move towards healthy diets (Burkhart et al., 2022). However, even with the anticipated rise in demand, the banana industry encounters significant supply hurdles, such as inconsistent production, the effects of climate change, and varieties that are vulnerable to diseases and pests (Wahome et al., 2021). These hurdles must be resolved to fulfill the projected market expansion. In addition, Andrianarimanana & Yongjian (2021) argue that increasing the integration of agricultural technology in Sub-Sahara Africa would increase productivity, farmers' welfare, and the profitability of their products.

1.1.2 Kenya and Vihiga County Outlook

According to an observational study on Meru Banana farmers, on a land area of 63,074 hectares, a total of 1.24 million kilograms of bananas were produced in 2016 in Kenya, representing an increase over the prior year's cultivation area of 60,744 hectares (Kahwai et al., 2021). Kahwai et al. (2021) also found that the production would be appraised at KES 18.1 billion ($180 million), representing approximately 31.6% of the country's total fruit production. Additionally, banana serves as a fundamental food crop for both rural and urban communities in Kenya, primarily cultivated by small-scale farmers (Nyamamba et al., 2020). Its production caters to both household consumption and the broader national market, offering significant potential to enhance nutrition, food security, and income generation for these smallholder farmers (Wahome et al., 2021). In addition, banana surpluses are sold in marketplaces, bringing much-needed revenue for countless small-scale farmers worldwide and assisting numerous homes Nyamamba et al., 2020). Furthermore, bananas remain essential for food security on the continent, notwithstanding the limited application of modern biotechnology in African agriculture (Waseem et al., 2020). With the global and local market demand for bananas, establishing agriculture and farmer networks that involve various farming communities in evaluating and selecting pest and disease-resistant banana cultivars will enrich biotechnology innovation research and implementation in Kenya and Africa at large.

According to Vihiga County’s integrated plan 2018-2022, banana farming occupies 998ha and more than 110,000 farmers have benefited from tissue culture banana seedlings. Like many other banana farmers in the globe, banana cultivation in Vihiga County faces common challenges such as low production, post-harvest losses, and restricted market access (Muthee et al., 2019). In Kenya, banana growing is a crucial agricultural activity that helps smallholder farmers increase their income and strengthen the nation's food security. According to Simiyu et al. (2021), Vihiga County in Western Kenya, is among the areas in Kenya where banana growing is a common practice either as a cash crop or food crop, and as a result, it is crucial to the agricultural industry and economy of the County. Banana farming is viable due to the County's good geography and climate despite the persistent issues associated with pests, diseases, prolonged dry seasons, and unstable market demands. Several technological developments in seedling sourcing, planting, post-harvest care strategies, and administrative agricultural-strengthening tactics have been implemented along the banana value chain to address these issues (Eyitayo Raji et al., 2024). Banana growers in Vihiga County may therefore significantly increase productivity, revenue, and overall industry sustainability if they integrate technology, innovation, and effective management practices. According to the Vihiga County integrated development plan, CIDP (2018-2022), bananas are the third largest produced crop, after maize and tea, respectively (Vihiga County, 2018). The crop is of utmost importance to food security in the County. To increase technology adoption and the overall efficiency of the banana value chain in Vihiga County, this study aims to investigate and assess factors that influence the adoption of these elements.

1.1.3: Adoption of Technologies, Innovations and Management Practices

The agriculture sector has not been left behind in the adoption of technological advancements in order to improve productivity, enhance crop resistance to diseases and pests, and profitability. The integration of various farm and market technologies such as ripening chambers, banana dryers, and soil testing kits adoption of innovative practices such as contract farming, agroforestry, cooperative farming models, and climate-smart practices, and optimizing management practices can enhance banana farming by improving crop productivity, plant resilience, and the profitability of the crop (Kathuri et al., 2021). According to Kangogo et al. (2021), modern farming has embraced the farmer-entrepreneurial-orientation approach that has popularized the increasing use of climate-smart scientific advancements. These advancements improve the quality of production and sustainability by mitigating the effects of climatic changes, pest invasions, diseases, and soil degradation. Implementing these components in the banana subsector in Vihiga County is crucial, given the unique environment of this study. In this context, the level of managerial, technological, or agronomic innovations that banana growers incorporate into their daily operations is called adoption.

This study examined the adoption of tissue culture banana cultivars, Integrated soil fertility management (ISFM) practices and technologies, Integrated Pest and Disease Management (IPDM) practices and technologies, soil sampling and testing, climate-smart irrigation technologies, tools for crop management, banana waste management innovations, and post-harvest technologies.

a. *Technology*

The adoption of technologies such as tissue culture, climate-smart irrigation, and pest-resistant banana varieties enhance yield, reduce pest and diseases, reduce crop losses, and enhance crops' adaptability and sustainability (Kathuri et al., 2021). Further, using pest-resistant banana varieties and tissue culture seedlings strengthens crops against pests and diseases while using climate-smart irrigation methods such as drip irrigation and moisture sensors optimize water use efficiently. However, Kirimi et al. (2021) argue that in Kenya, there is still low adoption of these technologies because of the associated high financial cost, inadequate experts, and expensive services. Despite the use of on-farm testing to increase awareness, most farmers prefer conventional methods because of the cost and the unstable market prices that demotivate farmers from making huge investments and commitments towards improving productivity and sustainability.

b. Innovations

Embracing innovations such as integrated pest management (IPM) that helps reduce the over-reliance on chemical pesticides, value addition techniques such as producing banana chips and banana fiber production, and the use of digital agricultural platforms further increases banana farming profitability (Grasswitz, 2019). In addition, embracing digital agricultural platforms and mobile-based extension services facilitates quick and easy knowledge transfer rates among farmers on sustainable practices and market trends. Innovation in banana farming therefore provides farmers with better opportunities to enhance profitability, increase their income, reduce post-harvest losses, and create employment.

c. Management Practices

Banana farming has for so long inclined towards traditional farming practices because of the belief that banana consumption is mainly for rural and traditional families (Pawlak & Kołodziejczak, 2020). However, banana farming has a global market, and integrating effective management practices such as proper land preparation, fertilization schedules, irrigation planning, and post-harvest handling play a crucial role in ensuring improved banana production and quality (Gambart et al., 2020). In addition, using optimal fertilizer application practices and combining these practices with soil irrigation and conservation techniques leads to better nutrient uptake, sustains banana production during dry periods, and increases yields (Gambart et al., 2020). Additionally, effective post-harvest handling techniques such as improved storage facilities, transportation logistics, and processing units can reduce post-harvest-related losses and enhance product quality (Grasswitz, 2019). Therefore, the integration of these three aspects (technologies, innovations, and management practices) can boost banana farming in Vihiga County by addressing production challenges and creating sustainable agricultural systems.

However, the adoption of these innovative management practices in Kenya has taken a slower pace due to various factors such as lack of enough extension services and financial constraints. According to a study by Ronoh et al. (2024), the greatest technology for preserving bananas for a more extended period was drying (51.3%), which was followed by cooling (38.5%). Other technologies that were highly recommended included those that are used to make banana wine (5.1%), crisps (5.1%), and value addition in general (2.6%). Additional technologies included ripening (6.7%), banana flour (3.3%), crisps (3.3%), jam (3.3%), and general value addition (6.7%) (Ronoh et al., 2020). In addition, the study by Ronoh et al. (2024) and Kanuna & Ngari (2021) reveals that a lack of proper communication and knowledge transfer from experts to farmers further slows down the adoption of technology and innovative practices. Technologies play a crucial role, either directly or indirectly, in the advancement of agriculture and rural regions. They contribute to increased productivity, bolster food security, and enhance the well-being and livelihoods of farmers. Adoption refers to the decisions that are made by individuals each instance they contemplate adopting an innovation/technology or choosing to utilize a new idea as the most favorable option. Adoption is not complete until the innovation or technology is used consistently.

Rajendran et al., (2016), found that farmers' age has an influence on their uptake of technologies is a widely researched aspect, but there is no unanimous agreement on its effects. Older farmers, leveraging their expertise and resources, may have increased chances to explore and test new technologies. Conversely, younger farmers, benefiting from higher levels of education compared to their older counterparts, tend to be more open to embracing new technologies. Further, Chavas & Nauges (2020) assert that farmer's uncertainty with technological changes and slow learning capacities negatively affect the adoption of technology and innovative practices among farmers. Therefore, training initiatives play a vital role in helping farmers acquire knowledge about management practices and proper procedures for their production. Additionally, these programs educate farmers about the benefits they stand to gain by transitioning from traditional practices to new and improved methods (Sapbamrer & Thammachai, 2021).

Another study by Yang et al (2021) in Southern China found that training in agriculture exerts a notable and favorable influence on the adoption choices of banana farmers. A rise in farmers' training exposure correlates with an enhancement in their adoption rates, highlighting the crucial role that agricultural training plays in the spread of agricultural technologies (Yang et al., 2021). A study in Uganda by Mulogo et al. (2019) found that the creativity and ingenuity of farmers play a crucial role in shaping the acceptance of agricultural technologies, specifically in the context of tissue-cultured banana planting materials. User innovation not only directly impacts technology adoption but also acts as a key influence in mediating other factors related to acceptance, including social influence. Additionally, it contributes to creating favorable conditions that enhance the reliability of predicting farmers' intentions to embrace technology more effectively. The lack of awareness and training among intended recipients regarding new technology is believed to result in knowledge gaps, which can lead to misinformation and delays or a lack of adoption of potentially beneficial technology (Ruzzante et al., 2021).

A report by the Tropical Center for Tropical Agriculture-CIAT (Ministry of Agriculture, Livestock, Fisheries and Cooperatives, Kenya, 2021), found that major agriculturally based economic activities within Vihiga County are livestock and crop production. Whereas the main crops grown for food in the County are beans, maize, sweet potatoes, bananas, sorghum, millet, and cassava, the considerable cash crops are tea and coffee. Vihiga County statistics (2022) show that food crops occupy nearly 40,000 ha, which is 83% of the County's arable land. Bananas take up approximately 30% of the County's arable land, on 12,000 ha. The inconsistency and unpredictability of rainfall levels and temperature variations adversely affect agricultural output, particularly in Africa, where adaptation strategies are inadequate. The future of rain-dependent farming remains uncertain, especially concerning banana cultivation by small-scale farmers, given the ongoing climate variability (Karienye & Kamiri, 2020).

Globally, and locally, several studies, such as those done by Chepwambok et al. (2021), Githumbi (2022), and Chavas & Nauges (2020) have researched the factors affecting the adoption of technologies and management practices individually. Nevertheless, the Kenya Agricultural and Livestock Research Organization (KALRO) has created multiple technologies, innovations, and management practices for specific value chains in Kenya, such as the banana value chain (Kirimi et al., 2021). These TIMPs have been promoted across the Country, through both the government extension services and the contracted service delivery models. Vihiga county is among the counties in Kenya, where banana farmers have been sensitized, trained, and adopted the TIMPs. However, a report by the County's Department of Agriculture, Livestock and Fisheries (DoALF) found that the adoption was low (Kings Agricultural Services, 2022). This study therefore seeks to find out the factors that influence the adoption of a combination of technologies, innovations, and management practices as described by KALRO, in Vihiga County.

1.2 Statement of the Problem

Several studies, like those done by Eyitayo Raji et al. (2024); Khan et al. (2021), and Ruzzante et al. (2021) attribute the expansion of the agricultural industry to the adoption of technologies, innovations, and management practices. However, the scale of adoption has varied and depends on several interrelated factors. The economic review of agriculture (ERA) in 2017 identified the following fruits as the most important produced in Kenya: passion fruit, bananas, mangoes, pineapples, avocado, pawpaw, oranges, and watermelon. The banana sector in Vihiga County involves more than 80% of the adult population, according to the Ministry of Agriculture, Livestock, Fisheries and Cooperatives, Kenya (2021). Almost every home has a banana plant in its farmland. The County Integrated Development Plan (2018-2022) states that bananas are the third largest crop produced in the County, after maize and tea. According to the County's Department of Agriculture, in 2018, the production of bananas in Vihiga was at 10 tons/ha. According to a report by the County’s Department of Agriculture Livestock and Fisheries (2019), bananas were cultivated on 1200 ha, and these gave a total of 12000 tons valued at KES 24,000,000. The report also revealed that banana consumption at the household level in the County was at 40% while 60% was for marketing (Department of Agriculture Livestock and Fisheries, 2019).

Vihiga County identified constraints to banana production, and they included poor agronomic/farm management practices by farmers, inadequate supply of quality planting materials of farmer-preferred banana varieties, and the impacts of climate variability banana cultivation, specifically erratic rainfall patterns (The Ministry of Agriculture, Livestock, Fisheries and Co-operatives (MoALFC), 2021). The marketing constraints included insufficient market information on market requirements and preferences, demand patterns, frequent price fluctuation, post-harvest losses are high and contributing to low returns at the farm level, and banana glut during the peak/harvest season combined with lack of technologies to process or extend the fruit shelf-life resulting in low returns to the farming communities (Vihiga County, 2019).

The adoption of technologies helps farmers to increase the productivity and profitability of their farming enterprises. While there have been studies on the factors that affect technology adoption among farmers, there is a lack of research specifically focused on the factors that influence the adoption of innovations, management practices, and technologies among banana farmers in Kenya, including Vihiga County. Since technologies do not work in isolation, they are accompanied by corresponding and suitable management practices for them to deliver the required results. The adoption of TIMPs is critical in addressing the growth of the banana value chain in Kenya and in Vihiga County. This study, therefore, aimed to determine the factors that influenced the adoption of technologies, innovations, and management techniques among banana farmers in Vihiga County, Kenya.

1.3 Research Objectives

The main objective of this research was to establish factors influencing the adoption of technologies, innovations, and management practices (TIMPs) among banana farmers in Vihiga County.

The specific objectives were: -

i. To determine how awareness of the technologies, innovations, and management practices influenced adoption among banana farmers in Vihiga County,
ii. To examine how the cost of the technologies, innovations and management practices influenced their adoption among banana farmers in Vihiga County,
iii. To establish if demand for bananas influenced the adoption of technologies, innovations, and management practices among banana farmers in Vihiga County and,
iv. To examine the effect of climate change on the adoption of technologies, innovations, and management practices among banana farmers in Vihiga County.

1.4 Research Questions

The following research questions guided the study.

i. What was the effect of awareness of the technologies, innovations, and management practices on their adoption among banana farmers in Vihiga County?
ii. What was the effect of the cost of technologies, innovations, and management practices on their adoption among banana farmers in Vihiga County?
iii. What was the influence of banana demand on the adoption of technologies, innovations, and management practices among banana farmers in Vihiga County? and,
iv. What were the effects of climate change on the adoption of technologies, innovations, and management practices among banana farmers in Vihiga County?

1.5 Scope of the Study

The study focused on banana farmers situated in Vihiga County, Kenya. Vihiga County is geographically located in the Western region of Kenya and comprises an area of 531.0 km^2 (County Government of Vihiga, 2024). Its northern, southern, southwestern, and eastern borders are shared with the counties of Kakamega, Kisumu, Siaya, and Nandi, respectively. The County is situated between 34°30' and 35° 0' East longitude and 0° to 0°15' North latitude (County Government of Vihiga, 2024). While the 2019 census, report indicated that Vihaga County's population was at 590,013, there is a projected increase in population by 0.9%, and by 2022, the population was estimated at around 606,044 (Vihiga County, 2019). According to FAO (2023) agriculture contributes about 33% of the Kenyan GDP. In Vihiga County, mixed farming (crops and livestock) takes up to 83% of the land, where crop productivity contributes to approximately 64% of the County's revenue (County Government of Vihiga, 2024).

Farmers within the County engage in the cultivation of both staple crops for consumption and cash crops for sale. According to the County's CIDP (County Government of Vihiga, 2024), the agriculture sector was responsible for 70% of the job possibilities in the County. The opportunities provided revenue for those employed in the agricultural and animal husbandry sectors. The primary agricultural crops that contributed to job opportunities were maize, tea, bananas, beans, and several others. This study encompassed all five sub-counties: Sabatia, Hamisi, Luanda, Emuhaya, and Vihiga. Sampling across all the sub-counties with diverse agro-climatic zones provided more reliable data at the county level. The focus was on the technologies, innovations, and management practices (TIMPs) along the banana value chain, as documented by the Kenya Agricultural and Livestock Research Organization (KALRO).

1.6 Significance of the Study

With the global focus on adopting modern agricultural technologies and practices that could increase productivity, sustainability, and resilience, adoption by smallholder farmers is still low. In addition, available research on technology and innovation adoption in banana farming mostly focuses on the whole country and specific counties including Meru, Embu, and Nyeri (Kahwai, et al., 2021); (Kirimi, et al., 2021); (Nyamamba, et al.,2020); (Githumbi, R. (2022). Vihiga County remains unexplored, and this study aimed to focus on Vihiga's banana farming practices. In addition, Adom & Adams (2020) argue that approximately 62% of Africa's agricultural output remains untapped, persistently integrating TIMPs can enhance agricultural and market efficiency in Africa. Most of the previous studies concentrated on technical efficiency and economic returns derived from the use of these innovations but it is little known what socio-economic, institutional, or environmental factors affect farm-level adoption processes (Barrett et al., 2022). According to Barrett et al. (2022), research on the adoption and efficiency of TIMPs focuses on general agricultural practices, failing to enrich different agricultural systems and crop-specific information and data that can be used to increase efficiency. The general availability of research in this area has created a major blind spot for farmers, researchers, and policymakers who are looking for specific data and information on particular geographical location, a crop, or a farming system.

Since this study focused on finding out the factors that influence the adoption of technologies, innovations, and management practices among banana farmers in Vihiga County, the findings were critical for the County and its development partners. In addition, the findings help in developing and prioritizing policies and projects that support and enhance the growth of the banana value chain which is a key value chain in the County. The findings of this study are further going to assist researchers develop technologies, innovations, and management practices that farmers can readily adopt. The findings also give insights into the demand side of the banana and if the technologies, innovations, and management practices add value to farmers, and their markets, hence contributing towards food security and incomes.

Unlike most prior studies that focused on technical efficiency and returns, this study offered a more nuanced exploration of the socio-economic, institutional, and environmental factors that influenced the adoption of TIMPs. It filled a significant gap by examining banana-specific systems rather than generalized agricultural practices, offering localized and crop-specific insights.

1.6.1 Significance to Theory

i. The study contributed to empirical validation of UTAUT and IDT Models. The study confirmed that awareness, cost, demand for banana and climate change variables affected technology adoption, thus reinforcing the frameworks of UTAUT and Innovation Diffusion Theory (IDT) in the agricultural context.
ii. Using the Multivariate Probit (MVP) model, the study demonstrated that adoption of TIMPs was not driven by single variables but by interconnected socio-economic and behavioral factors. This added a new dimension to the existing theoretical models by incorporating interdependence among adoption choices.
iii. The study supported contextual contribution by generating empirical evidence from a previously underexplored area (Vihiga County) and crop (banana farming), expanding the geographic and commodity-specific understanding of innovation adoption.

1.6.2 Significance to Practice

i. The findings of the study highlighted that while awareness positively influenced adoption, it was not sufficient alone. Farmers need targeted training and information, especially for post-harvest technologies, indicating a need for strategic extension services.
ii. Cost emerged as a consistent barrier across TIMPs, particularly for technologies like tissue culture banana seedlings. This suggested the need for cost-reduction strategies and farmer credit access programs.
iii. While farmers were willing to adopt productivity-enhancing TIMPs due to perceived market demand, the adoption of post-harvest technologies was low, exposing a gap in practical support systems and infrastructure.
iv. Although Vihiga's consistent rainfall made climate change impacts appear minimal, the study emphasized that older, more experienced farmers adopted climate-resilient technologies like irrigation systems, showing that climate education could further enhance TIMP uptake.
v. Additionally, scholars may find the study's findings beneficial for conducting further research in the domain of technologies, innovations, and management practices that influence adoption in the specified areas

1.6.3 Significance to Policy

i. The findings provided Vihiga County's departments (Agriculture, Commerce and Environment) with robust, evidence-based insights for designing support programs and allocating budgets to enhance adoption of TIMPs.
ii. The study encouraged policymakers to implement affordable financing models and subsidies that could reduce financial stress and promote adoption among resource-constrained farmers.
iii. The results could be used to guide national policy frameworks aimed at improving food security, supporting banana value chain development, and addressing rural livelihoods through innovation support.

1.7 Limitations of the Study

1. Geographical Scope

The study is limited to Vihiga County, and its findings may not be fully generalizable to other banana-growing counties in Kenya. There are many other counties in the country that produce bananas and whose farmers adopt technologies, innovations and management practices. This study, however, focused on banana farmers in Vihiga County.

2. Limited Scope of Technologies

There are also several other technologies used by farmers, either through indigenous technical knowledge, private sector-led innovations, or through exposure to other countries, this study focused on the technologies researched and compiled by KALRO. Farmers in Vihiga County mainly practice mixed farming, which means that they grow more than one crop. This study was limited to banana farmers within the County.

3. Time Constraints

The study was conducted within a specific timeframe, but agricultural practices evolve continuously.

4. Response Bias

The research employed a random sampling method to ensure that each member of the population (banana farmers) had an equal opportunity to be selected.

5. Mixed Farming Systems

Many farmers in Vihiga County practice mixed farming but since the study concentrated on banana farmers, it may not fully capture how TIMP adoption interacts with other agricultural activities.

1.8 Chapter Summary

This chapter introduced the study by providing a comprehensive background on the importance of agriculture, particularly banana farming, in both global and Kenyan contexts, with a specific focus on Vihiga County. It highlighted how the adoption of Technologies, Innovations, and Management Practices (TIMPs) has become essential for enhancing agricultural productivity, resilience, and sustainability among smallholder farmers. The chapter outlined the problem statement, noting that despite the development and dissemination of TIMPs by institutions such as KALRO, their adoption remained low in Vihiga. The research aimed to identify the socio-economic, institutional, and environmental factors influencing this gap. It articulated clear objectives and research questions focused on awareness, cost, market demand, and climate change as key variables. The scope was defined to include banana farmers across all five sub-counties of Vihiga, while the significance of the study emphasized its relevance to policymakers, researchers, and farmers in improving value chain efficiency. Finally, the chapter discussed limitations such as the study’s geographical focus, timeframe, and response bias.

CHAPTER 2: REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter explores the body of literature relevant to the research topic. The review encompassed the conceptual, theoretical, and empirical aspects. The theoretical literature examined the frameworks used in technology adoption, while the empirical literature focused on the factors influencing the adoption of innovations, technologies, and management practices. This study considered factors such as the demand for bananas and its impact on adoption, the costs associated with technologies, innovations, and management practices, the accessibility of these innovations, technologies, and management practices, and the influence of climate change on their adoption. This chapter clarified the areas of limited understanding that this study investigated.

2.2 Conceptual and Theoretical Review

From the past literature, understanding factors influencing the adoption of TIMPs in agriculture has been studied using the Technology Acceptance Model (TAM), the innovation-decision process model, and the Technology Readiness (TR) model (Dissanayake et al., 2022). According to Dai & Cheng (2022), the two primary factors that influence an individual's decision to adopt a new technology according to TAM are the perceived usefulness of the technology (including individual innovativeness) and its perceived ease of use. Other factors that influence the adoption of technology among farmers according to TAM include farmers' social norms, behavioral attitudes towards technology, government influence, facilitating conditions such as expert input, and relevance (Castiblanco Jimenez et al., 2020). In addition, Montes de Oca Munguia et al. (2021) argue that TAM is a result of the combination of the task-technology fitness models with either the Theory of Planned Behaviour (TPB) or the Theory of Reasoned Action TORA behavioral theories where the perceived fitness of the technology informs the "intent to adopt" or reject the technology.

Additionally, the innovation-decision process model by Rogers (1995) has been used in agricultural research because it explains the multidimensional decision-making process that is influenced by socio-economic conditions, technological knowledge, and personal perceptions before the adoption of agricultural innovative practices (Dissanayake et al., 2022). Individuals and organizations adopt innovation in five stages (implement or reject an innovation) knowledge acquisition and awareness, persuasion, decision-making, implementation, and confirmation, where the innovation implemented or rejected (Dissanayake et al., 2022). The model asserts that farmers must first become aware of technologies such as tissue culture banana varieties, post-harvest handling techniques, and climate-smart irrigation systems and evaluate the feasibility of the practice or technology before the adoption.

In addition, the Technology Readiness (TR) Model by Parasuraman (2000) states that an individual's or organization's inclination to adopt and use new technologies is impacted by four psychological dimensions: optimism, innovativeness, discomfort, and insecurity (Dissanayake et al., 2022). The TR model has been used in agricultural research to assess farmers' readiness to adopt digital and precision agriculture technologies, as well as biotechnologies and sustainable farming innovations. This theory has been used to analyze the adoption of precision farming tools such as mobile apps and smallholder farmers' readiness to embrace climate-smart technologies. In addition, the TR concept complements the Unified Theory of Acceptance and the Innovation Diffusion Theory (IDT) by highlighting psychological factors influencing farmers' adoption decisions, beyond economic and environmental considerations.

2.2.1 Contribution of the Theories

Given the scope of this study, the Unified Theory of Acceptance and Use of Technology (UTAUT) and Innovation Diffusion Theory were selected as the primary theoretical because of their direct relevance to the research. The UTAUT and IDT theoretical frameworks significantly enhanced the study's ability to examine factors influencing the adoption of TIMPs among banana farmers in Vihiga County, and to what extent by identifying the key drivers of adoption and the extent to which these factors shape farmers' decision-making processes. These two theories are complimentary, and they provide a comprehensive understanding of the technology adoption process by addressing different but complementary aspects. While the UTAUT focuses on behavioral factors among agricultural stakeholders on the adoption of TIMPs, IDT explains how and at what rate the stakeholders have adopted new TIMPs in Vihiga County. In addition, UTAUT will help identify and understand why banana farmers have rejected, adopted, or hesitated in adopting new technologies such as tissue culture and post-harvest innovations, while IDT helps identify the key characteristics in Vihiga County that could speed up TIMPs adoption and help policymakers design better diffusion strategies. By integrating UTAUT and IDT, the study was able to capture both the farmer's decision-making process and the spread of technology over time within Vihiga County.
In addition, using a holistic adoption approach that considers both individual adoption behavior

and the spread of best practices, the study used UTAUT and IDT to determine the adoption of management practices according to the performance expectancy, effort expectancy, social influence, and facilitation conditions, while the IDT helps examine the relative advantages, compatibility, trialability, and observability of the positive in Vihiga County.

2.2.2 Unified Theory of Acceptance and Use of Technology

According to Ronaghi & Forouharfar (2020), adoption of technology depends on behavioral intention, which is influenced by four important elements. The likelihood of adopting technology is impacted by several elements, such as effort expectation, performance expectancy, enabling circumstances, and social influence (Ronaghi & Forouharfar, 2020). This model is commonly used in empirical research that aims to understand the motivations and actions of end users in the field of technology dissemination and adoption (Rizkalla et al., 2024). The performance expectation is the extent to which an individual believes that using the technology will improve their work performance while the effort expectation refers to the level of ease involved in applying the technology, whereas social influence relates to an individual's sense of others agreeing that the technology is necessary (Rizkalla et al., 2024). Facilitating conditions refer to the extent to which an employee believes that the work environment will promote the deployment and use of technology (Ronaghi & Forouharfar, 2020). The perceived availability of resources such as technology, experts, and finance further enable an individual to adopt and utilize new technology or innovation.

The model comprises four constructs that apply to the adoption of management practices, innovations, and technologies. Adoption is influenced by various factors, including technological performance, user ergonomics, the level of effort required, the technology utilized by other producers (social influence), and facilitating conditions such as technology availability (Shi et al., 2022). The primary focus of the Unified Theory of Acceptance and Use of Technology (UTAUT) is on extrinsic motivators, with considerable emphasis on the practical advantages offered by technology (Shi et al., 2022). The significance of this emphasis is apparent in the notion of performance expectancy, which mirrors the practicality aspect and, according to the UTAUT model, is the most influential determinant of the intention to utilize technology (Markovits, 2024). In the context of this research, banana producers implement technologies into their operations only if they possess a firm conviction regarding the advantages they offer. UTAUT incorporates elements from various earlier technology acceptance theories, providing a broad and well-rounded perspective on the factors influencing how people adopt and use new technologies. Therefore, UTAUT offers a comprehensive framework for understanding the decision-making process of banana farmers and their behavioral patterns that can help drive the successful implementation of TIMPs.

Considering the use of this model in previous similar studies, the variables under research, and its relevance to this study, the UTAUT model was selected due to its robustness in addressing key issues that drive technology adoption among farmers.

2.2.3 Innovation Diffusion Theory

The Innovation Diffusion theory was advanced by Rogers (1995). As illustrated by this theory, several factors interact to affect the innovation diffusion process. Four main factors influence diffusion. These are the nature of innovation, innovation information transfer (awareness creation), time, and the type of social environment in which the innovation is targeting (Rogers, 1995). Through a clear comprehension of the drivers of innovation adoption, the product/technology design teams are better placed to interrogate, consider, and plan for the factors that drive or limit the adoption of their products (Chen & Li, 2022). For this research, diffusion will be considered to happen gradually and has four distinct stages, namely, awareness, characteristic of the innovation (based on cost and availability), decision-making, and adoption.

The economic growth derived from new technology can only be fully experienced when the technology is widely adopted and utilized. The diffusion process occurs through individual decisions to adopt the new technology, often involving a comparison between the potential benefits and costs associated with its adoption, both of which are uncertain (Chen & Li, 2022). The Theory of Innovation Diffusion aims to clarify the process, reasons, and pace at which innovations and technologies move within societies. Rodgers (1995) delineated five fundamental characteristics that provide insight into the rate at which innovations are adopted: (1) relative advantage, signifying the innovation's superiority over the preceding concept; (2) compatibility, indicating the extent to which the innovation is in harmony with the present values, past experiences, and requirements of prospective adopters; (3) complexity, pertaining to the perceived challenge of understanding and implementing the innovation; and (4) trialability, quantifying the trialability of the innovation and (5) observability, which highlights the visibility of the innovation's results to others.

A comprehensive understanding of diffusion and adoption theory is essential for analyzing and comprehending the dynamics involved in the adoption or rejection of agricultural practices. Researchers studying diffusion have primarily focused on analyzing the differences among farmers regarding their adoption or rejection of innovations and technologies. However, there has been minimal consideration given to the attributes of the technology itself or its suitability for specific contexts. For this reason, the innovation diffusion theory considers the attributes of the technologies and innovations, and how those attributes influence adoption.

In the context of this study, innovation adopters ought to be aware of the innovation, should be convinced as to the extra benefits of the innovation and make up their minds to adopt and utilize the innovation after its adoption. For this study, awareness (knowledge) of the technologies, innovations and management practices, their availability, cost, and banana demand are the main factors that influence the adoption of technologies among banana farmers in Kenya. This led to the adoption of the Innovation Diffusion Theory.

2.3 Empirical Review

It is widely known that the attainment of the Asian Green Revolution was an output of intensified Adoption of agricultural technologies (Ruzzante et al., 2021). Since then, several studies have been undertaken to determine factors that influence agricultural technology adoption. Most of these studies, however, have focused on agricultural production technologies and a few have been done on a combination of technologies, innovations, and management practices, specifically on bananas. In this study, adoption is defined as a deliberate and well-informed choice to extensively apply a new technology or practice for an extended duration (Montes de Oca Munguia et al., 2021)

Bananas (*Musa spp.)* are primarily grown in rural areas, serving as a vital source of income and sustenance for rural families. They rank fourth among the world's most significant fruits and are a crucial food crop in developing countries, following wheat, maize, and rice (Al-Dairi et al., 2023). In Sub-Saharan Africa, agriculture remains a prominent sector, providing livelihoods for millions of rural inhabitants (Oyetunde Usman et al., 2021). Despite Kenya's economy being largely agricultural, with 582,636 square kilometers of available land, only approximately 17% is considered highly suitable for rain-fed agriculture (De Jong et al., 2024).

FAO, in 2024, stated that nearly 5.6 million hectares of land were under banana production globally. In Kenya, banana is a popular food crop, consumed both as fruit (dessert) and cooked.

In 2013, the country produced approximately 2 million tons annually from nearly 80,000 ha (Nyamamba et al., 2020). Bananas are a fundamental food source for individuals living in both urban and rural areas of Kenya. Mostly cultivated by small-scale farmers, they serve as a staple for both household consumption and the broader national market. According to Murigi et al. (2024), bananas have the capacity to enhance food security, nutrition, and revenue for smallholder farmers.

Adopting enhanced agricultural technology enhances agricultural sector productivity and efficiency, diminishes poverty, and ensures food security in emerging nations (Yokamo, 2020). However, in as much as technologies, innovations and management practices have the potential to increase productivity, there is a lack of effort to raise awareness and to build the capacity of intended beneficiaries. According to Kairu (2020), the adoption of innovative strategies is still low among banana farmers in Kirinyaga County, Kenya. This has resulted in knowledge gaps, which in turn lead to misinformation and delays in adopting beneficial technologies. Moreover, (Osiemo et al. (2021) argue that the lack of a conducive environment, which encompasses insufficient policies and regulations impacting input accessibility, interactions between the private sector and public agricultural research, and the advancement of agricultural businesses, significantly hampers the progress and acceptance of promising technologies in developing nations.

According to Kenya's Vision 2030, the agriculture sector in Kenya has been designated as one of the six sectors necessary to achieve a 10 percent rate of economic growth. The primary objective of this sector is to improve agricultural production by promoting and advancing technology, while also allocating more resources towards this goal. Alongside initiatives like policy regulation, coordination, and information management, the sector also focuses on crop development and management as a major program (Republic of Kenya, 2012). These efforts are geared towards promoting technologies that enhance agricultural productivity.

The County Integrated Development Plans, 2013-2017 and 2018-2022, by the County Government of Vihiga, both have placed a strategic focus on the banana value chain. The value chain is essential to the attainment of the County's food security, and in alleviating poverty. Over the past the past 10 years has implemented key projects in the enhancement of productivity and profitability of the banana value chain. The programs encompass the Agriculture Sector Development Support Programme (ASDSP) and the National Agriculture and Rural Inclusive Growth Project (NARIGP), among other initiatives.

This study focused on the adoption of technologies including the adoption of tissue culture banana varieties, climate-smart irrigation technologies, post-harvest technologies such as drying, ripening, and other value addition technologies, innovations along the banana value chain such as banana waste management innovations, including making of banana fiber and vermicomposting of banana pseudo stems to make organic fertilizer. Management methods are techniques that facilitate the utilization of technology to enhance productivity. These practices encompass integrated pest and disease control, integrated soil fertility management, and other crop management procedures before and after harvesting.

2.3.1 Cost of Technologies

The decision of whether a farmer adopts a technology or not is a financial decision. Farmers' decisions, particularly in Sub-Saharan Africa, including Kenya, are greatly impacted by the financial implications of adopting new technologies and methods (Khaspuria et al., 2024). Empirical research has provided insight into the difficulties faced by smallholder farmers because of the exorbitant expenses associated with implementing innovations. Notably, the age of smallholder farmers impacts their adoption decisions. According to Kahwai et al. (2021), older Kenyan farmers may exhibit declining enthusiasm for using new technologies when they consider adoption factors like the technology's perceived benefits, ease of use, and perceived cost-effectiveness frequently have an impact. The study also found that many farmers were discouraged from switching to disease-resistant banana cultivars due to the hefty upfront costs.

This study sought to highlight how the price of inputs, particularly for farmers with constrained resources, can significantly influence adoption choices. The high costs associated with implementing sustainable agricultural practices, such as organic pest management and fertilization, have posed challenges for farmers with limited resources (Khaspuria et al., 2024). The cost issue emphasizes the need for interventions and support mechanisms to reduce the financial stress on smallholder farmers and make adopting promising technologies and practices more widely available. Moreover, a study by Kahwai et al., (2021) found that farmers are willing to meet the cost of a technology, if they are convinced that it will help them increase their incomes. The technology adoption decision is a financial decision. Consequently, technology adoption can be said to depend on the technology cost and on whether target users have the required financial resources (Mapanje et al., 2023). (Mapanje et al., 2023) also found that technology cost is a main limitation to adoption, and that expensive technologies can only be accessed by wealthier individuals or farms with large turnovers. From the study by

(Chepwambok et al., 2021), technologies that had a higher capital expenditure had low adoption levels.

A study conducted in Ghana by Worku (2019) found that economic aspects comprised the size of the farm, the financial resources associated with adoption, availability of credit, anticipated advantages from adopting the technology, and the off-farm income sources that farm households are involved in. The technology diffusion process occurs because of a sequence of individual choices to start utilizing the new technology, with these decisions frequently stemming from a comparison of the potential advantages and the innovation adoption costs. Kurgat et al. (2020) and Ndiritu & Ruhinduka (2019) found that insufficient capital hinders the adoption of various management practices and that this is a recurring theme observed in agricultural technology literature. A study done in Thailand, by (Supapunt et al., 2021) found that capital ownership and access to finance positively influenced the adoption of management practices.

Findings from these studies demonstrated the impact of Cost on the uptake of technologies and innovations. However, they considered the initial expenses of acquiring the technology. The costs of utilizing the technologies and innovations, through the technology or innovation management practices have been rarely studied. Thus, this research studied the costs of technologies, innovations, and management practices and how the combination of the costs of acquisition and utilization influences adoption among banana farmers in Vihiga County.

2.3.2 Knowledge of Technologies and Practices

Numerous empirical studies have emphasized the significance of farmers' awareness of new technology and practices as a crucial factor affecting its adoption. For instance, a study by Eshetu et al. (2020) in Ethiopia found that access to training and information programs improved the likelihood that smallholder farmers to adopt better farming practices, such as using disease-resistant banana varieties. Waseem et al. (2020), who conducted research in Pakistan, came to the same conclusion. The researchers discovered that initiatives to increase awareness positively impacted adopting sustainable agricultural procedures among banana growers. A study conducted in China by Gao et al. (2020), found that extending agricultural technology plays a critical role in speeding up the integration of agricultural scientific and technological advancements, thus fostering the progress of agricultural modernization.

In a study conducted by Kabirigi et al. (2022) titled "The Utilization of mobile phones and its Impact on Banana Farmers' Heterogeneity," it was discovered that banana farmers with lower income levels exhibited a reduced likelihood of encountering limitations stemming from insufficient awareness regarding the accessibility of agricultural services provided through mobile phones, in comparison to subsistence farmers. This was true when contrasting low-income farmers with farmers who only raised food for themselves. It should not be surprising that elderly farmers were more likely than younger ones to experience technical difficulties with cell phone-based agricultural services.

According to Nyang'au (2019), information acquisition on new innovations and technologies clarifies and explains them, making them readily available to the target users. In addition, the study found that proper linkage between extension service providers and technology manufacturers is critical in the dissemination of technologies and their adoption. This leads to a reduction in information asymmetry that exists between target users of the technology, in this case, the banana farmers in Vihiga County. A study by Kairu (2020) attributed low adoption of technologies to a scarcity of affordable technologies, the high cost associated with them, as well as a lack of awareness regarding the available biotechnologies such as tissue culture banana. From these studies, technology and innovation awareness play a critical role in shaping adoption decisions by farmers.

A study by Agnes et al. (2024) found that the most significant factors influencing decisions on value-addition technologies were age, perception of risk, and lack of information. Creation of awareness is significant in postharvest technologies adoption and plays a significant role in the adoption of the technologies. Ruzzante et al. (2021) concluded that technology availability alone cannot guarantee adoption unless target technology users are well-informed and sensitized to increase their awareness levels. Awareness influences technology adoption. In addition, increased awareness and understanding of technologies and practices typically result in their adoption. The provision of extension services has been demonstrated to facilitate the dissemination of knowledge and enable farmers to remain informed about improvements in agricultural technology, hence facilitating the adoption of new technologies. Several researchers have noted a positive correlation between extension services and the adoption of technology (Yokamo, 2020). In addition to awareness, technology, and practice accessibility and availability are significant drivers of adoption decisions among farmers. Findings from multiple studies provide strong evidence for this association. For instance, research by

(Madalla et al., 2023) in Tanzania and Uganda discovered that the lack of disease-resistant banana cultivars posed a considerable barrier to adoption. This study showed that even when farmers were aware of the advantages these cultivars offered, their inaccessibility impeded their adoption.

A study in Taiwan, by Chuang et al. (2020) found that the lower rates of adoption of sustainable agricultural technologies were attributed to insufficient information, lack of knowledge, limited awareness about the technologies, and a perceived lack of practical benefits. The study concluded that there was a considerable barrier to the widespread adoption of modern farming practices due to the absence of critical inputs, notably better planting materials. Even while farmers wanted to use these advancements, their unavailability was a significant hurdle. These findings demonstrate the significance of providing farmers simple access to the equipment and innovations required to speed up adoption.

A study in Kenya Kabunga et al. (2012), found that although awareness of TC technology was spread among farmers, its effective implementation necessitated significant alterations in farming methods. These findings also hold significance for other knowledge-intensive technologies that demand substantial modifications to conventional practices. This lays emphasis on the need to consider the management practices that make technologies and innovations work better for farmers. Policymakers and agricultural stakeholders must address the awareness and accessibility difficulties to fully realize the advantages of technology adoption in banana growing and subsequently increase agricultural productivity and livelihoods.

Whereas most of these studies have been conducted on biotechnologies, this research sought to study biotechnologies and other technologies, such as post-harvest technologies and crop management technologies such as climate-smart irrigation, and their adoption among banana farmers. This study focused on technologies across the entire value chain.

2.3.3 Demand for Banana

Although agriculture is widely recognized as crucial for economic growth, rural development, and alleviating poverty in agriculture-dependent countries, its use for development purposes has been sluggish. In response, initiatives have been launched to activate an Agriculture-for-Development process, employing strategies from both the supply and demand sides to address constraints and promote inclusive value chain development (De Janvry & Sadoulet, 2020).

Many studies such as those conducted by; (Gao et al. 2021), (Kahwai, et al.2021), (Kanuna & Ngari,2021), and (Kathuri et al., 2021) have focused on the adoption of technologies from the supply side, without taking cognizant of the demand of the produce, whose production is being prioritized from the supply side.

In fact, a report by Mitchell et al. (2021), titled "Transforming Africa's Food Systems from the Demand Side" argues that demand and supply are interconnected aspects, implying that any action taken on the demand side will also affect the supply side. However, prioritizing the establishment of markets, securing demand, setting up distribution systems, and subsequently focusing on supply development is likely to yield superior outcomes. This approach ensures that volumes and value are aligned effectively throughout the supply chains. Consequently, the demand for bananas has a crucial impact on the implementation of technology, innovations, and management techniques in the supply side of the value chain.

For bananas, their domestic and international demand significantly influences the adoption decisions made by the farmers. It is crucial in influencing the choices made by banana growers in Kenya and Africa. Empirical studies such as those by Kanyenji et al. (2020) in Western Kenya have repeatedly highlighted the significant impact of market demand on farmers' adoption habits. The economic feasibility of banana production is closely correlated with market factors. Farmers are urged to utilize modern farming practices and technologies to improve the quantity and quality of their produce when there is a high demand for specific banana varieties, such as dessert bananas or plantains. As a result of this demand-driven adoption, farmers are utilizing the financial opportunities provided by adjusting to consumer demands. Adopting novel disease-resistant banana cultivars, eco-friendly farming practices, or efficient post-harvest processing procedures become economically sound decisions in such conditions (sufficient demand).

Additionally, market-oriented farming fosters regional and national economic growth and enhances individual farmers' livelihoods. It creates a vibrant, competitive agriculture sector, supports the expansion of value chains, and creates employment opportunities. Therefore, choice depends on the presence of a collection of desired qualities that a specific cultivar confers, as the farmer judges. The only features desired may be those for consumption (such as taste and color), the only traits desired are those for production (such as yield and disease resistance), or the only traits desired are both (such as taste and yield).

A report by KAVES (2017) found that banana production was insufficient to meet demand, resulting in heightened post-harvest losses caused by the perishable nature of the fruit. Therefore, there is a necessity to introduce and endorse simple technologies to farmers for storing bananas in controlled environments, delaying ripening, and extending the shelf life of banana produce under typical conditions. A study done in Tanzania found that Farmers in selected improved varieties based primarily on the demand in their local markets (Mwalongo et al., 2020).

These studies have shown that the demand side of the value chain influences the adoption of technologies by farmers. There is limited literature on studies done on banana demand, and its influence on farmers adopting a combination of technologies, innovations, and management practices (TIMPs), which this study sought to find out and contribute to the literary development of that field of study.

2.3.4 Climate Change

Undoubtedly, the worldwide agricultural food system is experiencing unparalleled challenges recently, primarily due to climate change. This situation frequently creates production uncertainties and jeopardizes the productivity and livelihoods of farmers, particularly smallholder farmers in Sub-Saharan Africa (SSA) who depend heavily on agriculture (Oyetunde Usman et al., 2021). Studies, such as that done by Vijayasarathy and Ashok (2015), concluded that embracing technology is critical in enabling smallholder farmers to sustain their farming activities amidst climate change. The study also found that data regarding climate change has illustrated a substantial and favorable influence on the prospect of adoption of technology.

A study in China by Zhu et al. (2021) found that the implementation of adaptation strategies substantially boosted the land productivity of banana farmers. In Kenya, farmers face significant challenges due to climate change. The country is vulnerable to climate-related occurrences, and predictions indicate that the consequences of climate change will persist. Severe and fluctuating weather patterns are now the norm across many parts of the country. Rainfall is erratic and unreliable; some parts of the country now experience floods and intense rainfall during the short rains and prolonged dry spells during the long rainy seasons. Traditionally drier parts of the country, such as the northeastern and other semi-arid areas are specifically susceptible to the changes, putting the socio-economic lives of millions of the populace at risk (Ministry of Agriculture, Livestock, Fisheries and Cooperatives, Kenya, 2021).

A study by Nwokoro et al., (2023) found that climate-smart innovations were not being accessed by smallholder farmers, thereby hindering advancements in essential socio-economic and ecological enhancements for both smallholders and the environment. This means that in as much as technologies help farmers mitigate the effects of climate change, they need to be accessible. The technologies, however, have been found to present a promising opportunity to enhance the economic, social, and environmental sustainability of agricultural and food systems worldwide (Blakeney, 2022).

Kenya developed a National Climate Change Response Strategy (NCCRS) ten years ago, recognizing the significance of climate change and its effects on the country's progress. After a span of two years, the government introduced a National Climate Change Action Plan, which serves as a structure for executing the plan and determining the main goals for adapting agriculture. While these activities mostly concentrated on a national scale, it became crucial to include climate change considerations into laws, programs, and development plans at the county level. In 2019, Vihiga County became the first County to legislate and pass the County Climate Change Act. However, the operationalization of the act required financing, the County then enacted the Climate Change Fund Act. Grassroots implementation of these Acts is in preliminary stages. Farmers within the County are susceptible to the effects of climate change. Banana farming has shown a decline in productivity, a factor that is attributed to climate change, among other factors. The Vihiga County climate risk profile highlights that the primary climatic hazards to the banana value chain are extended periods of drought and unpredictable, inconsistent rainfall. Extended periods of drought reduce the accessibility of resources like seeds and natural fertilizers, resulting in increased production expenses for farmers. During the production phase, longer dryer periods lead to an increment in land-preparation costs, render the crop calendar unreliable, and heighten the incidences of pests. The consequences in total have a negative effect on banana production. The ends result in poor quality, reduced shelf life, and increased pre- and post-harvest losses leading to farmers making financial losses. Technologies, such as drought-resistant banana varieties, can help farmers avoid such risks.

In examining the effects of climate change, alongside cost, and awareness of the technologies on adoption Omotilewa et al. (2019) identified the main challenges in climate change adaptation strategies as insufficient funding for adopting new technologies and a lack of knowledge about technology. This is in line with the objectives of this study, which sought to not only to find out the effects of climate change on adoption, but also on the costs and awareness of the technologies, innovations, and management practices, among banana farmers in Vihiga County.

2.3.5 Other Factors Influencing Adoption of Technologies

Multiple components in the literature impact the acceptance and implementation of post-harvest technology. Factors such as age, educational attainment, income, gender, and availability of extension services were influential in determining the Adoption of technologies (Chepwambok et al., 2021). According to the same study, there was a significant and positive association between education, income levels, and the adoption of post-harvest technology. Research conducted by Omari et al. (2023) revealed that the adoption of tissue-cultured bananas was impacted by many parameters, including the educational attainment of the family head, household size, off-farm income, farm size, and availability of extension services. The study also discovered that families headed by persons with higher levels of education and those who had access to extension knowledge were more likely to embrace tissue culture banana technology. Household heads who had received a higher degree of education and had access to extended knowledge were more likely to have greater access to information. This increased access made them more inclined to try out new technologies, in contrast to individuals with lesser levels of education.

A study conducted by Ndiritu & Ruhinduka (2019) revealed that the availability of resources has a significant role in the acceptance and implementation of advanced and contemporary storage technologies. Additionally, the study revealed that having access to extension services enhanced the probability of adopting post-harvest technology. The report, titled "Adoption Study of postharvest and Agro-processing Technologies and Interventions in Nigeria: Reasons for Adoption and Non-adoption (2012 – 2016)" conducted by BK Consult Ltd in 2016, identified ignorance of technology existence, non-availability, and high Cost as the primary factors hindering the adoption of technologies. In addition, the influence of wealth inequality on technology adoption has been observed, though earlier research has primarily focused on examining this phenomenon at a micro level (Hooks et al., 2022). For processors, the ease of doing business in each country also influences the decision on technology adoption. A study by Githumbi (2022) also found that experience was a factor that positively influenced the adoption of post-harvest technologies. Nevertheless, there is a scarcity of empirical assessments about the factual knowledge of adoption and the effects of technology.

Critically examining these factors, their interconnectedness, and their complex nature is a challenge for farmers because demand, cost, awareness, perception/attitude, and facilitation are the primary factors that are not mutually exclusive. While access to education, income levels, and extension services play a pivotal role, they also cannot be considered in isolation. These variables interact to shape farmers' decision-making processes such that even with high levels of education and knowledge about technology, without adequate financial resources, adoption rates may remain low. In addition, market demand can encourage technology uptake, but if the farmers feel that the costs of technology and integration of innovative practices are prohibitive, even high demand may not be enough to drive adoption. Additionally, finances remain a fundamental barrier because awareness and education alone cannot guarantee adoption if farmers lack funding for new technologies or when they cannot match the exorbitant prices. Once we can understand how these factors interrelate in this study, policymakers and agricultural stakeholders can develop more targeted interventions that enhance technology uptake among banana farmers in Vihiga County.

2.4 Conceptual Framework

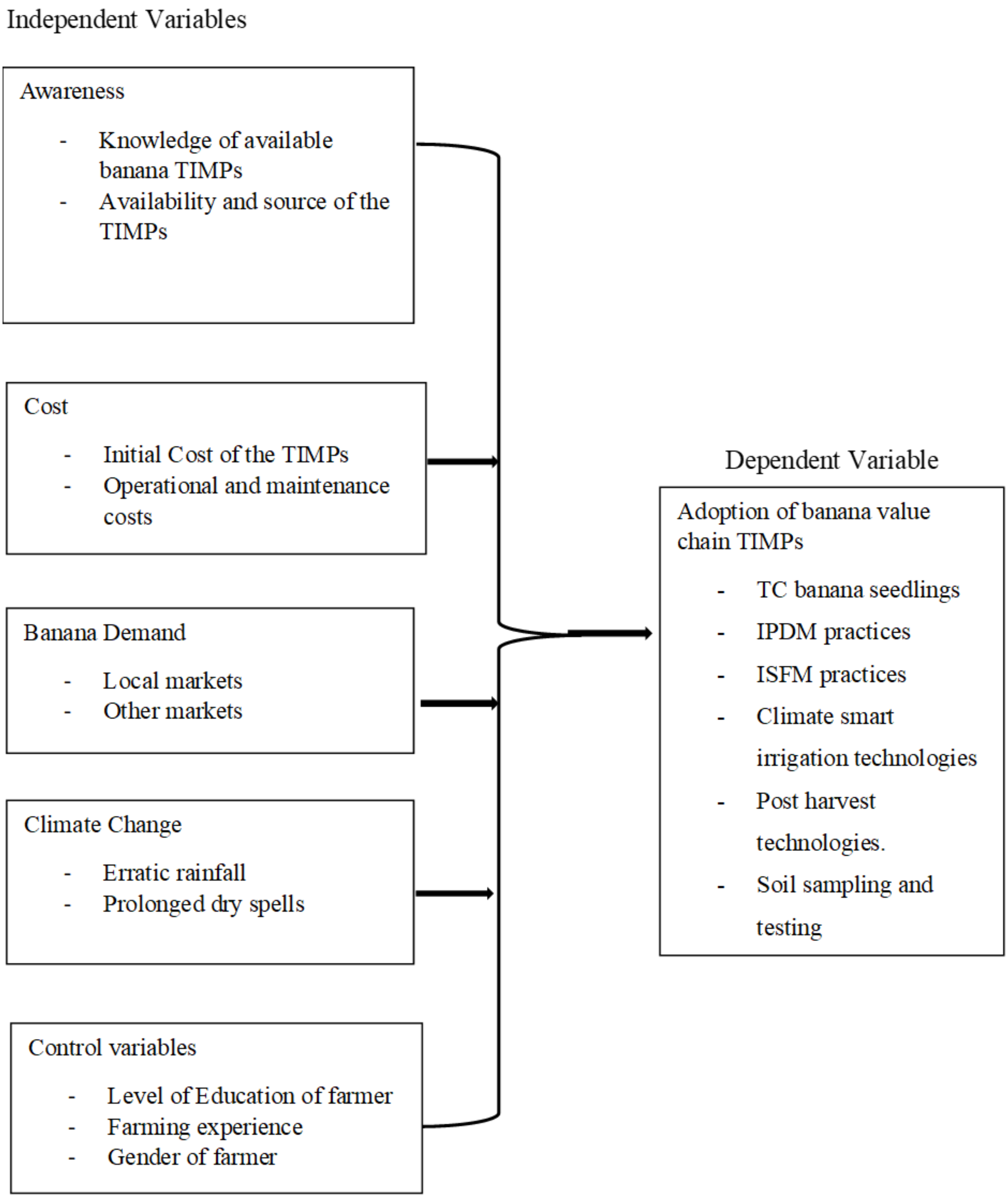

Figure 1:Conceptual Framework

Source: Author, 2024

2.5 Operationalization of Variables

2.5.1 Independent Variables

1. Awareness: Farmers' knowledge and familiarity with Technology and innovative practices influence their adoption rates. Considerably, farmers with higher awareness levels have positive attitudes toward innovative practices and the adoption of agricultural technologies. Awareness can be measured through surveys, participation in training, and familiarity with specific TIMPs (Acheampong et al., 2018).

2. Cost: The financial factor affects the adoption of TIMPs because these practices require a heavy initial investment and some might have maintenance expenses, which affect farmers' or institution's ability to adopt innovation and technology, especially for small-scale farmers. While some technological inputs might be expensive, cost also entails the willingness to pay and the availability of credit or subsidies, which might motivate the stakeholder to adopt technology (Khaspuria et al., 2024).

3. Market Demand for Bananas: Market demand is dictated by consumer preferences, product availability, and variety, which then affects the farmer's need to increase production. This might prompt farmers' interest and need for TIMPs to increase their productivity and reduce post-harvest loss (FAO, 2024). It is measured through banana sales volume, price trends, and farmers' perceptions of market stability (Kanyenji et al., 2020). With high market demand and stable conditions, there is a strong motivation for farmers to invest in productivity-enhancing TIMPs because the returns justify the investment in TIMPs.

4. Climate Change: Climate change impacts banana crops by causing low yields or increasing vulnerability to diseases due to various environmental changes, such as prolonged drought and irregular rain patterns. This impacts the adoption of TIMPs. This is measured through historical weather data of different climatic zones or geographical locations, and depending on the climate change disruptions experienced, farmers embrace appropriate climate-smart technologies and practices such as drought-resistant varieties or modern irrigation technologies, according to the need.

2.5.2 Dependent Variable

Adoption of TIMPs: This is the degree to which farmers accept integrating TIMPs into their farming practices. A high adoption rate signifies the successful diffusion of TIMPs among farmers, whereas low adoption may indicate barriers such as financial constraints, lack of awareness, or insufficient market incentives (Omari et al., 2023). The adoption rates can be measured by the intensity of adoption, the number of technologies and practices adopted, and the reported satisfaction with their performance.

The dependent variable is a combination of six variables. These are tissue culture banana cultivars (tissue culture is a biotechnology), integrated pest and disease management, integrated soil fertility management and soil testing which are management practices. The others are climate smart irrigation technologies and post-harvest technologies, which are technologies and innovations.

Soil testing

Soil testing is the scientific analysis of soil samples to determine nutrient content (e.g., potassium, nitrogen, and phosphorus), pH level, organic matter composition, and soil texture to help farmers determine what crops work for their land, the fertility of their soil, and make informed decisions on fertilization, soil amendments, and irrigation (Swafo & Dlamani, 2023). According to Swafo and Dlamini (2023), banana farmers can use soil testing to identify the fertility of their soil, use it for intrinsic value, and integrate it with extrinsic properties such as environmental factors for increased production. In addition, site-specific soil management practices enhance crop productivity, and since banana farming requires optimal soil conditions to achieve high yields and disease resistance, farmers should test their soil to determine the nutrients and pH levels that will determine their fertilization decisions (Swafo & Dlamani, 2023). According to SHEP PLUS/MOALF (2019), banana production is best in fertile soils with a pH range of 6.0-7.5 and rich in organic matter. Soil testing practices, therefore, aim to inform the farmer on the fertility of their soil, nutrient deficiencies, pH levels, and drainage to help them identify optimization practices to integrate, such as irrigation, use of organic fertilizers, and nutrient management. Soil testing is therefore a dependent variable in this study because farmers' decision to conduct soil testing depends on their knowledge of soil fertility and nutrients, the perceived benefits of testing, and access to extension services. T

Tissue culture (TC) banana cultivars

Tissue culture (TC) banana cultivars are banana plantlets propagated in a controlled laboratory environment through micropropagation to create cultivars that are disease-free, genetically uniform, and more productive (Kumar et al., 2024). These plantlets come in varieties such as Cavendish, William Hybrid and FHIA family undergo a hardening process in nurseries that ensures they effectively adapt to outdoor conditions before being transplanted into farms (Kumar et al., 2024). According to Wahome et al. (2021), TC banana cultivars have helped address challenges such as pests, diseases, and declining soil fertility in Kenya, promoting faster growth because they grow and mature in 12-15 months, compared to the traditional 18+ months. In addition, bananas produced from TC cultivars have larger bunches and better fruit quality, increasing their market value (Wahome et al., 2021). Banana Farmers in Vihiga County can benefit from this practice because it is sustainable and increases production. Farmers' adoption of TC banana cultivars is dependent on farmers' access to nurseries or cooperatives supplying TC plantlets and the cost. TC adoption can also depend on IPDM because, as farmers become aware of pests and diseases, they might prefer TC plantlets due to their resistance to common banana diseases.

Integrated Pest and Disease Management (IPDM)

Integrated pest and disease management (IPDM) is a comprehensive approach that combines biological, cultural, mechanical, and chemical control variables to manage pests and diseases in crops effectively (Angon et al., 2023) to promote sustainable production. Banana crops are susceptible to various pests and diseases such as banana weevils, nematodes, Fusarium wilt, Black Sigatoka, and Banana Xanthomonas wilt that IPDM can help address (Angon et al., 2023). According to Angon et al. (2023), IPDM can be used to maintain ecological balance and biodiversity by integrating natural pest control methods and reducing the overreliance on chemical pesticides. Implementing IPDM can lead to increased agricultural profitability by lowering pest management expenditures and improving crop yields. Cultural control practices use disease-free seedlings such as the TC plantlets and advocate for intercropping and crop rotation to disrupt the pest life cycle, while biological control uses biopesticides or introduces natural predators or parasitoids to target specific banana pests (Angon et al., 2023). Applying the IPDM approach, mechanical control uses trapping and physical barriers to capture pests, while chemical control is the last resort and uses pesticides (Angon et al., 2023). The integration of these controls promotes sustainable banana farming by reducing losses caused by pests and diseases and helping farmers achieve better economic returns, but there is still slow adoption of the practice among banana farmers. Therefore, the adoption of IPDM depends on farmers' knowledge of pests and diseases, control methods, and access to biological and chemical pest management solutions.

Climate-Smart Technologies

Climate-smart technologies (CSTs) are innovative agricultural practices, tools, and techniques such as drip irrigation, biofertilizers, rainwater harvesting, agroforestry, cold storage, and solar drying, that help farmers adapt to climate change and improve productivity while enhancing crop resilience, sustainability, and efficiency to promote food security despite climate variability (Zhou et al., 2023). Since banana farming is highly sensitive to climate change, climate-smart technologies can help farmers protect their crops from erratic rainfall, prolonged droughts, rising temperatures, and increased pest and disease outbreaks (Zhou et al., 2023). According to Zhou et al. (2023), agricultural cooperatives play a vital role in promoting the adoption of climate-smart agricultural practices among banana farmers because of the slow adoption rate per farmer. Climate-smart technologies enable banana farmers to adapt to climate change, increase productivity, and ensure environmental sustainability. Climate-smart technology adoption is dependent on climate variability and water availability.

Integrated Soil Fertility Management (ISFM)

Integrated soil fertility management (ISFM) is a sustainable approach to improving soil fertility by combining organic inputs, inorganic fertilizers, and soil conservation techniques (Kihara et al., 2022). ISFM enhances soil productivity, optimizes nutrient use, and promotes environmental sustainability in banana farming by improving soil productivity and crop yields, soil structure, and water retention by increasing soil organic matter, and reduces soil degradation (Kihara et al., 2022). In addition, ISFM enhances soil nutrient efficiency and balances soil fertility by avoiding excessive use of a particular fertilizer, increasing nutrient uptake by crops (Kihara et al., 2022). Therefore, the adoption of ISFM depends on farmers' awareness of soil fertility and degradation. Farmers who conduct soil testing are more likely to adopt ISFM, as test results inform them about nutrient deficiencies that require correction.

Post-harvest technologies

Post-harvest technologies in banana farming include the integration of scientific methods, tools, and innovations after harvesting to preserve the quality of the fruit, reduce losses, and extend its shelf life (Guo et al., 2020). As a perishable product, banana harvesting requires proper mechanized picking to minimize physical damage, a transportation system, and mechanized de-handling to separate banana hands from bunches (Guo et al., 2020). In addition, banana ripening technologies such as the micro-bubble technique that uses ethylene can accelerate and promote uniform ripening (Pongprasert et al., 2020). These technologies reduce post-harvest losses, improve efficiency while reducing labor costs, hasten ripening, and improve market value through banana processing and packaging of banana chips, puree, and flour (Pongprasert et al., 2020). The adoption of post-harvest technologies depends on the size of the farm and awareness of mechanized handling, storage, and ripening techniques.

Therefore, since these adoption decisions are not independent and farmers adopt multiple TIMPs simultaneously based on their needs, resources, and market conditions, a Multivariate Probit (MVP) model was used to simultaneously estimate seven equations. The MVP model recognizes that the probability of adopting one TIMP depends on whether another TIMP has been adopted.

2.5.3 Control Variables

These are factors that might influence the adoption of TIMPs but are not primary independent variables in this study.

- **Age:** According to Omari et al. (2023), younger farmers are more likely to adopt TIMPs because they are exposed to innovative practices and use of technology in different industries, they have innovative mindsets, and their inclination towards agri-business, compared to older farmers who are more familiar with conventional farming practices.
- **Education Level:** According to Kabirigi et al. (2022), farmers with formal and higher education levels have a greater likelihood of adopting TIMPs compared to uneducated farmers whose perspectives incline towards informal and traditional farming practices.
- **Farm Size:** Larger farms may have greater resources and need to invest in TIMPs compared to smaller farms because of their economic scale (Madalla et al., 2023).
- **Access to Funding:** According to Kurgat et al. (2020), farmers with access to subsidies and financial credit are more likely to adopt TIMPS because they have a way of handling the economic constraint compared to farmers with no access to any form of funding.
- **Extension Services and Facilitation:** Waseem et al. (2020) argue that farmers who can easily access experts and training programs have a higher adoption rate because of enhanced knowledge diffusion and a supportive environment.

2.6 Chapter Summary

This chapter was a review of related literature in theories, constructs, and concepts on technologies, innovations, and management practices adopted among banana farmers in Vihiga County. The chapter looked at theoretical theories guiding the study. These are the UTAUT theory and the Innovation Diffusion Theory. Additionally, it reviewed the empirical studies on awareness and cost of the technologies, innovations, and management practices. It also reviewed the demand for bananas and the effects of climate change on the adoption of technologies, innovations, and management practices. This chapter also presented a conceptual framework for the research and covered the operationalization of variables.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter provides an overview of the technique that was used in this study, including the research design, the target population, and the sampling processes. Additionally, it provides a comprehensive explanation of the procedures used to gather data and the analytical tools employed for data analysis.

3.2 Research Philosophy

According to Ryan (2018), research philosophy is the set of beliefs, assumptions, and principles that guide a researcher's approach to knowledge development. For this study, we shall follow positivism. According to Park et al. (2019), positivism emphasizes empirical observation, measurement, and experimentation to gain knowledge and understanding. To prioritize objectivity when studying factors influencing the adoption of TIMPs among banana farmers, the study will minimize individual and social bias and subjective interpretations by using structured data collection methods such as questionnaires, standardized surveys, and integrated statistical controls (multivariate probit model). When studying technology adoption, positivism helps researchers collect and analyze data unbiasedly, focusing on measurable indicators such as adoption rates, usage patterns, and economic impacts. Furthermore, positivism strongly supports using quantitative approaches for gathering and analyzing data, such as surveys, experiments, and statistical procedures.

3.2.1 Ontological and Epistemological Justification

Since ontology addresses the nature of reality, positivism is justified because it assumes that objectivity exists independent of human perception (Al-Ababneh, 2020). This aligns with this study because it measures real-world adoption rates and trends among banana farmers through empirical observation and statistical analysis. Additionally, Al-Ababneh (2020) asserts that epistemology concerns how knowledge is acquired and validated. The philosophy justifies positivism because knowledge is acquired and validated using empirical verification that is derived from observable and measurable data. This complements the study’s reliance on statistical data analysis, ensuring that findings are based on quantifiable evidence to establish a factual relationship between factors that influence the adoption of TIMPs.

3.2.2 Consideration of Alternative Research Philosophies

Interpretivism: According to Ryan (2018), this approach expands on the subjectivist approach since it argues that knowledge is socially constructed. This asserts that social phenomena are to be understood based on the social meanings that people or groups assign to them, rather than through measurable variables. This philosophical approach is not viable for this study because we are looking for quantifiable insights.

Pragmatism: According to Maarouf (2019), the flexibility of this philosophy suggests that the researcher should not choose a single paradigm, but the selection should be based on the research questions and what approach works best in answering them. This approach could allow for qualitative and quantitative methods, but it is not fit for this study because we seek explanations through statistical analysis.

Given the realist ontology (an objective reality exists) and the empirical epistemology (knowledge is based on measurement and observation), positivism aligns best with the study's goals. Since this was quantitative research, the positivist philosophy was suitable. Positivism also identifies causal relationships between variables. Positivism assessed the technology features, training programs, economic incentives, and adoption outcomes for this research.

3.3 Research Design

A research design functions as a detailed plan and structure for the research process, directing the gathering of information to address the research inquiries being examined (Cash, 2018). It provides a framework for the research and instructions on how different research components come together to answer the main research questions of the investigation. The study adopted a quantitative descriptive research methodology to achieve its objectives. This design is pertinent as it elucidates the relationship between the variables under study. Quantitative research designs prioritize systematically measuring the studied phenomenon using mathematical and statistical methods. Moreover, the descriptive aspect of this methodology focuses on addressing questions related to the "what," "where," and "how" aspects of the subject matter (Siedlecki, 2020).

3.4 Population and Sampling

3.4.1 Target Population

According to Mugenda and Mugenda (2003), the population is defined as a group of persons, things, or items from whom samples are chosen for measurement. Vihiga County has a population of 590,013 (KNBS, 2019), 85% of whom reside in the rural areas and practice agriculture (County Government of Vihiga, 2018) The target population for the study was the banana farmers located within the five sub-counties of the country.

According to data from the Kenya Integrated Agriculture Management Information System (KIAMIS), 2023, Vihiga County has 37,877 registered banana farmers.

Table 3.1: Study Population

Sub County	**No. of Banana farmers**
Sabatia	15,510
Hamisi	11,297
Vihiga	5,252
Emuhaya	2,991
Luanda	2,827
Total	**37,877**

Source: KIAMIS (https://www.kalro.org/kiamis/), 2024

3.4.2 Sampling Design

A sample is defined as the portion of a more significant population research interest that is selected for analysis (Mugenda & Mugenda, 2003). For this study, a simple random sampling technique was used.

To find out the sample size, Yamane's formula was used as follows; -

$n = N/1+N (e)^2$

Where; -

n= the sample size

N = the population of the study

e = the margin error of calculation at 0.05

This means that -

$n = 37,877/1+37,877 (0.05)^2$

=396 farmers

This study's lowest recommended number of respondents is 396 banana farmers. The percentage distribution was based on the number of registered banana farmers, who were registered as individuals, within their respective sub-counties.

Table 3.2: Sample size

Sub County	**No. of Banana farmers**	**Sample size**	**Portion of sample (%)**
Sabatia	15,510	162	41%
Hamisi	11,297	118	30%
Vihiga	5,252	55	14%
Emuhaya	2,991	31	8%
Luanda	2,827	30	7%
Total	**37,877**	**396**	**100%**

Source: KIAMIS & Author (2024)

3.5 Data Collection Methods

The data collection instrument for this study was a questionnaire that was scripted and administered via the Kobo collect toolbox. The researcher acquired the required documentation, including a cover letter and a participant consent form, which were used to introduce the researcher to the respondents and provide them with information about the study. The questionnaire had both closed-ended and open-ended questions that were constructed to address the four specific research objectives. Enumerators helped with data collection. The consent note, cover letter and questionnaire are attached to this dissertation as appendix 1,2 and 3 respectively.

3.5.1 Operationalization of Variables

Table3.3: Operationalization of Variables

Variable	Indicators	Data Collection Instrument	Measure
Awareness of technologies, innovations, and management practices	Access to information (from technology providers to farmers) Accessibility of experts and services	Questionnaire	Knowledge of the TIMPs Access to extension services Distance to nearest TC nursery and to center selling banana technologies
Cost of the technologies, innovations, and management practices	Financial resources spent on existing TIMPs. Financial resources willing to spend on TIMPs	Questionnaire	Amount spent on acquiring adopted TIMPs. Amount willing to spend to acquire other TIMPs.
Banana demand	Quantity of bananas produced since adoption of TIMPs. Quantity of banana sold	Questionnaire	Quantity of bananas produced and sold. Banana demand patterns
Effects of climate change on the adoption of TIMPs	Effects of erratic rainfall Effects of longer dry spells	Questionnaire	Rainfall patterns Duration of dry spells
<u>Dependent Variables</u> TC banana seedlings IPDM and ISFM practices Post harvest technologies.	Quantities adopted	Questionnaire	No. of technologies Level of adoption

Source: Author, 2024

3.6 Research Quality

Validity is the extent to which the questionnaire tests what it intends to measure, while reliability indicates the consistency and relevance of the measurements to the study's objectives. In this research, questionnaire development underwent pre-testing, verification, and validation processes. To ensure the validity of the results, the questionnaire was developed using comprehensive peer-reviewed research with the input of an expert. It was also reviewed by the expert before deployment to ensure it covered all relevant aspects of TIMPs' adoption in banana farming (Hayashi et al., 2019). We also had a pre-test with 10 respondents in Vihiga County to analyze the responses and eliminate any leading or ambiguous questions. Since the study uses the Multivariate Probit Model, validity was tested using a predictive test that compared the actual TIMPs adoption behaviors with the predicted probabilities from the MVP Probit Model.

3.7 Data Analysis

Before conducting the main data analysis, the study underwent a pilot test to evaluate the clarity, reliability, and validity of the research instrument. The pilot study was conducted among 15 banana farmers in Vihiga County, who were not part of the final survey. The aim was to identify ambiguities, assess question comprehension, and refine the questionnaire before full deployment.

Before analysis, data was cleaned and checked for completeness and accuracy. Based on the objectives of this study, a correlational analysis and a regression analysis were used to analyze the data. A multivariate probit model was used in the analysis because the adoption of technologies, innovations, and management practices, which was the dependent variable, was determined by awareness, cost, availability, banana demand and the effects of climate change on adoption. The response was binary and was either adoption or non-adoption; hence, the multivariate probit model was used for the analysis. Descriptive statistics helped in contextual understanding of the variables and summarized the data in tables and pie charts and represented the distribution frequencies.

3.7.2 Multivariate Probit Regression

A Multivariate Probit model (MVP) is a model that is particularly suitable for analyzing correlated binary data. The expected findings of this study were binary, as the banana farmers either adopted the TIMPs or did not adopt them. The MVP model was selected to recognize the correlation in the error terms of adoption equations (Zhang, 2020). The model was summarized as follows; $A_i^* = \beta_{ij} X_j + \varepsilon_i$

$$A_i = \begin{cases} 1 \text{ if } A_i^* > 0 \\ 0 \text{ Otherwise} \end{cases}$$

Where; -

i = 1…k denotes the factors influencing the adoption of the technologies, innovations, and management practices. Dummy variables will be constructed for the following adoption factors: awareness of the TIMPs, availability of the TIMPs (distance to nearest market/place to purchase them), cost of the technologies, banana demand (banana quantities sold), and the effects of climate change (rainfall patterns) on adoption.

X is the control variable. These are the same for the different factors influencing adoption.

ßij is a vector of parameters to be estimated and ε is an error term that may be correlated.

i refers to adoption of soil sampling and testing, tissue culture banana seedlings, integrated pest and disease management practices (IPDM) and technologies, climate smart irrigation technologies, integrated soil fertility management practices (ISFM) and technologies.

3.8 Ethical Issues

This research was conducted in a straightforward and honest manner, guided by integrity, respect for the participants' rights, and objectivity, where the participants had the freedom to engage willingly, without coercion. Approval from the Strathmore University Ethics Review Board and the National Commission for Science, Technology, and Innovation (NACOSTI) was obtained before carrying out the research. Moreover, the participant's consent was sought before data collection commenced.

However, there was potential bias from enumerators because, with their training, their perception and interpretation can cultivate interviewer bias. We therefore eliminated any leading questions for standardization. There were some confidentiality concerns among the respondents, and we resolved this by eliminating any identifiable data, such as names, and the enumerators had to sign non-disclosure agreements (NDAs) to prevent data misuse. In addition, data security was assured by the use of the Kobo Collect system, which encrypts data and stores it in secure servers, and only the principal investigator had access to the data before it was removed after the study**.** The study considered all social safeguards and data protection standards required before, during, and after the study. The privacy of the information provided by study participants and the anonymity of respondents were upheld.

3.9 Chapter Summary

This chapter outlined the research methodology employed to investigate the factors influencing the adoption of Technologies, Innovations, and Management Practices (TIMPs) among banana farmers in Vihiga County. The study was grounded in a positivist research philosophy, using a quantitative descriptive design to ensure objectivity and replicability. It targeted a population of 35,860 banana farmers across all five sub-counties of Vihiga County, from which a representative sample of 392 respondents was selected through stratified random sampling. Data was collected using structured questionnaires and analyzed using a Multivariate Probit (MVP) regression model to account for the interdependence of adoption decisions across multiple TIMPs. The chapter also discussed the operationalization of variables, ethical considerations, and measures taken to ensure reliability and validity of the research, thereby laying a robust foundation for the subsequent presentation and interpretation of findings.

CHAPTER 4: RESEARCH FINDINGS PRESENTATION

This chapter includes the analysis of data, findings, and interpretations. Results are displayed in tables and diagrams. The analyzed data is organized into themes aligned with the research objectives. It provides demographic information about the farmers, descriptive statistics of the findings, correlation and multivariate probit model findings and a chapter summary.

4.1 Response Rate

The dataset comprised of 392 survey responses collected from farmers in five sub-counties within Vihiga County: Vihiga, Sabatia, Hamisi, Luanda, and Emuhaya. This represented 99% of the target, which was 396 farmers. The response rate achieved was deemed adequate according to the assertions of esteemed scholars (Mugenda & Mugenda, 2003).

Table 4.1: Respondent Response Rate

Sub-county	Targeted sample size	Achieved	Percentage Achieved
Sabatia	162	158	98%
Hamisi	118	118	100%
Vihiga	55	55	100%
Emuhaya	31	31	100%
Luanda	30	30	100%
Grand Total	**396**	**392**	**99%**

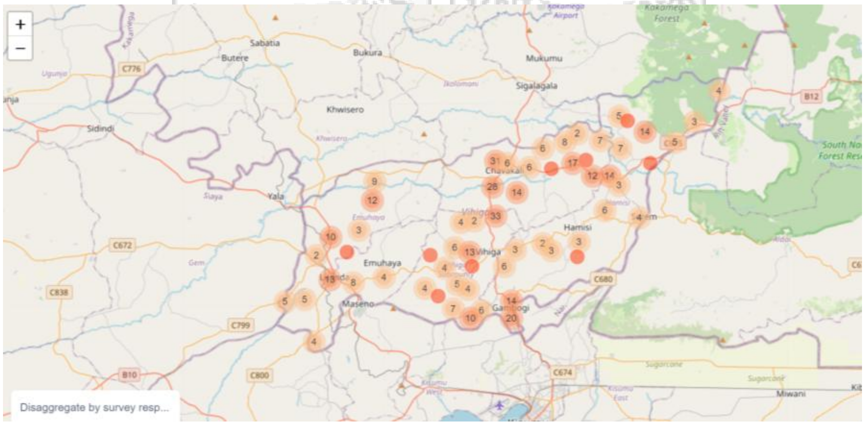

Figure 2: Distribution of respondents across the County

4.2 Farmer Demographics and Farm Sizes

4.2.1 Age

The average age of the farmers was 57 years, with a standard deviation of 15 years. The age range ranged from a minimum of 25 years to a maximum of 91 years. 27% of respondents were aged between 50-59 years, 24% aged between 60-69 years, 16% were aged between 40-49 years, 15% were aged between 70-79 years, 10% were aged between 30-39 years, 5% of banana farmers were aged between 80-89 years. Only 3% of farmers interviewed were aged between 20-29 years and 1% were aged between 90-100 years. These demographic characteristics promote understanding of the awareness and adoption of TIMPs. Since older farmers may have more farming experience yet, the younger farmers are inclined to adopt new technologies affecting overall adoption rates.

Table 4.2: Age of banana farmers

Age of banana farmers (respondents)	
Mean	56.610
Standard deviation	14.530
Minimum	25
Maximum	91
Number of observations	392

4.2.2 Gender of Respondents

The survey included both male and female farmers; however, female respondents represented a larger portion of the sample, with 227 responses compared to 165 from male farmers. 58% of respondents were female, while 42% were male. The high response rate therefore indicates that the data collected is highly representative, with minimal potential non-response bias. Since gender differences can influence access to resources and training, if women face greater financial or informational barriers, it could impact their ability to adopt TIMPs.

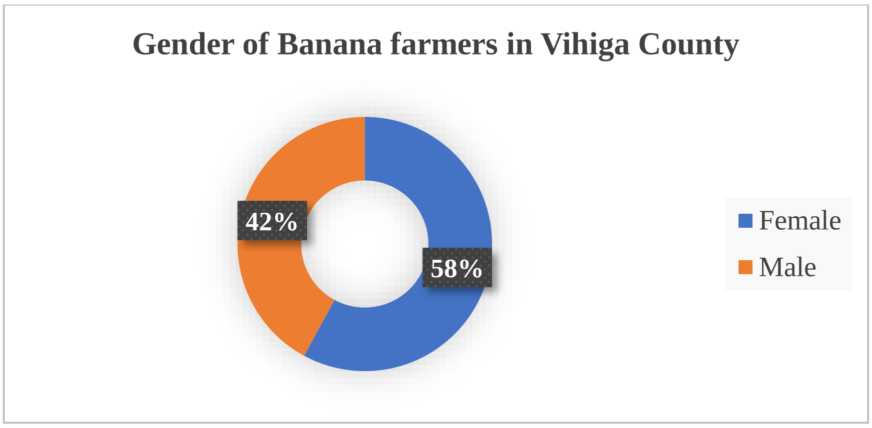

Figure 3: Pie chart showing gender of banana farmers in the county

4.2.3 Schooling Years

Most farmers completed primary education, with secondary school being the next most common level attained, indicating that higher levels of education are less prevalent among this group. On average, the respondents spent 10 years in school. On average, 43%, 33%, 21%, and 3% of the respondents attained primary, secondary, college/TVET, and University as their highest education respectively. Education levels influence awareness and willingness to adopt new farming technologies and farmers with higher education levels may better understand the benefits and methods of implementing TIMPs, increasing their adoption rates.

Table 4.3 and Figure 4 summarize the findings.

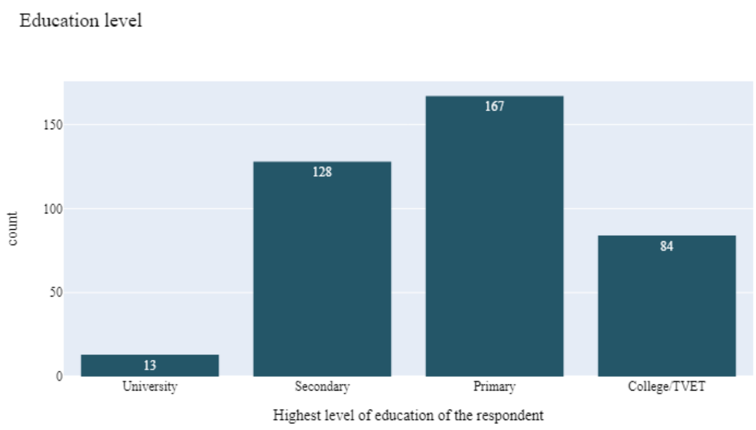

Figure 4: Education Level of Banana farmers

Table 4.3: Average years spent in school

Average years spent in school	
Mean	9.870
Standard Deviation	4.024
Minimum	0
Maximum	19
Number of observations	392

4.2.4 Banana Farming Experience

The average duration of experience in banana cultivation among farmers is 20 years, with a range extending from 1 year to 65 years. Significantly, 75% of farmers have over 27.25 years of experience, indicating a considerable level of expertise among the majority. Furthermore, 61% of these farmers have reported receiving formal training in banana farming, which further enhances their skill set and knowledge in the field.

Table 4.4 summarizes the banana farming experience in the county.

Table 4.4: Banana farming experience

Banana farming experience	
Mean	19.73
Standard Deviation	13.425
Minimum	1
Maximum	65
Number of observations	392

4.2.5 Farm size

Farm sizes in Vihiga County varied from 0.02 acres to 20 acres, with an average size of 1.5 acres. The land specifically used for banana farming ranges from 0.01 acres to 2 acres, with an average of 0.24 acres and a standard deviation of approximately 0.25 acres. These figures indicate that banana farming in Vihiga County is predominantly small-scale, and this may decrease the demand or need for TIMPs in Vihiga County.

Table 4.5: Total farm size and land under banana(acres)

	Total land size owned by the respondent (acres)	Land under banana (acres)
Mean	1.507	0.238
Standard Deviation	1.650	0.235
Minimum	0.02	0.01
Maximum	19	2
Number of observations	391	391

4.2.6 Banana Production

Production levels exhibit considerable variation, with yields ranging from 500 kg to 10,000 kg and an average annual yield of 976.10 kg from their banana orchards which averaged 0.2 acres (12.2t/ha). This is slightly above the county average of 10t/ha in 2022. However, the production is below FAO's recommended production of between 20-50t/ha. The minimum was zero because some farmers had young banana orchards that had not started fruiting. Therefore, increased demand would increase the adoption of TIMPs and high adoption levels would further increase production and profitability.

Table 4.6: Average banana production

Quantity of bananas (Kgs)harvested in the last 12 months	
Mean	969.960
Standard Deviation	1218.764
Minimum	0
Maximum	10000
Number of observations	391

4.3 Awareness of Technologies, Innovations, and Management Practices

4.3.1 Training, Access to Information, and Extension Services

The data revealed several critical insights into the information sources utilized by farmers for banana cultivation. 60% of the respondents indicated that they have received training on banana production, while 40% of respondents have not received training on banana production. On the same line, 60% of respondents indicated that they have regular access to information on banana TIMPs, and 40% of the respondents do not have regular access to information on TIMPs.

62% of the respondents have access to extension services, and 38% do not have access to extension services. Table 4.7 below shows the distribution of the training, regular access to information on TIMPs, and access to extension services across the sub-counties.

Table 4.7: Training, Access to Information, and Extension Services

		Emuhaya	Hamisi	Luanda	Sabatia	Vihiga	Overall
Training in banana production	Yes	32%	65%	41%	66%	62%	60%
	No	68%	35%	59%	34%	38%	40%
	Total	100%	100%	100%	100%	100%	100%
Regular access to information on banana TIMPs	Yes	35%	78%	38%	63%	51%	60%
	No	65%	22%	62%	37%	49%	40%
	Total	100%	100%	100%	100%	100%	100%
Access to extension services	Yes	32%	83%	34%	61%	58%	62%
	No	68%	17%	66%	39%	42%	38%
	Total	100%	100%	100%	100%	100%	100%

4.3.2 Source of Information on Banana TIMPs

Banana farmers acquired information on TIMPs from multiple sources. A significant majority, specifically 257 farmers, relied heavily on government extension officers for information on technologies, innovations, and management practices (TIMPs). This reliance highlighted the essential role of government extension services in disseminating agricultural knowledge. However, the fact that 145 farmers lacked access to these services indicated a notable gap, underscoring the need for expanded extension programs to better reach and support all farmers. In addition, e-extension methods, such as radios, television, and mobile phones, are vital sources of information for 208 farmers. This demonstrates the effectiveness of digital and broadcast media in reaching a wide audience. Public events like exhibitions, shows, and field days also play a crucial role, with 148 farmers engaging in these interactive and hands-on experiences, which complement other information sources.

Social media is emerging as a smaller source of information, utilized by 66 farmers. Conversely, print media was used minimally, with only 64 farmers relying on it. Overall, the data highlights an urgent need to improve access to information and extension services, as 153 farmers do not receive relevant information, and 145 lack extension support. Figure 5 illustrates the sources of information for farmers.

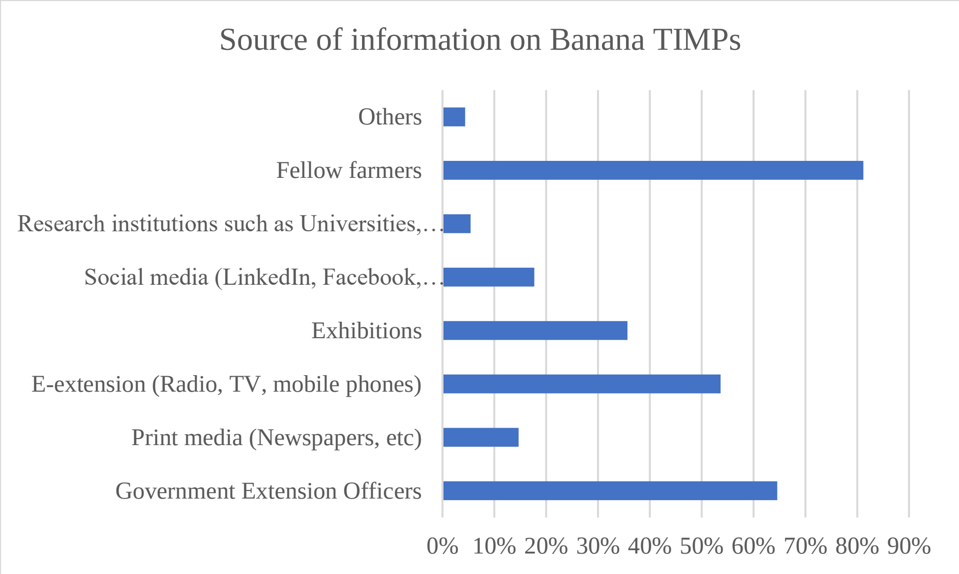

Figure 5: Sources of information on TIMPs by banana farmers

4.3.3 Awareness and Adoption of Banana TIMPs

The comparison of adoption rates relative to awareness of various technologies, innovations, and management practices among farmers revealed distinct patterns. For tissue culture banana cultivars, the adoption-to-awareness proportion is 77.0%, indicating a strong conversion of awareness into practice. Integrated soil fertility management (ISFM) practices and technologies had an even higher proportion of 85.0%, showing effective uptake among those who were aware. In contrast, integrated pest and disease management (IPDM) practices and technologies exhibited a lower adoption-to-awareness proportion of 67.0%, suggesting that while many farmers are aware of these practices, fewer have adopted them. Soil sampling and testing faced a significant gap, with a proportion of only 21.0%, reflecting a low adoption rate despite awareness.

Climate-smart irrigation technologies had a proportion of 45.0%, indicating some level of adoption relative to awareness. Tools for crop management had a proportion of 52.0%, showing a moderate level of adoption among those aware of these tools. Banana waste management innovations and post-harvest technologies faced particularly low adoption-to-awareness proportions, at 17.0% and 14.0%, respectively. These low proportions highlighted substantial barriers to translating awareness into actual adoption.

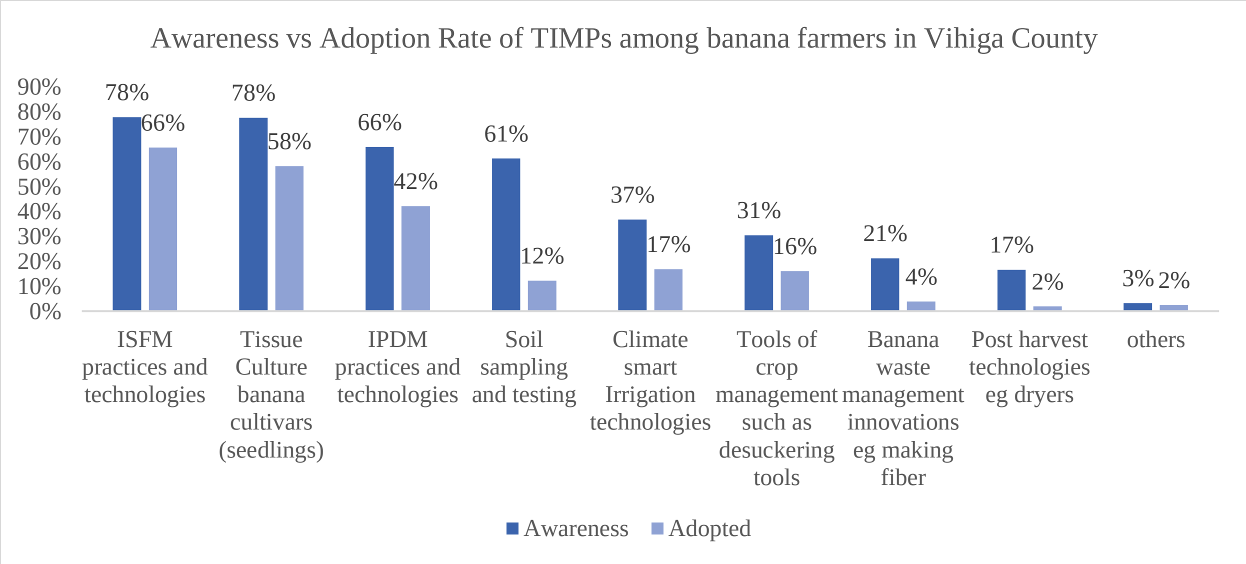

Figure 6: Awareness vs Adoption Rate of TIMPs among banana farmers in Vihiga County

4.3.4 Availability of TIMPs

Approximately 59.7% of banana farmers reported that TIMPs sources were available to them when needed, whereas 40.3% had a contrary opinion. This suggests that while many farmers had access to TIMPs, a significant portion do not perceive them as readily accessible. Despite this availability, a considerable majority of farmers, 277 out of the total surveyed, did not engage in research to explore all available technologies, nor did they conduct cost-benefit analyses to evaluate their effectiveness. Only a smaller group of 115 farmers actively undertook these practices, indicating a gap in the proactive utilization of available resources.

In terms of accessibility, 60.5% of farmers stated that sources of TIMPs were either on their farms or easily reachable, with an average distance of 11.2 kilometers to the nearest purchase center for banana TIMPs. The shortest distance reported was just 0.1 kilometers. However, 39.5% of farmers reported difficulties in accessing these technologies, with some having to travel up to 20 kilometers to reach a TIMPs center.

Table 4.8: Banana TIMPs availability

		Emuhaya	Hamisi	Luanda	Sabatia	Vihiga	Average
Famers who do a cost benefit analysis before adoption	Yes	13%	27%	28%	36%	27%	30%
	No	87%	73%	72%	64%	73%	70%
Farmers who indicated that the TIMPs are available	Yes	39%	80%	28%	63%	27%	57%
	No	61%	20%	72%	37%	73%	43%
Farmers who indicated that the TIMPs are accessible	Yes	35%	77%	24%	71%	24%	59%
	No	65%	23%	76%	29%	76%	41%

4.3.5 Challenges Faced in Accessing the Technologies Innovations, and Management Practices

The research sought to find out the challenges faced by farmers in their quest to access banana technologies, innovations and management practices. The respondents indicated that financial constraints were the biggest barrier, followed by information asymmetry on banana TIMPs within the country. Financial resources are required to purchase TIMPs and pay for transport and labour. Extension officers and institutions producing the TIMPs did not share information and skills on operationalizing the TIMPs. Inadequate information was a result of limited awareness of the technologies.

4.4 Cost of Technologies, Innovations, and Management Practices

4.4.1 Banana Farming Costs

Among the costs associated with banana production, the acquisition of Tissue Culture (TC) banana seedlings was noted as the highest expense, followed by the costs for IPDM practices. This is attributed to the fact that there was no tissue culture propagation center within the county and the neighboring counties (FSPN Africa). The cultivars are imported from central Kenya, specifically Kiambu (mainly JKUAT) and Murang'a counties, and from Kisii county. Conversely, the least expensive components are categorized as other TIMPs, harvesting and post-harvest handling costs, and tools for crop management. These insights underline the financial challenges faced by farmers in adopting advanced agricultural practices and highlight the importance of accessible credit solutions to support their needs. Figure 7 below depicts the highest costs associated with the adoption of technologies, innovations, and management practices among banana farmers in Vihiga County.

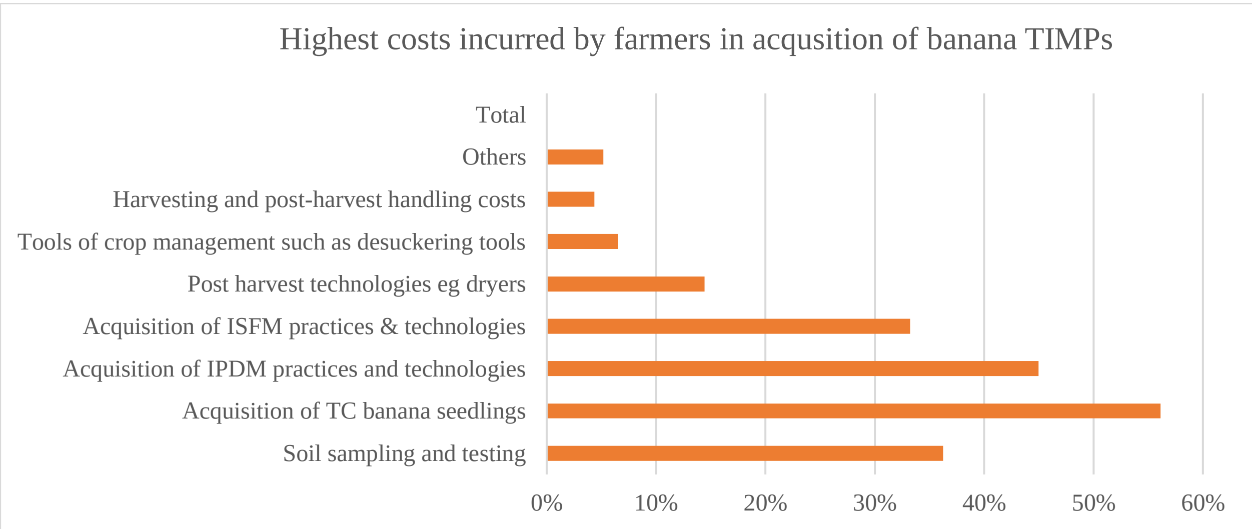

Figure 7: Highest Costs incurred by Farmers in the acquisition of Banana TIMPs

On average, the cost incurred by farmers for the acquisition and implementation of TIMPs on banana farms is KES. 37,119.50. The range of expenditure is considerable, with the maximum amount reported being KES 622,222.20. Notably, 75% of farmers spend more than KES 5,800 on TIMPs, whereas the remaining 25% invest less than KES 1,500. Among the various TIMPs, tissue culture banana seedlings are reported to have the highest implementation cost, as cited by 209 farmers. This was followed by costs associated with IPDM practices and technologies, post-harvest technologies, and ISFM practices and technologies. In contrast, tools for crop management and harvesting and post-harvest handling were the least expensive to implement.

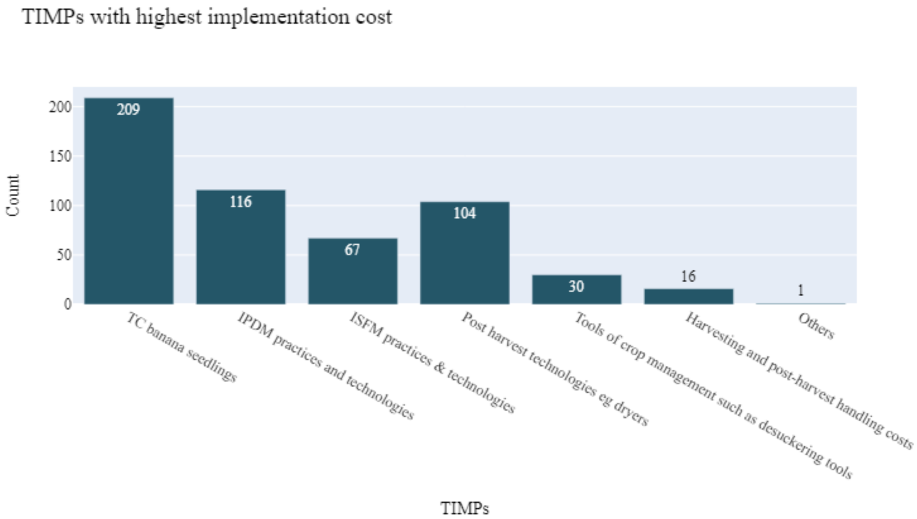

Figure 8: Highest implementing costs of banana TIMPs in Vihiga County

4.4.2: Access to Credit

Financial accessibility was a significant concern for many farmers, with 74% indicating that they required credit to purchase banana TIMPs. Only 26 % of farmers reported being able to finance these purchases without external credit. The credit was mainly from village savings and loan associations (VSLAs), mobile FinTechs, and overdraft facilities. Since, in most cases, the amounts needed are less than KES 20,000 on average, the farmers did not visit microfinance institutions and banks to seek credit. This can be attributed to the fact that many of the banana farmers are mixed farmers, and that the banana farming enterprise may not be the prioritized value chain within the farm, hence, the farmers tend to be risk-averse when it comes to investing their resources to grow the enterprise on their farms. They tended to focus on the staples, mainly maize and beans, and traditional cash crops of the county, such as tea.

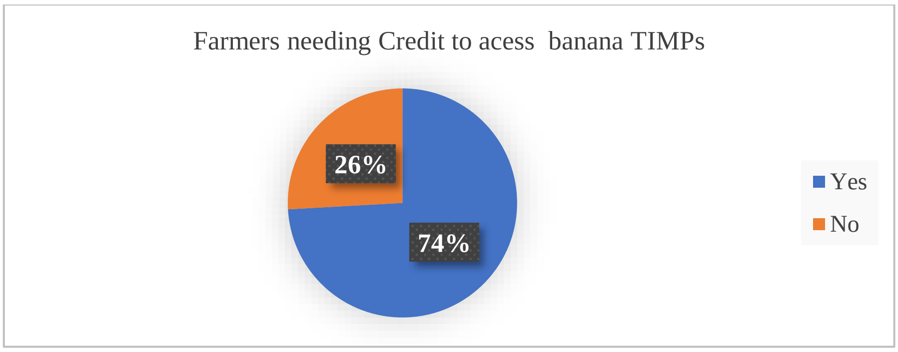

Figure 9: Percentage of farmers needing credit for purchase of banana TIMPs.

The research also sought to find which TIMPs the farmers would need credit to access. It was clear that farmers needed credit to access several TIMPs. As shown in Figure 9 below, 63% of respondents indicated that they would need credit for soil testing services, 59% would need credit to acquire and practice IPDM practices, 56% would need credit to acquire and practice ISFM practices while 55% would need credit for purchase of tissue culture banana seedlings. On harvesting and post-harvest handling TIMPs, 30% of the farmers would need credit to access them.

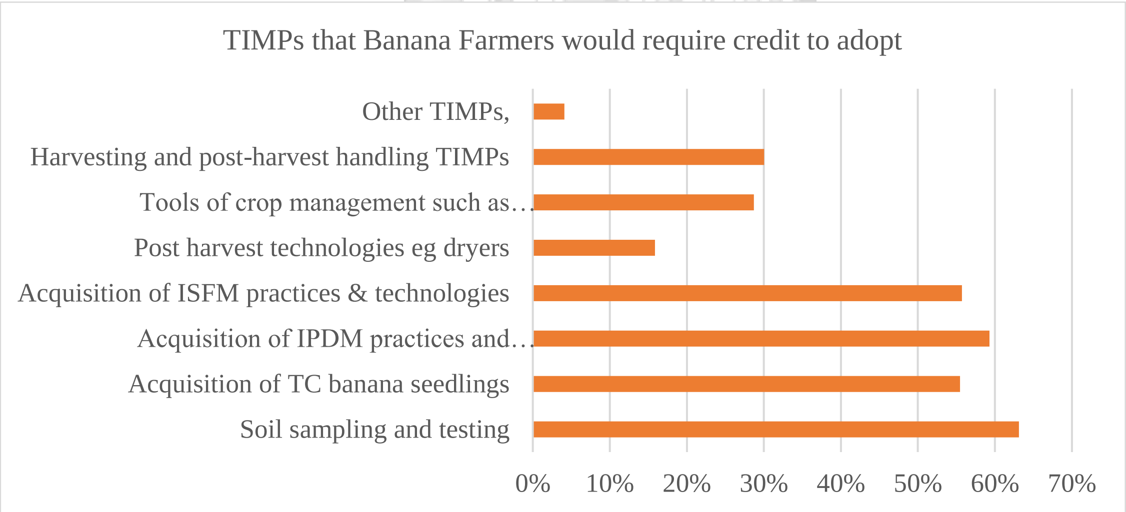

Figure 10: TIMPs that farmers would need credit for adoption.

The adoption of banana TIMPs was cost sensitive. As summarized in Table 10 below, 66% of respondents would consider the cost of the TIMPs before adopting them, while 34% would adopt them without considering the cost. This is attributed to the low incomes of most of the banana farmers, and the fact that they do not practice commercial banana farming. Emuhaya had the highest percentage of farmers who did not consider the cost of TIMPs at 71% since most of the farmers interviewed are medium-scale farmers and produce for both subsistence and commercial purposes.

4.4.3: Affordability of Banana TIMPs Within Vihiga County

The respondents were asked to select TIMPs that they could comfortably pay for, meaning that they considered those TIMPs affordable. 63% of the respondents were comfortable in acquiring integrated soil fertility management practices. This was attributed to the fact that they could compost manure directly on their farms. 52% of the respondents indicated that IPDM costs were affordable, while 48% said that TC banana seedlings cost was affordable. 38% of respondents indicated that harvesting and post-harvest handling costs were affordable to them. Figure 10 below summarizes the affordability of the TIMPs.

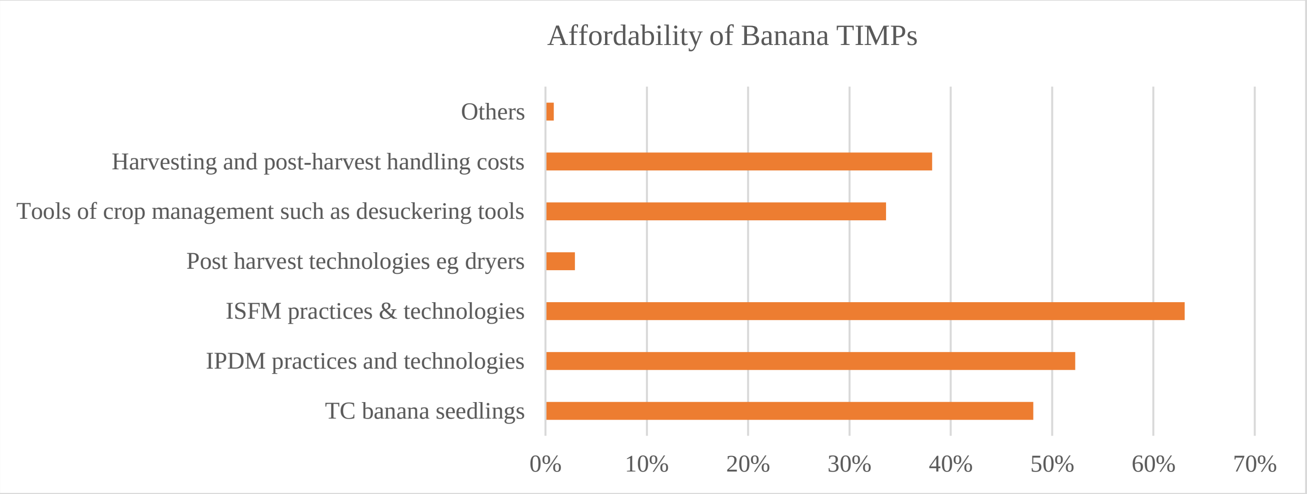

Figure 11:Affordable banana TIMPs within Vihiga County

On a Likert scale, where extremely unaffordable=1, unaffordable=2, neutral=3, slightly affordable=4 and very affordable=5, most farmers, 56.7%, perceive these practices as slightly affordable. In contrast, 24.4% held a neutral stance, while 13% believed the TIMPs were unaffordable. A smaller segment, 4.7%, considered them very unaffordable, and only 1.3% viewed them as very affordable. Additionally, 1.6% of respondents did not provide an opinion. On average, the respondents indicated that they had spent KES 3000 on banana TIMPs already adopted, they are, however, willing to spend on average KES 5000 on banana TIMPs they are yet to adopt. This clearly shows that the value chain is yet to be developed as a commercial crop in the county.

4.4.4 Other Costs in Adoption of Banana TIMPs

In addition to the primary expenses related to the acquisition of banana TIMPs, farmers identified several other significant costs associated with banana production. These include land preparation, manuring, planting and crop management practices, which are essential for maintaining the health and productivity of banana crops. Labor costs further contribute to the overall expense, along with transport costs for moving products and materials. Post-harvest losses, which reflect the economic impact of losses occurring after the harvest, and the replacement of diseased plants add to the financial burden. Additionally, terracing for water harvesting, an important practice for managing water resources efficiently, is noted as another cost.

4.5 Banana Demand and Markets

The research sought to understand the influence of banana demand on the adoption of technologies.

4.5.1 Market for Banana

A significant majority of 296 farmers believed that there was sufficient market demand for the bananas they produce within their county, reflecting a robust confidence in the local market conditions. This consensus suggests that most farmers were optimistic about the demand for their products and perceived the local market as a reliable outlet. However, the 39 farmers who disagreed and the 57 who were uncertain point to some level of skepticism or lack of clarity regarding market demand. This uncertainty could stem from factors such as regional market fluctuations, varying levels of access to market information, or concerns about market saturation.

In terms of market distribution, the primary outlet for bananas was the local market, which was the leading destination for farmers' produce. Following this, bananas were produced for personal consumption, then to local aggregators, and to other markets. Cooperatives and processors were less prominent in the market hierarchy. Figure 12 shows the current markets for bananas. The banana value chain within the county lacked a market champion.

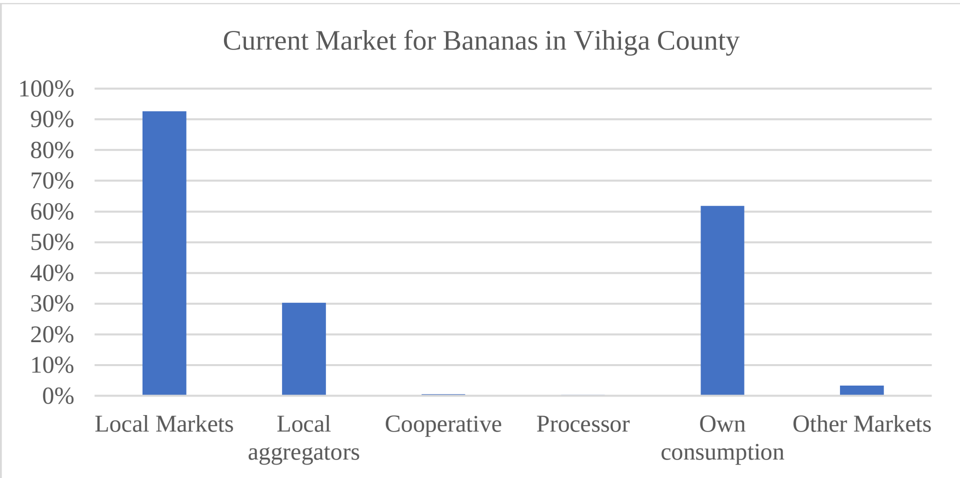

Figure 12: Market for bananas in Vihiga County

In terms of meeting market demand, the research found that 74% of respondents could access a sufficient market for their bananas, either by selling to local markets or for their own consumption. 11% of respondents did not have a sufficient market for their bananas, while 16% were not sure if the market was sufficient. Figure 13 below gives the banana market status per sub-county. In Luanda subcounty, 97% of respondents had a sufficient market. This is attributed to the location of the Luanda market, which attracts traders from Vihiga and neighboring counties.

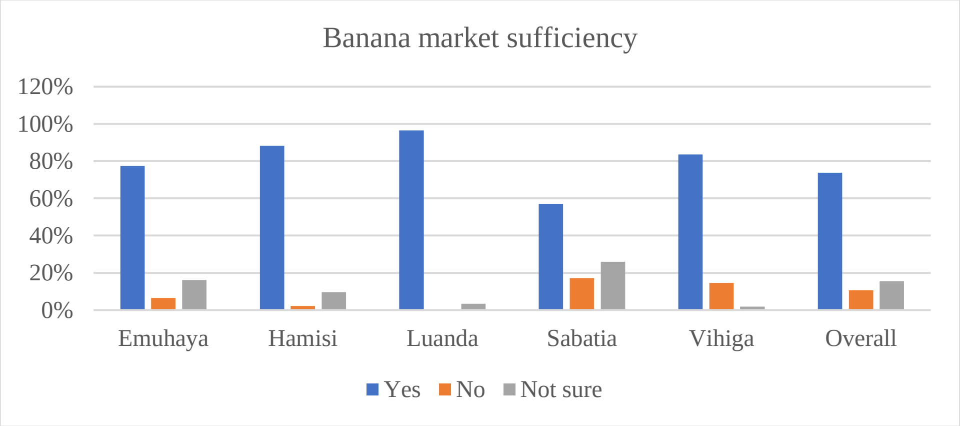

Figure 13: Banana Market in Vihiga

In terms of banana production, 74% of respondents could get sufficient market for their bananas if they could increase their banana production. 3.5% of respondents could not get enough market for their bananas if they increased production, whereas 22.5% of respondents were not sure if they could secure markets for their bananas if they increased production.

4.5.2 Market for Value-Added Banana Products

55% of the respondents could access the market for value-added banana products, mainly ripe bananas and banana flour. 45% of respondents could not access the market for value-added banana products, as shown in Figure 14 below. This clearly shows that the efforts in the county have been on the supply side of the value chain of enhancing production, and limited interventions have been geared towards value addition of the bananas and market development for value-added products.

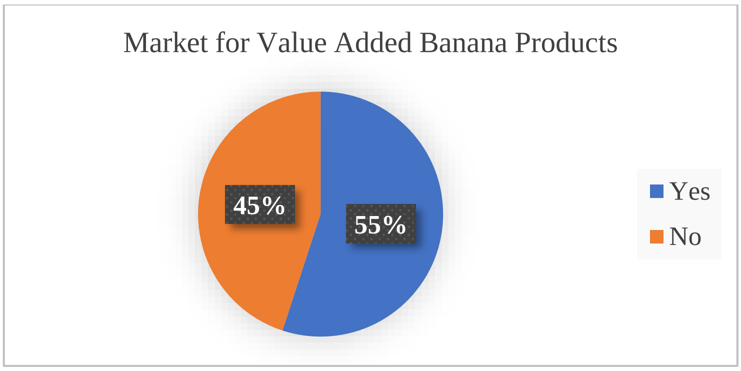

Figure 13: Market access for value added banana products.

4.5.3 Adoption of TIMPs and Banana Demand

In terms of scaling up production, 296 farmers were confident that an increase in production capacity would still find a market for their bananas. This indicated a belief in the growing demand. On the other hand, the 83 farmers who were unsure and the 13 who believed they would struggle to find a market suggested concerns about potential market constraints.

When considering the adoption of TIMPs, 331 farmers were willing to implement these practices if they received large volumes of orders. This readiness indicates that increased order volumes are a strong motivator for adopting advanced practices, aligning with the goal of improving productivity. Conversely, the 30 farmers who would not adopt TIMPs and the 31 who are unsure reflect concerns or barriers related to the adoption of these technologies. Figure 15 below summarizes the findings per subcounty.

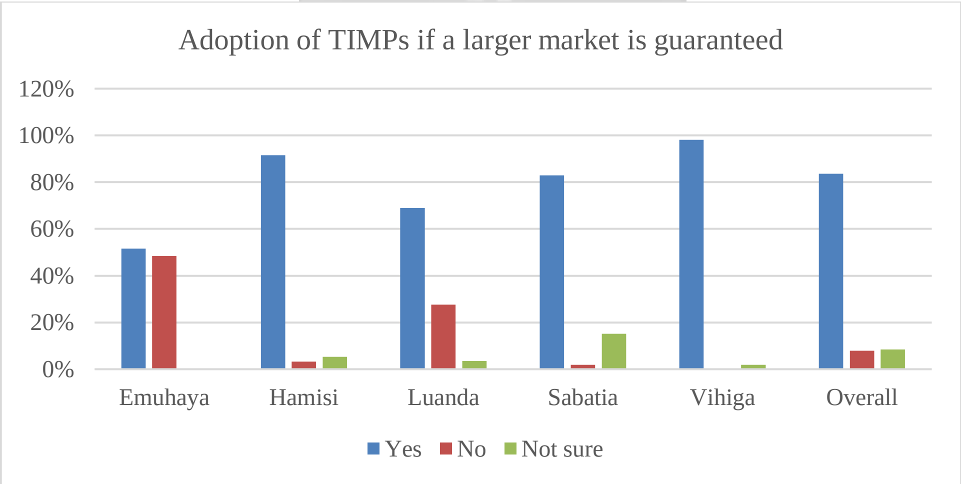

Figure 14: TIMPs adoption with guaranteed market

4.6 Effects of Climate Change on Banana Production

The study sought to find out the effect of climate change on banana farming in Vihiga County.

4.6.1 Climate Change and Adoption of TIMPs

A substantial majority of farmers, totaling 356, recognized that climate change impacted banana production. Of these, 211 farmers believed the effect is slightly greater, and 72 considered it to be a very great effect, demonstrating broad consensus on the significance of climate change as a factor influencing banana production. Conversely, 50 farmers disagreed with this view, 14 remained neutral, and only 7 strongly disagreed, while 36 farmers did not believe climate change affects banana production at all. This distribution highlights a general acknowledgment of climate change's role, though there remains a small segment of farmers who are less convinced.

As shown by Table 4.9 below, 90% of respondents noted that climate change, specifically erratic rainfall and longer periods of dry spells, affected their banana production. 91% of respondents thought that the adoption of Banana TIMPs (drought-resistant TC varieties, disease-free varieties, irrigation technologies, etc) could help them produce bananas optimally, even in the phase of climate change. 91% of respondents also indicated that the adoption of TIMPs was one of the ways to mitigate the effects of climate change on banana production. There is a strong belief that the adoption of TIMPs, especially irrigation and drought-resistant varieties, could help banana farmers produce bananas despite climate change. However, adoption is still low, and this is attributed to the fact that the county is divided into two distinct agroecological zones, namely the upper and lower midlands, which receive relatively high precipitation. Therefore, the effects of climate change on banana farming are minimal.

Table 4.9 Climate change and adoption of TIMPs

		Emuhaya	Hamisi	Luanda	Sabatia	Vihiga	Overall
Climate change affects banana production	Yes	90%	96%	90%	84%	100%	90%
	No	10%	4%	10%	16%	0%	10%
Adoption of banana TIMPs is a strategy to produce bananas optimally, even in the phase of climate change	Yes	87%	98%	83%	87%	100%	91%
	No	13%	2%	17%	13%	0%	9%
Adoption of TIMPs is one of the ways to mitigate effects of climate change on banana production.	Yes	84%	99%	83%	87%	100%	91%
	No	16%	1%	17%	13%	0%	9%

4.6.2 Effect of Climate Change on Quantity and Quality of Harvested Bananas

Regarding specific impacts, 343 farmers acknowledged that climate change affects the quantity of bananas harvested, and 346 believed it impacts the quality of bananas. However, 28 farmers did not think climate change affected the quantity, and 21 were unsure about its impact on harvest quantity. Similarly, 27 farmers did not believe climate change affected banana quality, while 19 were unsure. These figures indicate that while the majority recognizes the negative effects of climate change on both quantity and quality, there is some uncertainty and disagreement among a smaller portion of the farming community.

Furthermore, 359 farmers viewed TIMPs as an effective mitigation measure against climate change, believing that adopting these practices could help optimize banana production. In contrast, 33 farmers held a contrary opinion, suggesting that they either did not see TIMPs as effective in addressing climate change or had reservations about their benefits. This overall positive perception of TIMPs as a mitigation strategy underscores their potential role in enhancing resilience and productivity in the face of climate challenges.

Table 4.10: Climate change effect on quantity and quality of harvested bananas

		Emuhaya	Hamisi	Luanda	Sabatia	Vihiga	Overall
Climate change effect on quantity of harvested bananas	Yes	87%	93%	90%	78%	100%	87%
	No	13%	3%	10%	11%	0%	8%
	Not sure	0%	4%	0%	11%	0%	6%
Climate change effect on quality of harvested bananas	Yes	68%	93%	79%	87%	96%	87%
	No	29%	1%	21%	7%	0%	7%
	Not sure	3%	6%	0%	6%	4%	5%

4.6.3 Other Effects of Climate Change on Banana Farming

The respondents highlighted that climate change, especially longer periods of dry spells, led to bananas experiencing water stress. Water stress led to weak stems that could easily fall under strong winds. The water stress led to delayed maturity of fruiting plants, and led to small banana fingers of lower quality, leading to reduced incomes. In addition, longer periods of dry spells made the soil dry up and become loose, and when their farms experienced high rainfall, the soil was washed off through runoff.

4.7 Multivariate Probit Model Evaluation

The multivariate probit model was developed to analyze the adoption of various banana value chain technologies, innovations, and management practices (TIMPs), specifically focusing on tissue culture banana seedlings, integrated pest and disease management (IPDM) practices, integrated soil fertility management (ISFM) practices, climate-smart irrigation technologies, and soil testing. Post-harvest technologies were excluded from the analysis due to insufficient variability in the data; only 9 out of the 392 participants reported adopting these technologies, which made it challenging to perform a meaningful statistical analysis. To evaluate the factors influencing the adoption of TIMPs, this study tested the following hypotheses:

- H1: Awareness of TIMPs significantly influences their adoption among banana farmers in Vihiga County.
- H2: The high cost of TIMPs negatively affects their adoption.
- H3: Market demand positively influences TIMP adoption.
- H4: Climate change significantly impacts the adoption of TIMPs.

Table 4.11 below presents pairwise correlation coefficients of the error term obtained by estimating the MVP model. The coefficients depicted the relationship between adoption of different banana technologies, innovations, & Management Practices (TIMPs) such that the probability of adopting one TIMP was dependent on whether another TIMP had been adopted or not. Positive correlation indicated that the relationship between the TIMPs was complementary, while negative correlations indicated that the relationship was substitutive.

Table 4.11: Correlation analysis

Binary Correlation	Correlation coefficient	Robust Standard errors	P value
rho21	0.177685	0.135216	0.189
rho31	0.107454	0.128072	0.401
rho41	0.195664	0.142261	0.169
rho51	-0.25457	0.12252	0.038
rho32	0.169508	0.105997	0.110
rho42	0.25539	0.151994	0.093
rho52	-0.28688	0.123299	0.020
rho43	0.044629	0.163334	0.785
rho53	0.355451	0.109216	0.001
rho54	-0.1435	0.140393	0.307

a) Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0: $chi^2(10) = 29.7203$ Prob > $chi^2 = 0.0010$

b) The numbers in the rho refer to 1= soil sampling and testing, 2=Tissue Culture banana seedlings, 3=IPDM practices, and technologies, 4=Climate smart irrigation technologies, 5=ISFM practices, and technologies

From Table 4.11 above, the null hypothesis that the error terms are not correlated is rejected since the $chi^2(10) = 29.7203$ with Prob > $chi^2 = 0.0010$ of the likelihood ratio test of overall error terms correlation is highly significant at 99%. Therefore, the responses between different binary banana TIMPs are correlated, supporting the choice of the Multivariate probit (MVP) model. Moreover, the adoption of one TIMP is dependent on whether the farmer adopts another TIMP or not.

Table 4.12 MVP Model results

Variables	Soil testing	TC Banana Cultivars	Integrated Pest and Disease Management (IPDM)	Climate Smart Technologies	Integrated Soil Fertility Management (ISFM)
Gender	-0.060	0.271	-0.163	0.340	-0.037
	(0.265)	(0.194)	(0.188)	(0.240)	(0.202)
Age	0.146	0.276**	-0.154	0.325**	-0.385***
	(0.148)	(0.114)	(0.114)	(0.130)	(0.134)
Education level	0.202	0.388***	-0.021	0.343***	-0.149
	(0.127)	(0.115)	(0.110)	(0.132)	(0.111)
Banana farming experience (years)	-0.034	-0.160	-0.076	-0.534***	0.223
	(0.164)	(0.115)	(0.112)	(0.156)	(0.145)
Banana farming training	0.018	-0.292	0.003	0.385	0.953***
	(0.245)	(0.189)	(0.182)	(0.247)	(0.188)
Distance to nearest TIMPs	-0.029	-3.330**	-1.108	0.027	0.010

Variables	Soil testing	TC Banana Cultivars	Integrated Pest and Disease Management (IPDM)	Climate Smart Technologies	Integrated Soil Fertility Management (ISFM)
purchase Centre (Kms)					
	(0.036)	(1.471)	(1.462)	(0.042)	(0.039)
Extent of affordability of Banana TIMPs	1.087***	0.443***	0.207*	0.147	0.053
	(0.277)	(0.110)	(0.110)	(0.226)	(0.105)
Banana TIMPs highest cost at acquisition	-3.086	-5.429	-9.373	-0.194	0.250**
	(7.537)	(6.591)	(7.289)	(0.133)	(0.111)
Amount spent of acquiring Banana TIMPs including grants	-0.053	0.580	0.987*	0.028	0.095
	(0.068)	(0.543)	(0.565)	(0.060)	(0.104)
Amount willing to spend on TIMPs to Increase Production	-5.253**	-0.182***	7.862**	-0.102***	0.099***
	(2.661)	(0.035)	(3.516)	(0.034)	(0.032)
Constant	-6.223***	-2.473***	-0.916	-2.861***	0.101
	(1.111)	(0.669)	(0.732)	(0.907)	(0.400)
Model chi-square (50)	318.05***				
Log pseudolikelihood	-555.919				

Variables	Soil testing	TC Banana Cultivars	Integrated Pest and Disease Management (IPDM)	Climate Smart Technologies	Integrated Soil Fertility Management (ISFM)
N	242				

Robust standard errors in parenthesis *** p <0.01 ** p <0.05 *p <0.1

The MVP model results gave insights into the factors influencing the adoption of various technologies, innovations, and management practices (TIMPs) among banana farmers, drawing on demographic, economic, and spatial variables. The model presented relationships across five TIMPs: soil testing, tissue culture (TC) banana cultivars, integrated pest and disease management (IPDM), climate-smart technologies, and integrated soil fertility management (ISFM).

For the adoption of soil sampling and testing as a management practice, the extent of affordability of banana TIMPs was significant at a 99% confidence level. For the adoption of tissue culture banana seedlings, several variables were statistically significant in explaining changes in the probability of adoption: age, education level, affordability of banana TIMPs, and extent of affordability of tissue culture banana seedlings. Specifically, each additional year of the farmer's age increased the likelihood of adopting tissue culture banana seedlings, holding all other factors constant at the 99% confidence level. Additionally, at the 99% confidence level, an increase in the affordability of banana TIMPs significantly raised the probability of adopting tissue culture banana seedlings, holding all other factors constant. Farmers who perceived tissue culture banana seedlings as affordable were more likely to adopt them, while those who found harvesting and post-harvest handling costs affordable experienced a decrease in the likelihood of adoption, all else being equal.

For the adoption of integrated pest and disease management (IPDM) practices and technologies, the affordability of bananas TIMPs was statistically significant at the 95% confidence level, Male farmers were more likely to adopt IPDM practices, holding all other factors constant. Furthermore, farmers who found IPDM and tissue culture banana seedlings affordable were more likely to adopt IPDM, holding other factors constant.

Regarding the adoption of climate-smart irrigation technologies, age was statistically significant at a 95% confidence level while education level and banana farming experience were statistically significant at a 99% confidence level. The constant term indicated a baseline latent propensity of -2.861 units for adopting climate-smart irrigation technologies when all independent variables are zero. An increase in age was associated with a higher probability of adoption, suggesting that older farmers are more likely to adopt these technologies, holding all other factors constant. Similarly, an increase in education level raised the likelihood of adoption, while more years of banana farming experience decreased the likelihood of adopting climate-smart irrigation technologies, holding all other factors constant.

For the adoption of integrated soil fertility management (ISFM) practices and technologies, the variables of age, training in banana farming, and the affordability of ISFM were statistically significant. An increase in age decreased the probability of adoption, suggesting that older farmers have a lower propensity to adopt these practices, holding all other factors constant at the 90% confidence level. In contrast, receiving training in banana farming, being aware of IPDM practices, and perceiving ISFM as affordable all increased the likelihood of adopting ISFM practices, holding all other factors constant at the 99% confidence level.

The model underscored the role of affordability, with significant positive associations between TIMP affordability and adoption rates for several technologies. Affordability's influence was particularly evident for soil testing and TC banana cultivars, which indicated that farmers prioritized TIMPs based on financial accessibility. Furthermore, a negative relationship with TIMPs' acquisition costs underscored those high initial costs deterred adoption, particularly in resource-constrained farming communities. Additionally, the model reveals that an increased willingness to spend on TIMPs correlates with a greater likelihood of adopting IPDM and ISFM. Farmers perceiving productivity gains from investments in TIMPs might view these as necessary expenditures for long-term benefits.

The results of the model demonstrated that the distance to TIMP purchasing centers negatively impacted the adoption of TC banana cultivars. As shown by significant coefficient, increased distance reduces the likelihood of adopting tissue culture. This observation underscored the logistical challenges of accessing inputs, suggesting that improving TIMP accessibility could increase adoption rates by lowering travel-related costs and efforts.

4.8 Chapter Summary

The chapter presented the findings of the study, linking descriptive and inferential statistics to the research objectives and hypotheses. The study achieved a 99% response rate, and its validity and reliability were examined via predictive test and composite reliability coefficient, respectively. The study found that the cost of adopting TIMPs was a major barrier, with tissue culture (TC) banana seedlings and integrated pest and disease management (IPDM) practices being the most expensive for banana farmers such that 74% of farmers required credit to afford TIMPs. Additionally, the market demand for bananas was perceived to be a strong factor, with 74% of farmers indicating that they were confident with increased TIMPs adoption, they would sell more products. The study however revealed that banana production is faced with limited value addition innovation and there is limed market structure that would motivate the farmers to adopt TIMPs to enhance productivity and efficiency. Further, the inferential statistics confirmed the role played by H1 (awareness affects adoption), H2 (cost negatively affects adoption), H3 (market demand influences adoption), and H4 (climate change influences adoption) in the adoption of TIMPs among banana farmers. The MVP results demonstrated that TIMP adoption was interdependent since farmers who adopted one TIMP were more likely to adopt others.

CHAPTER 5: DISCUSSIONS AND CONCLUSIONS

5.1 Discussion of Findings

This chapter provides an in-depth discussion of the research findings presented in chapter four. The discussions are organized according to the study's objectives: awareness of technologies, innovations, and management practices (TIMPs); cost of technologies; demand for bananas; and the effect of climate change on the adoption of TIMPs among banana farmers in Vihiga County. The discussion integrates the results from the descriptive analysis and from the Multivariate Probit (MVP) model used in this study. The aim of this study was to analyze the factors influencing the adoption of TIMPs among banana farmers in Vihiga County.

The study aimed to:

i. Determine how awareness of the technologies, innovations, and management practices influenced adoption among banana farmers in Vihiga County,
ii. Examine how the cost of the technologies, innovations, and management practices influenced their adoption among banana farmers in Vihiga County,
iii. Establish if demand for bananas influenced the adoption of technologies, innovations, and management practices among banana farmers in Vihiga County and,
iv. Examine the effect of climate change on the adoption of technologies, innovations, and management practices among banana farmers in Vihiga County.

By addressing these objectives, the study will provide insights into the factors influencing the adoption of TIMPs among banana farmers. The chapter also interprets the key findings and provides actionable insights for banana farming stakeholders. This chapter concludes with recommendations for policymakers, farmers, and further research.

5.1.1 Awareness of Technologies, Innovations, And Management Practices

From the findings, awareness emerged as a significant factor influencing the adoption of TIMPs among banana farmers in Vihiga County. The findings revealed that farmers who were more aware of available technologies, innovations, and management practices were more likely to adopt them. The findings align with the conclusions drawn by (Hansen et al., 2017) who emphasized that awareness was a crucial determinant in the adoption of value addition technologies. Similarly, Tefera and Abass (2012) noted that technology availability alone does not guarantee adoption; awareness and sensitization are essential to increase adoption rates.

Moreover, the positive correlation between awareness and TIMPs adoption supports the need for continuous education and awareness programs (Dissanayake et al., 2022). These programs should aim to inform farmers about the benefits and applications of new technologies and practices. The findings were consistent with those of Yokamo's (2020), who highlighted the role of extension services in disseminating knowledge and facilitating technology adoption among farmers.

The study also found that farmers who received more targeted information through extension services and agricultural training were more likely to adopt TIMPs. This finding aligns with the Unified Theory of Acceptance and Use of Technology (UTAUT), which posits that performance expectations and facilitating conditions, such as access to information and training, significantly influence the likelihood of adopting new technologies (Shi et al., 2022).

The results indicated that awareness played a crucial role in the adoption of TIMPs. The MVP model results confirmed that awareness of TIMPs, such as tissue culture banana seedlings and integrated pest and disease management (IPDM) practices, positively influenced their adoption ($p < 0.05$). This finding supports the Innovation Diffusion Theory, which posits that awareness is a critical stage in the technology adoption process (Rogers, 1995). Higher levels of awareness, particularly for IPDM and soil fertility management, were associated with increased adoption probabilities, suggesting that farmers' access to information remained a significant determinant of adoption. However, the study also revealed gaps where high awareness did not translate into adoption, particularly for soil sampling and post-harvest technologies. While farmers were aware of these technologies, adoption rates were low due to other barriers such as cost and availability. This highlighted the complexity of the adoption process, which is not solely driven by awareness but also by factors such as the perceived cost and practicality of the technology.

5.1.2 Cost of Technologies, Innovations, and Management Practices

While awareness levels were high, cost was identified as a significant barrier to TIMP adoption. Farmers expressed concerns about the initial costs associated with acquiring technologies, particularly TC banana seedlings, and the recurring costs involved in implementing and maintaining practices such as ISFM and IPDM. This finding was consistent with Rogers' Diffusion of Innovation Theory, which asserts that cost is a critical factor in the adoption decision, particularly in resource-constrained environments (Person et al., 2021) .

The finding aligns with several other studies that have identified cost as a barrier to technology adoption. For instance, (Madalla et al.., 2023) discovered that the high cost of disease-resistant banana cultivars was a significant impediment to their adoption in Tanzania and Uganda. The findings agree with findings from studies by (Kurgat et al.,2020) and (Ndiritu and Ruhinduka, 2019), which identified insufficient capital as a significant hindrance to the adoption of various agricultural technologies.

However, banana farmers that belonged to farmer groups within the county received grants through NARIGP, a project that supported the increase in productivity and profitability of banana farming in the county over the last 5 years. Some of the major costs incurred by the farmers were labor costs and transport costs to markets. Through the grants, the farmers procured technologies, innovations, and management practices for their banana farming enterprises. This finding suggests that while cost is a critical factor, its impact can be lessened through supportive financial mechanisms.

The MVP results demonstrated a strong correlation between the affordability of technologies and their adoption. For instance, as the affordability of tissue culture banana seedlings and IPDM practices increased, so did the probability of their adoption ($p < 0.01$). This finding was consistent with findings from previous studies, which suggested that affordability played a significant role in technology adoption, especially in low-income rural settings (Kabirigi et al., 2022).

However, the affordability of post-harvest technologies did not significantly influence their adoption. This discrepancy could be attributed to the limited availability and practical use of these technologies among small-scale farmers in the County, further supporting the argument that accessibility and awareness must complement affordability to enhance adoption rates.

5.1.3 Demand for Bananas

The results highlighted the role of market demand in promoting the adoption of TIMPs. Farmers who perceived a higher market demand for bananas were more likely to adopt climate-smart technologies, such as irrigation systems. The results confirmed that larger banana orders significantly increased the likelihood of adopting TIMPs, particularly for technologies aimed at increasing productivity and meeting market standards.

This finding aligns with the Unified Theory of Acceptance and Use of Technology (UTAUT), which emphasizes the importance of performance expectancy in technology adoption (Ronaghi & Forouharfar, 2020). Farmers adopted TIMPs as a strategy to enhance productivity and meet the growing demand for bananas, reflecting the extrinsic motivators that drive technology adoption in agricultural settings.

Farmers who had access to stable banana markets, both local and export-oriented, were more inclined to adopt TIMPs. This is particularly true for farmers engaged in value-added banana products, such as banana flour, crisps, and wine, which fetch higher prices and thus provide the financial incentive to invest in technologies that improve banana quality and yield.

This finding aligns with previous research, such as the work by (De Janvry and Sadoulet, 2020), which found that market demand plays a crucial role in technology adoption by providing economic incentives.

The banana market structure in the county was mainly the local markets, which have been developed through strategic programs funded by the County government of Vihiga and its development partners. Moreover, farmers in Vihiga were content with selling their bananas within the local markets and for their own consumption. The cooking varieties were mainly for consumption while the ripening varieties were sold.

5.1.4 Effects of Climate Change

Climate change emerged as a key determinant in the adoption of climate-smart TIMPs. The study found that older farmers were more inclined to adopt irrigation technologies, which were perceived as essential in mitigating the adverse effects of erratic weather patterns. The results confirmed that age and experience were significant predictors of adopting climate-smart irrigation practices aligning with studies suggesting that experienced farmers are more likely to adopt innovations that address environmental risks (Ndiritu & Ruhinduka, 2019).

The study highlighted the growing impact of climate change on banana production in Vihiga County, with erratic rainfall patterns and prolonged dry spells being the most cited issues. These climatic changes have the potential to adversely affect the quantity and quality of banana yields, thereby influencing farmers' decisions to adopt climate-resilient technologies such as drought-resistant TC banana varieties and climate-smart irrigation systems. This finding is consistent with (Zhu et al., 2021), who found that adaptation strategies to climate change significantly boosted land productivity among banana farmers in China.

Furthermore, 87% of the respondents reported that climate change negatively affected banana farming, leading to reduced banana quality and yield. Tis aligns with the study by Oyetunde Usman et al. (2021) that the adoption of climate-smart practices represents a strategic response to these environmental challenges. However, the low adoption of post-harvest technologies underscores the need for further interventions to support farmers in managing the entire banana value chain, from production to post-harvest handling.

In as much as climate change has the potential to affect the quality and quantities of bananas harvested, the impact on the banana farmers in the County was minimal. This is attributed to the geographical location of the County. The county experiences a tropical climate with consistently distributed rainfall throughout the year, averaging an annual precipitation of 1900 mm. Therefore, the effects of climate change on banana farming in Vihiga County were minimal.

5.2 Contributions of the Study

5.2.1 Theoretical Contributions

The findings support Rogers' Diffusion of Innovation Theory (1995) by proving that awareness plays a critical role in TIMPs adoption and aligns with the Unified Theory of Acceptance and Use of Technology (UTAUT) (Shi et al., 2022), by demonstrating that the adoption of TIMPs is influenced by multiple factors. In addition, the MVP model's results support previous studies on the adoption of technology and innovative practices such as: (Kathuri et al. 2021; Githumbi, 2022; Chuang, et al. 2020), demonstrating that TIMPs adoption is influenced by multiple interrelated factors rather than a single variable. This study, therefore, expands the understanding of adoption dynamics by integrating both economic and behavioral perspectives.

In addition, the study provides empirical evidence on banana farming in Vihiga County, a relatively underexplored area, unlike previous studies that focus on staple crops (e.g., maize and rice) or the whole country. It offers new insights into the paradox of having low adoption rates among farmers despite high awareness by revealing other interrelated factors such as cost and farm size. While previous studies such as those done by (Hansen et al., 2017; Tefera & Abass, 2012), attribute adoption gaps to lack of awareness, this study identifies cost and perceived practicality as additional barriers and the need for a multi-faceted approach. For agricultural stakeholders, including researchers and extension officers, this study reveals the need for targeted awareness campaigns because simply disseminating information is not enough.

5.2.2 Generalizability of Findings

The findings of this study offer valuable insights into TIMPs adoption among banana farmers in Vihiga County. However, generalization should be considered in light of several contextual factors, such as regional and crop-specific differences, because these findings may not be applicable to regions in different climatic zones and other crops, such as rice and maize.

5.3 Conclusions

The findings from this study confirmed that the adoption of TIMPs among banana farmers in Vihiga County was influenced by multiple factors, including awareness, affordability, market demand, and climate change. Other factors such as age, farming experience, level of education and gender also influenced adoption. While awareness is a critical driver of adoption, it was not sufficient on its own. The study highlighted the importance of considering affordability and accessibility to enhance the adoption of innovative agricultural practices. The findings of this study largely align with existing literature, particularly regarding the importance of awareness in technology adoption. Awareness of TIMPs is crucial for their adoption among banana farmers in Vihiga County. Extension services and awareness campaigns need to be intensified to increase the adoption rates of these beneficial practices. Consistent with many studies, the higher cost of technologies deterred their adoption among farmers in Vihiga County. This suggests that financial mechanisms such as support programs were effectively mitigating cost barriers.

Market demand plays a significant role in motivating farmers to adopt productivity-enhancing technologies. However, the low adoption of post-harvest technologies points to a gap in the current support systems available to farmers, which may hinder the overall effectiveness of TIMPs in improving productivity and profitability. Similarly, the effect of climate change did not significantly impact the adoption of TIMPs. This non-significance suggests the need for further research to understand the complex relationship between climate variability and agricultural practice adoption in different contexts, especially regions like Vihiga, which on average receive adequate rainfall.

5.4 Recommendations

Based on the findings, the following recommendations are proposed.

5.4.1 Practice Recommendations

1. The agriculture stakeholders within the county should enhance extension services to meet the specific needs of banana farmers, with a focus on providing timely information and practical training on TIMPs. This would help bridge the gap between awareness and adoption.
2. Efforts should be made to support banana market development to ensure that farmers have a reliable and profitable outlet for their produce, fresh and value-added, with emphasis on value addition. This could include establishing better market linkages and improving infrastructure to facilitate market access for both fresh and value-added banana produce.
3. Policymakers and development agencies should prioritize expanding financial support mechanisms for banana farmers to alleviate the cost barriers associated with TIMPs adoption. This will encourage more farmers to adopt beneficial technologies and practices without the constraint of high costs.
4. Climate change education to inform farmers about the impacts of climate change and the importance of adopting resilient agricultural practices. This will ensure that farmers are better prepared to cope with future climatic challenges.

5.4.2 Recommendations for Further Research

1. Additional research should be conducted to explore other factors that influence the adoption of TIMPs. Understanding these unique factors can help tailor more effective interventions. Researchers could conduct research separately on technologies, innovations, and management practices, outside the context set by KALRO to broaden the scope.
2. Studies to conduct longitudinal analyses to assess how adoption rates of TIMPs evolve over time, particularly in response to changes in market conditions, climate variability, and financial support mechanisms, are recommended.
3. There is a need to examine the role of gender in the adoption of agricultural technologies, particularly to understand how socio-cultural factors may influence the adoption decisions of women farmers in Vihiga County.

4. More research is recommended to assess the economic impact of value-addition technologies on the livelihoods of banana farmers, particularly those involved in producing banana-based products such as flour, crisps, and wine.

These recommendations aim to enhance the adoption of technologies, innovations, and management practices among banana farmers, thereby improving their productivity and livelihoods.

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APPENDICES

APPENDIX I: RESPONDENT CONSENT FORM

Allan Migaili from Strathmore University Business School requests you to participate in a research study. If you have any comments, concerns, or questions, please do not hesitate to contact us on +254718716536 or allan.migaili@strathmore.edu.

Purpose of the Study

The purpose of this study is to determine factors Influencing Adoption of technologies innovations, and management practices among banana farmers in Vihiga County, Republic of Kenya.

Procedure

Filling out a questionnaire if you are willing to participate in this study.

Potential Risks

There are no potential risks or discomforts for participants.

Benefits to Society

The study will help understand factors affecting adoption of technologies, innovations, and management practices among banana farmers in Vihiga County. This will give insights to relevant stakeholders to act and increase uptake of the technologies. The uptake will contribute towards attaining household food security in the county and increase farmers' incomes.

Payment for Participation

There will be no monetary incentives for taking part in this study.

Confidentiality

Responses and information given will be used solely for the purposes of this study and will be kept confidential.

Participation

Participation in the study is entirely voluntary, and you can choose to participate or not to.

Withdrawal and Rights of Research Participant

By volunteering to be a part of the research study, you have the option to withdraw at any time without consequence or penalty.

Signature of Research Participant

I hereby consent to take part in this research study. I have read and comprehended the information provided for the research as described in this questionnaire.

Name of Participant: Date: Signature:

APPENDIX II: INTRODUCTION LETTER

Allan Migaili
P.O BOX 4892-00100
Nairobi, Kenya
Email: allan.migaili@strathmore.edu

Dear Sir/Madam,

RE: ACADEMIC RESEARCH

I am a graduate student at Strathmore University Business School pursuing a Master of Management in Agribusiness degree.
In partial fulfillment of my degree requirements, I am required to conduct a research study and thus I am undertaking a study on factors influencing adoption of technologies, innovations, and management practices among banana farmers in Vihiga County, Kenya. The responses collected in this study will be strictly used for academic purposes only and will be entirely confidential.

Sincerely,

Allan Migaili

Student Number: 152348
Strathmore University Business School.

APPENDIX III: RESEARCH QUESTIONNAIRE

This questionnaire is aimed at seeking information about factors influencing the of technologies, innovations, and management practices among banana farmers in Vihiga County, Kenya.

Kindly answer the questions by **ticking** and or **filling** in the spaces provided.

1.0 BASIC INFORMATION

1.1 Name of Respondent: ………………………….

1.2 Gender of respondent:

Male ☐ Female ☐

1.3 Age of respondent: ……………………………...

1.4 Location of the respondent:

Sub county: ……………………… Ward: ………………………….

1.5 How many years did you attend school? (From primary to date) ………… (years)

1.6 Highest level of education of the respondent

Primary ☐

Secondary ☐

College/TVET ☐

University Graduate ☐

1.7 Banana farming experience (years): …………………………

1.8 Total land size owned by the respondent (acres) ………………………….

1.9 Total land size under banana production (acres) ………………………….

1.10 How many bananas did you harvest in the last one year from your farm? ………… (kgs)

1.11 GPS coordinates of location Latitude: ………………………… Longitude: ……………………

2.0 AWARENESS OF TECHNOLOGIES, INNOVATIONS AND MANAGEMENT PRACTICES

Answer the following questions.

2.1 You have been trained in banana farming?

Yes ☐ No ☐

2.2 As a farmer, do you regularly get information on technologies, innovations, and management practices (TIMPs)?

Yes ☐ No ☐

2.3 As a farmer, do you have access to extension services?

Yes ☐ No ☐

2.4 What is your source of information on banana technologies, innovations & Management Practices (TIMPs)?

Government Extension Officers ☐

Print media (Newspapers, etc) ☐

E-extension (Radio, TV, mobile phones) ☐

Exhibitions/shows/field days ☐

Social media (LinkedIn, Facebook, WhatsApp etc) ☐

Research institutions such as Universities, KALRO ☐

Fellow farmers ☐

Other sources, specify. ☐

2.5 Are you aware of the following Banana TIMPs (Tick all that apply)

Soil sampling and testing ☐

Tissue Culture banana cultivars (seedlings) ☐

IPDM practices and technologies ☐

Climate smart Irrigation technologies ☐

ISFM practices and technologies ☐

Post harvest technologies eg dryers ☐

Tools of crop management such as desuckering tools ☐

Banana waste management innovations eg making fiber ☐

Other sources, specify. ☐

2.6 Have you adopted any of the Following TIMPs? (Tick all that apply)

Soil sampling and testing ☐

Tissue Culture banana cultivars (seedlings) ☐

IPDM practices and technologies ☐

Climate smart Irrigation technologies ☐

ISFM practices and technologies ☐

Post harvest technologies eg dryers ☐

Tools of crop management such as desuckering tools ☐

Banana waste management innovations eg making fiber ☐

Other sources, specify. ☐

2.7 When you want to acquire a technology for banana, do you conduct research to find out all the available technologies and do a Cost Benefit Analysis?

Yes ☐ No ☐

2.8 Are the technologies available when you need them?

Ye ☐ I ☐

2.9 Are the technologies within your farm or easily accessible from your farm?

Yes ☐ No ☐

2.10 What's the distance from your farm to the nearest center where you can buy the banana TIMPs? …….. (Kms)

2.11 What challenges do you face in accessing the technologies innovations and management practices? Name at least three …………………………………………

3.0 COST OF TECHNOLOGIES, INNOVATIONS AND MANAGEMENT PRACTICES

3.1 What are the highest costs you incur in banana production? (tick the highest two)

- Soil sampling and testing ☐
- Acquisition of TC banana seedlings ☐
- Acquisition of IPDM practices and technologies ☐
- Acquisition of ISFM practices & technologies ☐
- Post harvest technologies eg dryers ☐
- Tools of crop management such as desuckering tools ☐
- Harvesting and post-harvest handling costs ☐
- Other Costs, specify. ☐

Please indicate your level of agreement with the following statements by ticking the appropriate box. *Extremely unaffordable=1, unaffordable =2, Neutral=3, Slightly affordable=4, Very affordable=5*

	Statement	Likert Scale				
		1	**2**	**3**	**4**	**5**
3.2	To what extent would you say the banana TIMPs are affordable?					

3.3 Do you need credit to purchase banana TIMPs?

Yes ☐ No ☐

3.4 What are the TIMPs that you would adopt, if you had access to a credit facility? (Tick all that apply)

- Soil sampling and testing ☐
- Acquisition of TC banana seedlings ☐
- Acquisition of IPDM practices and technologies ☐
- Acquisition of ISFM practices & technologies ☐
- Post harvest technologies eg dryers ☐
- Tools of crop management such as desuckering tools ☐
- Harvesting and post-harvest handling TIMPs ☐

Other TIMPs specify. ☐

3.5 What are the other costs you incur in the process of banana farming?

Name them: ………...

3.6 What is the highest cost you incur, as a farmer in **acquisition and implementing** TIMPs in your banana farm?

3.7 As a farmer, do you consider the cost of the banana TIMPs before adoption?

Yes ☐ No ☐

3.8 Which of the following TIMPs would you say are affordable (*You can comfortably pay for them*) within Vihiga County? (tick all that apply)

- TC banana seedlings ☐
- IPDM practices and technologies ☐
- ISFM practices & technologies ☐
- Post harvest technologies eg dryers ☐
- Tools of crop management such as desuckering tools ☐
- Harvesting and post-harvest handling costs ☐
- Others, specify. ☐

3.9 Which of the following TIMPs incur the highest implementation costs (*operational costs*) within Vihiga County? (tick all that apply)

- TC banana seedlings ☐
- IPDM practices and technologies ☐
- ISFM practices & technologies ☐
- Post harvest technologies eg dryers ☐
- Tools of crop management such as desuckering tools ☐
- Harvesting and post-harvest handling costs ☐
- Others, specify. ☐

3.10 If you have adopted banana TIMPs, how much money did you spend acquiring them? What's their value (If received them through a grant)? ……………… (KES)

3.11 How much money would you be willing to spend on TIMPs (all relevant TIMPS) to increase your banana productivity? ……………… (KES)

4.0 BANANA DEMAND

4.1 What is the current market of your Banana? (Tick as appropriate)

Local Markets ☐

Local aggregators ☐

Cooperative ☐

Processor ☐

Own consumption ☐

Other Markets ☐

1.2 Is their sufficient market for banana produced in Vihiga County?

Yes ☐ No ☐ Not sure ☐

4.3. If you increase the production capacity of bananas, will you have market for them?

Yes ☐ No ☐ Not sure ☐

4.4 If you get orders for larger volumes of banana, will you adopt TIMPs to increase productivity?

Yes ☐ No ☐ Not sure ☐

4.5 Is their market for value added banana products?

Yes ☐ No ☐

5.0 EFFECTS OF CLIMATE CHANGE TO ADOPTION OF TECHNOLOGIES, INNOVATIONS AND MANAGEMENT PRACTICES

5.1 Does climate change (erratic rainfall, longer periods of dry spell) affect your banana production?

Yes ☐ No ☐

If yes, please indicate your level of agreement with the following statements by ticking the appropriate box. *No effect at all =1, Neutral=2, Slightly affected=3, Severely affected =4*

	Statement	Likert Scale			
		1	**2**	**3**	**4**
5.2	To what extent would you say Climate change affects your banana production				

5.3 Do you think adoption of Banana TIMPs (drought resistant TC varieties, disease free varieties, irrigation technologies etc) can help you produce bananas optimally, even in the phase of climate change?

Yes ☐ No ☐ Not sure ☐

5.4 Adoption of TIMPs is one of the ways to mitigate effects of climate change on banana production.

Yes ☐ No ☐

5.5 Does Climate change affect the quantity of bananas you harvest?

Yes ☐ No ☐ Not sure ☐

5.6. Does Climate change affect the quality of bananas you harvest?

Yes ☐ No ☐ Not sure ☐

5.7 What are the other effects of climate change on your banana production? (Name at least three)

Name them: …………………………….

APPENDIX IV: ETHICAL APPROVAL

Strathmore
UNIVERSITY

24th April 2024

Mr Avugwi Allan,
allan.migaili@strathmore.edu

Dear Mr Avugwi,

<u>RE: Factors Influencing Adoption of Technologies, Innovations and Management Practices among Banana Farmers in Vihiga County</u>

This is to inform you that SU-ISERC has reviewed and **approved** your above **SU-masters** research proposal. Your application reference number is **SU-ISERC2203/24.** The approval period is from **24th April 2024 to 23rd April 2025.**

This approval is subject to compliance with the following requirements:

i. Only approved documents including (informed consents, study instruments, MTA) will be used.
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by SU-ISERC.
iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to SU-ISERC within 72 hours of notification.
iv. Any changes anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to SU-ISERC within 72 hours.
v. Clearance for the export of biological specimens must be obtained from relevant institutions.
vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
vii. Submission of an executive summary report within 90 days of completion of the study to SU-ISERC.

Before commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology, and Innovation (NACOSTI) https://research-portal.nacosti.go.ke/ and obtain other clearances needed.

Yours sincerely,

Mr Ambrose Rachier,
Chairperson; SU-ISERC

STRATHMORE UNIVERSITY INSTITUTIONAL SCIENTIFIC AND ETHICAL REVIEW COMMITTEE
(SU-ISERC)
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APPENDIX V: NACOSTI CLEARANCE

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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