Stakeholder interactions and capacity development for innovation and adoption of agricultural technologies: the case of banana value chain in Uganda

by

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Abstract

The low level of adopting improved technologies has been a major challenge towards increasing agricultural productivity and ensuring food security in developing countries. Although multiple studies have been conducted with regard to how the adoption of improved technologies could be enhanced, less attention has been focused on understanding the role of interactions among stakeholders in an agricultural system such as the value chain and their capacities to influence innovation and adoption of improved technologies. This study examined interactions and capacity development needs for innovation and adoption of technologies among stakeholders in the Ugandan banana value chain. The study employed a mixed methods design, involving the use of qualitative and quantitative methods as complements in collecting and analyzing primary data. Primary data were collected by conducting focus group discussions with banana farmers and traders; the key informant interviews (KIIs) with the banana traders (retailers, wholesalers, bicycle/motorbike banana traders), the processors for various banana products, export farmers, researchers and extension agents as key influential stakeholders in the banana value chain. A household survey was also conducted among banana farming households. The study took place in low-land, highland, and mid-highland agroecological zones in Uganda; specifically, in Nakaseke, Bunyangabu, and Isingiro districts respectively, representing the historical banana growing areas in Uganda. The data collected through FGDs and KIIs were analyzed qualitatively using the Social Network Analysis (SNA) methodology to establish the stakeholder interactions for innovation and technology adoption. Thematic analysis was also conducted to establish Capacity Development (CD) gaps for innovation and adoption of technologies. Data from the household survey was analyzed using the Multivariate probit and Ordered probit models in order to establish factors that influence multiple adoption decisions of improved technologies among banana farming households. According to the study findings, there are various stakeholders in the banana value chain with the potential to contribute to innovation and adoption of technologies. Social Network Analysis (SNA) results indicate the densities of 28.0%, 25.6%, and 26.8% from Bunyangabu, Isingiro, and Nakaseke value chains, respectively, implying the existence of weak linkages among stakeholders in such areas which indicates that most of them are working in isolation. This limits the possibility of innovating together. Particularly, research and extension had weak or missing connections with the key stakeholders such as the processors, traders, and farmer groups. This depicts the existing limited discussions, cooperation and feedback among them, with the likely outcome of generating and promoting technologies that are not acceptable among end users.

Betweenness results indicate that in Bunyangabu, regulatory bodies were the most influential stakeholders for facilitating information exchange and service delivery as indicated by the relative betweenness of 1. The position of regulatory bodies in this area depicts the importance of an enabling environment in facilitating information exchange and service delivery for innovation and adoption of technologies. In Isingiro and Nakaseke, farmer groups were the most influential stakeholders. The results show that the potential of various stakeholders to engage in innovation activities could be unlocked by engaging in capacity development at individual, organizational and enabling environment dimensions. Capacity development needs at all the dimensions were similar and are; banana value addition, marketing and financial access options, and management in order to improve adoption. Results from the econometric analysis show that a number of banana technologies can be adopted as complements or substitutes. The results further show that household size, total area under banana production, ecological location, household membership to a farmer group, access to formal sources of credit, and, input and output markets in major towns of Uganda produced significant results with the MVP model and ordered probit model. This indicates that the type and the number of technologies that can be adopted at a time are determined by similar factors which should be taken into account when designing adoption interventions for multiple agricultural technologies. The study results provide evidence that there were missing linkages among essential stakeholders (such as research, extension, processors, financial service providers, and traders) which further limits their involvement in the innovation activities in banana value chain. The need for improved access to and management of finance and marketing services to facilitate innovation and adoption of technologies is reflected in the capacity development needs and was identified as a key limiting factor for the adoption of technologies among banana farming households. Therefore, the banana farming environment should be improved such that there are favorable marketing systems and availability of funding at low-interest rates affordable by the value chain stakeholders. By answering the three research questions, this study provides a guiding framework for identification of appropriate technological packages, intervention zones and training topics as capacity development requirements to be fulfilled in order to facilitate innovation and adoption of technologies in the Ugandan banana value chain.

Declaration 1: Originality

I declare that this thesis, hereby submitted in partial fulfilment of the Doctor of Philosophy in Agrarian Extension at the University of Pretoria, is my own work and has not been submitted to any other university for a degree of an award. The research reported in this thesis is my original work. I understand plagiarism, other sources have been properly acknowledged and referenced.

Student: Stella Kiconco

Signed………………………………

Date: 21st February 2024

Supervisor: Prof. Suresh Chandra Babu

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Date:…………………………………….

Declaration 2: Publications

These published papers are presented in this thesis as main chapters.

Publication 1- Chapter 4 of this thesis

Kiconco, S., Stevens, J.B., Akankwasa, K. & Kubiriba, J. (2022). Agricultural information exchange and service delivery within social networks: evidence from Uganda's banana value chain actors, The Journal of Agricultural Education and Extension, DOI: 10.1080/1389224X.2022.2131585

Publication 2- Chapter 5 of this thesis

Kiconco, S., Babu, S. C. and Akankwasa, K. (2022) Adoption Patterns and Intensity for Multiple BananaTechnologies in Uganda., *Sustainability (Switzerland)*, 14(23), pp. 1–14. doi: 10.3390/su142315986.

Dedication

Dedicated to the female scholars who alongside their reproductive responsibilities have perfectly excelled in career.

Acknowledgment

I am grateful to you God for the love and mercy upon me throughout my life but most especially in this study, Philippians 4:13.

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List of acronyms and abbreviations

AGRA: Alliance for Green Revolution in Africa

AIS: Agricultural Innovation System

AKIS: Agricultural Knowledge and Information System

AUC: African Union Commission

BBW: Banana Bacterial Wilt

BXW: Banana Xanthomonas Wilt

CAADP: Comprehensive Africa Agriculture Development Program

CD: Capacity Development

CDAIS: Capacity Development for Agricultural Innovation System

DRC: Democratic Republic of Congo

ECA: East and Central Africa

FAO: Food and Agriculture organization of United Nations

FGDs: Focus Group Discussions

GDP: Gross Domestic Product

GFSS: Global Food Security Strategy

KIIs: Key Informant Interviews

MAAIF: Ministry of Agriculture Animal Industry and Fisheries

NAADS: National Agricultural Advisory Services

NAES: National Agricultural Extension Strategy

NARL: National Agricultural Research Laboratories

NARO: National Agricultural Research Organization

NBRP: National Banana Research Program

NDP: National Development Plan

OWC: Operation Wealth Creation program

SLT: Social Learning Theory

SNA: Social Network Analysis

SSA: Sub Saharan Africa

T&V: Training and Visit

UBOS: Uganda Bureau of Statistics

Chapter 1: Introduction

1.1 Background

The world population is projected to be 9.15 billion by 2050; with the largest percentage increase expected in sub-Saharan Africa (SSA) (Food and Agriculture Organization (FAO), 2017); United Nations (UN), 2022). The growth in population is likely to increase global food demand, raise food prices, and pose a threat to future food security and nutrition. Moreover, since 2019, the global food systems have been faced with multiple interruptive crises such as the COVID-19 pandemic, locust invasion in many African countries, and the ongoing Russian-Ukraine war (Alliance for a Green Revolution in Africa (AGRA), 2022), whose consequences, in addition to the already rapid population growth, contribute to the long-term negative effects on food systems due to their impact on global supply networks.

Countries in the SSA are likely to be affected most because of the persistent low agricultural productivity experienced, coupled with the protracted dependency on the importation of food items and farm inputs (FAO, 2022). Besides, agricultural productivity in SSA countries such as Uganda is faced with multiple challenges and constraints including pests and diseases, inferior crop varieties, low soil fertility, effects of climate change; poor extension delivery systems, poor farming methods leading to land degradation, lack of access to input and product markets, lack of access to finance, low levels of value addition and low adoption of improved technologies and practices (World Bank, 2018; Macours, 2019;Takahashi et al., 2019). Such multiple constraints affect agricultural productivity by reducing the volumes and quality of the products which eventually affect their availability and marketability both locally and globally. Previous studies (FAO, ECA & AUC, 2021; FAO, 2022) indicate that unless there are deliberate efforts in place to reduce the constraints or increase resilience to multiple constraints, agricultural productivity will remain low in SSA. This would further contribute to the persistent food insecurity, malnutrition, and poverty which threaten efforts towards achieving sustainable development in the region (FAO, 2022).

Interventions such as the Green Revolution suggest that adoption of improved technologies could be one of the most feasible ways to reduce the constraints and eventually increase agricultural productivity, food production, improve nutrition and income (Otsuka & Muraoka, 2017; Hillbur, 2014; Zeweld et al., 2018; FAO, ECA & AUC, 2021). The technologies can be categorized as input intensification technologies (the use of inorganic fertilizers, pesticides, herbicides, hybrid varieties, and irrigation) (Pingali, 2012; Otsuka & Muraoka, 2017) and low external input technologies which involve the implementation of various agronomic practices such as the use of organic manure, mulching, cover crops, intercrops, and crop rotation (Ahmed, 2015; Wainaina et al., 2016). The adoption and use of the above technologies have been low in SSA (Otsuka & Muraoka, 2017; FAO, ECA & AUC, 2021), further contributing to the persistent poor agricultural productivity with severe cases of food shortage, malnutrition, and poverty. The low adoption could be partly attributed to the lack of access to relevant information and technologies as a result of poor interactions among key stakeholders, especially researchers, extension agents, farmers, and those involved in policy and funding agricultural developments in Africa (Kilelu *et al.*, 2017; Forum for Agricultural Research in Africa (FARA), 2022; Onumah *et al.*, 2022).

The poor interactions as well as the lack of managerial and organizational capacities limit effective stakeholder engagement in several aspects of agricultural innovation for the adoption of technologies (Babu et al., 2015). The agricultural development strategies in most SSA countries are characterized by one-way communication aiming at the transfer of knowledge and technologies generated by research to the farmers (Anandajayasekeram & Gebremedhin, 2009; Perdomo et al., 2010; Klerkx et al., 2012). Such strategies limit the interactions among key stakeholders during problem identification, technology development, and promotion (Hall et al., 2003; Rajalahti et al., 2008; Hellin, 2012; Davis & Sulaiman, 2015), thus disregarding their capacities to contribute to the innovative solutions to agricultural constraints and challenges experienced.

In other instances, agricultural research and development agendas in Africa are conducted according to the donor recommendations which in most cases cannot address the prevailing constraints faced by the target end-users (Sanya et al., 2018). Such situations lead to a mismatch between the implemented agenda, the associated technologies, and the main constraints and challenges to the Africa's agricultural development.

In order to address such problems and improve the adoption of technologies, innovative agricultural approaches that emphasize the active involvement of various stakeholders in technology development and implementation could be deployed (FARA, 2022; Onumah *et al.*, 2022). Such approaches provide a platform for stakeholder interactions, understanding the contexts (challenges and constraints), and provide an enabling environment for utilizing the wide knowledge base and services to generate and promote technologies and innovations that are responsive to the constraints and challenges (Juma, 2007; Yongabo & Göktepe-Hultén, 2021). In addition, stakeholder interactions create synergies and complementarities which enhance the utilization of each other's capacities to innovate collectively and utilize the technologies (Anandajayasekeram & Gebremedhin, 2009).

Stakeholder involvement can take place at different levels such as national, regional, and sectoral to form an innovation system (IS) (Hall et al., 2005). The agricultural innovation system (AIS) is one of the sectoral systems that is regarded as a holistic intervention framework for analyzing constraints and challenges faced by the agricultural sector and provides innovative solutions for improving productivity (Schut et al., 2015). The AIS intervention framework provides guidelines on how to engage various agricultural and other relevant stakeholders effectively. Such engagements become the sources of innovation, information, and support services such as marketing, insurance, and financing which are necessary for adopting productivity-enhancing technologies (Onumah *et al.*, 2022; Perdomo et al., 2010; Davis & Sulaiman, 2015; Saravanan & Suchiradipta, 2017). This shows the effectiveness of the AIS framework in analyzing gaps in agricultural service delivery and potential stakeholder support networks required to fill the gaps.

An agricultural value chain is one of the probable entry points into this analysis (Kilelu et al., 2017; Janssen & Swinnen, 2019; Horton et al., 2022). The value chain is organized in such a way that it contains a series of interdependent activities that involve interactions among various stakeholders. Such interactions provide opportunities for network building, synergies, and complementarities to exchange knowledge and deliver services for technology generation, promotion, and adoption (Lema et al., 2018). An effective analysis to identify these opportunities is one step towards understanding and identifying the key stakeholders to engage with for effective information exchange and service delivery for technology adoption. However, the extent to which value chain analysis is conducted in regard to such a purpose, in most cases is always limited, especially in SSA. Thus, this study explored the possible interactions among stakeholders and service providers in the Ugandan banana value chain as opportunities for innovation and adoption of technologies.

The banana value chain in Uganda and the entire East and Central African (ECA) region (Tanzania Rwanda, Burundi, Kenya, and the Democratic Republic of Congo (DRC) employs diverse stakeholders in various capacities as farmers, researchers, traders, processors, financial service providers among others (Karamura et al., 1998; Nalunga et al., 2015). These stakeholders affect information exchange and service delivery for innovation within the banana value chain and adoption of technologies (Kiconco et al., 2022a). Banana is one of the most important crops in ECA and its consumption in the region is the highest in the world, contributing up to 22% of total daily calorie consumption estimated at 147 kcal per person (FAOSTAT, 2014). According to Tinzaara et al. (2018), the major types of bananas grown in ECA can be categorized as (i) Green cooking banana varieties (AAA) known as *Matooke* in Uganda, which are mainly produced for home use and the surplus sold to the local markets; (ii) Beer varieties (AB, ABB, and AAA-EA) which are processed into banana beer, wine and juice and sold in local markets; and (iii) dessert banana types (AAA and AB) which are eaten when ripe. The green cooking banana varieties are the most common ones in Uganda and have been grown for over 150 years (Sabiiti *et al*., 2016).

Much of the bananas grown in Uganda are consumed at household level and farmers only enter the market as opportunities and needs arise (Kalyebara *et al.*, 2007). The cooking banana varieties are mainly traded in domestic markets and once in a while are exported to East African countries or directed to a niche market of emigrants (Bagamba *et al*., 2006). Domestic banana markets in Uganda are in major towns located at 150-400 kilometers from the farming communities. The banana value chain in Uganda, just like any other agricultural value chain is affected by various challenges right from production through post-harvest handling and during the marketing of the bananas and banana products (Ngambeki et al., 2010; Ariho et al., 2015). At the production level, the challenges are associated with soil and moisture conservation, pests and diseases, and low-yielding banana varieties (Akankwasa et al., 2016; Sanya et al., 2020).

At the post-harvest and marketing levels, bananas pose a challenge of quick ripening yet with limited processing options (Ariho et al., 2015). Banana farmers usually operate at the lower end of a very long chain of middlemen where they get very low prices for their products. In addition, the farmers experience price fluctuations due to the seasonal nature of bananas, while poor road network and the scattered nature of banana farmers limit their access to the lucrative banana markets (Tinzaara et al., 2018).

Such challenges, reduce the farmers' profits and discourage them from adopting new technologies especially those that require initial capital investments such as the use of fertilizers. As a result, the productivity levels in Uganda have remained low, with less focus on commercial banana production. Solutions to the above challenges require the use of an agricultural development approach that utilizes stakeholder capacities and enhances interactions for knowledge exchange and service delivery among them (Kiconco et al., 2022a). Such an approach improves adoption by increasing farmer access to information, financial services, access to alternative banana markets and processing options, which increase farmer profits from agricultural production.

1.2 Problem statement

Banana is the most preferred staple crop in many areas of Uganda and commands a relatively high price in urban food markets (Akankwasa et al., 2016; Ariho et al., 2015). The crop is grown by the majority population across diverse agro-ecological zones in the country. According to the MAAIF's strategic intervention plan 2015/16 - 2019/20, banana is among the priority crops for sustaining Uganda's food security. Owing to the crop's national importance, the National Banana Research Program (NBRP) was initiated in 1989 under the National Agricultural Research Organization (NARO) to specifically focus on research into how banana production and productivity can be improved and sustained countrywide (Tushemereirwe et al., 2003). Thus, for decades, the program has been spearheading the generation and promotion of several technologies for improving productivity which include among others; (i) Banana plantation management practices such as timely weeding, banana sucker management, male bud removal, banana propping and intercropping; ii) Soil and water conservation practices including mulching, use of organic and inorganic fertilizers and construction and maintenance of basins and trenches for water and soil retention (Nyombi, 2014); (iii) Pests and disease prevention and control measures including the use of clean planting material, trapping the weevils and use of chemicals (Gold *et al*., 2002; Tushemereirwe *et al*., 2003; Tinzaara *et al*., 2002); (iv) Integration of trees in banana plantations (Ssebulime et al., 2017); and (v) Breeding and promotion of *matooke* and introduced (FHIA) varieties which are disease and pests resistant and high yielding (Akankwasa *et al*., 2016; Sanya et al., 2020).

Despite the multiplicity of the available improved technologies, banana productivity in Uganda is still very low. On-farm banana productivity, for example, is at 10 tonnes as compared to a potential of 60 tonnes per hectare per year recorded at research stations (Van Asten *et al*., 2005; Uganda Bureau of Statistics (UBOS), 2023). The low productivity could be attributed to the low levels of adopting technologies; for example, Kagezi et al. (2013) reported adoption of *Matooke* hybrid varieties ranging from 5% to 15% nationwide. Quite a lot of studies have been conducted in the quest for the ways in which agricultural technology adoption could be improved as a means to increase productivity, especially in SSA countries including Uganda (Aryal et al., 2018; Zeweld et al., 2018). Most of these studies suggest technological; farmer, household farm; and institutional characteristics as factors that influence adoption. In these studies, the effect of interactions among value chain stakeholders and utilization of stakeholder capacities to innovate and adopt technologies is not exhaustively discussed. Most banana studies in Uganda for example, provide minimal information regarding the active engagement of banana value chain stakeholders in innovation activities and adoption of technologies (Gold et al., 1999; Katungi, 2007; Akankwasa et al., 2013; Akankwasa et al., 2016; Sanya et al., 2018; Sanya et al., 2020). This limits stakeholder capacity utilization to exchange valuable information and services that are necessary to innovate and adopt technologies.

Thus, there is limited empirical evidence with regards to: (i) the existing interactions and relationships for exchanging information and services between research, extension, and other stakeholders in the banana value chain; (ii) the capacities needed by the stakeholders in the banana value chain in order to innovate and adopt technologies; and (iii) what determines the adoption patterns and intensity for multiple banana technologies and innovations.

Therefore, this study examined the agricultural innovation arrangements in place to enable stakeholders in the Ugandan banana value chain to interact and develop capacities to innovate and/ or influence the adoption of technologies. The study results provide a basis on which to develop a holistic extension approach that facilitates synergistic interactions among various stakeholders in the value chain, addresses the capacity development needs of individuals, and organizations, and enables the environment to participate in innovation and adoption of technologies.

1.3 Research objectives

The general objective of the study was to examine the agricultural innovation arrangements in place to enable the stakeholders in the Ugandan banana value chain to interact and develop capacities for participating in agri-based networks for innovation and adoption technologies. The study was structured around three research questions :

Research question 1: How do the stakeholders in the banana value chain interact and support one another to innovate and adopt technology?

Research question 2: What capacity development needs are required in the banana value chain to improve innovation and uptake of technologies?

Research question 3: What determines household adoption patterns and intensity for multiple banana technologies in Uganda?

1.4 Study outline

The study comprises seven chapters.

Chapter 1 presents the general introduction to the study highlighting the background, problem statement, and objectives of this study.

An account of the reviewed literature is presented in Chapter 2 and covers the status and nature of existing interactions among stakeholders in the banana value chain, the current capacities of individual stakeholders and organizations, the enabling environment for innovation in the banana value chain, and review of adoption studies of banana technologies in Uganda.

Chapter 3 describes the methodology used for this study and covers the study area, sampling procedure, methods of data collection, and analysis procedures.

The first empirical chapter which presents the results of objective one of identifying the stakeholders in the banana value chain and relationships for exchanging information and services is presented in Chapter 4.

Chapter 5 then describes the results of objective 2 and covers the current capacities of individual stakeholders, organizations, and the enabling environment to innovate. In this chapter, capacity development needs for individuals, organizations, and enabling environment to innovate are also identified.

The last empirical chapter, Chapter 6 presents the results of objective 3 which covers the adoption patterns and intensity for multiple banana technologies in Uganda.

The summary, conclusions, and recommendations for the study are finally presented in Chapter 7.

Chapter 2: Literature Review

2.1 Introduction

This chapter gives a detailed review of stakeholder interactions and their importance in agricultural innovation and the adoption of technologies with a specific focus on the banana value chain in Uganda. The capacity development for agricultural innovation and details of its three dimensions are also covered in this chapter. The chapter also presents the determinants of the adoption of agricultural technologies, the banana production technologies in Uganda, the approaches used for measuring adoption, and the theoretical and conceptual framework.

2.2 Stakeholder interactions and innovation in the banana value chain

In the early days, innovation was regarded as knowledge and technologies generated by scientists on research stations (Anandajayasekeram & Gebremedhin, 2009). With this definition, agricultural development approaches regarded research as the sole source of innovations and public extension as the only intermediary to the transfer of information and technologies from research to the farmers (Adejuwon, 2016). However, with the increased recognition of agriculture's contribution to poverty alleviation, environmental conservation, food, nutrition, and income security; innovation, on top of knowledge and technology production, is currently regarded as various ways of organizing the farmers, facilitation of linkages with markets and financial sources and fostering partnerships with other development organizations (Anandajayasekeram and Gebremedhin, 2009; Birner et al. 2009; Stevens & Letty, 2014; Schut et al. 2015) This then implies the integration of knowledge from stakeholders of diverse disciplines including research, extension, NGOs, producer groups, individual farmers, policy institutions, market players, consumers, processors, CBOs, and government, among others into agricultural development (Ojijo et al., 2016; Moschitz et al., 2015). The application of the value chain approach to agricultural development presents one of the pathways for engaging a wide range of stakeholders in the learning and co-production of innovations (Stevens and Letty, 2014). The value chain comprises various stakeholders involved in diverse activities together with their relationships for value creation and market linkages (Kilelu et al., 2017). Over the years, the National Banana Research Program (NBRP) and development partners have been generating technologies and actively implementing various innovative activities to increase banana productivity, and at the same time get access to the different banana market channels as a form of sustainable banana production. However, the level and the extent to which the different and key stakeholders have been actively engaged in banana development activities presented the challenges and opportunities for the adoption of technologies and innovations for improved productivity. Sanya et al (2018) for example noted that, although some stakeholders such as farmers and extension agents are usually engaged in banana breeding activities, their active involvement at critical stages, for instance, setting the breeding agenda is limited, which affects the receptiveness of hybrid banana varieties among farming communities in Uganda. On the engagement of value chain stakeholders, Kiconco et al (2022a) reported a low network density (cohesion) among the banana value chain stakeholders and service providers in the central, southwestern, and western regions of Uganda. This shows the existing low level of interaction and the associated exchange of information and services necessary for innovation to take place among them. Innovation can be defined as an interactive learning process through which stakeholders bring about new products, processes, and forms of organization for social and economic use (World Bank, 2006). Stakeholder interactions in specific banana improvement activities in Uganda are detailed below.

2.2.1 Banana improvement and natural resources management (2001-2007): Banana is a climate-smart perennial crop that grows in diverse agroecological zones including dry areas such as central Uganda (Nansamba et al., 2022). Thus, the implementation of natural resource management practices in this area was a result of the need to improve soil fertility and water conservation to ensure constant banana harvests throughout the year (Tushemereirwe et al., 2003). It involved the promotion of technologies such as the construction and desilting of water trenches, the use of compost manure, and mulching of plantations. These practices maintained the banana gardens in good condition throughout 1.5 years of dry spells in 2004-2005. This was implemented through farmer groups as a form of participatory approach to encourage farmers to learn from one another (Okuthe, 2014). The promoted practices were a modification of cultural practices of soil and water conservation which were previously practiced among the farmers. Therefore, they were easy to implement, and up to now, they are still practiced among many banana farmers (Kiconco et al., 2022b).

2.2.2 Promotion of banana technologies through the NAADs program (2001-2014): The NAADS program was a participatory approach to agricultural extension in Uganda where farmer groups were engaged in making decisions with regard to the priority agricultural enterprises they wanted to engage in (Nkonya et al., 2020). For the farmer groups that selected bananas, the NAADS in connection with the NBRP and commercial banana seedling producers provided clean and high-yielding hybrid banana varieties (Akankwasa et al., 2016). This was accompanied by the knowledge package of good banana husbandry practices (Tushemereirwe et al., 2003) to enhance adoption.

Although the adoption of hybrid bananas reduced the incidence of pests and diseases and boosted on-farm banana productivity (Akankwasa et al., 2016), this achievement was not sustainable because the promoted banana varieties tasted differently and had low market value thus, they were later abandoned by the farmers (Sanya et al., 2018). As a result, the farmers resumed the planting of local varieties which are not only susceptible to pests and diseases but are also low-yielding. This indicates that the opinions of the key value chain stakeholders such as banana traders and consumers were not sought and considered to influence on-farm adoption. Thus, in order to achieve sustainable adoption, there is a need to actively engage a wide network of value chain stakeholders during technology development processes and incorporate their desired traits in the technology.

2.2.3 The integration of livestock into the banana farming system in Central Uganda (2005-2007): The farmers in central Uganda argued that the biggest challenge they faced was the lack of livestock compared to western Uganda as a sustainable source of organic manure for improving soil fertility (Katungi, 2007). Moreover, animal manure facilitates organic banana production for a competitive market for Ugandan bananas (Ntale et al., 2015). In addition, the use of animal manure is a climate-smart practice, an alternative to over-dependence on imported chemical fertilizers, and improves the resilience of the banana farming system (Chinseu et al., 2022). Thus, the NBRP in consultation with some stakeholders such as Send a Cow, Caritas, and World Vision identified the constraints, opportunities, and threats to the integration of livestock with banana farming. In addition, they procured and offered Friesian cows to the farmer groups and trained them in livestock production (Katungi, 2007). However, caring for Friesians within farmer groups did not last long because of the labor constraints that came along with caring for the cow. Furthermore, there was competitiveness of the available area for fodder production and expansion of banana production which left many banana farmers to continue producing bananas with little or no application of manure and the continued low banana productivity.

2.2.4 Emergency project on the control of Banana Bacterial Wilt (*Banana Xanthomonas wilt)* (2005-2008):

Banana Bacterial Wilt was a threat to the banana farming communities in Uganda during 2005-2008. The control of the disease involved the engagement of diverse stakeholders at different levels such as local communities, scientists, and civil society organizations. They were involved in setting the action plans and by-laws that guided the implementation of a technology package of cultural control practices (Kubiriba et al., 2016). The use of cultural practices contributed to the successful control of the disease because the local stakeholders especially the farmers identified with the practices. In addition, the quick results could be from the use of various stakeholders' capacities and strengths to collaboratively control the disease. Ojijo *et al*. (2016) affirm that transforming smallholder agriculture into a productive, efficient, competitive, and sustainable system requires a cadre of scientists, technicians, agribusiness personnel, and farmers with various capacities to ensure success. However, the sustainability of such collaborations is usually challenging due to the changing enabling environment which limits consistent results in agricultural interventions (Anandajayasekeram & Gebremedhin, 2009). In other instances, sustainable collaboration is challenged by the lack of harmonization of the roles to be played by the different stakeholders involved, for example, the NAADS program in Uganda (Afranaakwapong & Nkonya, 2015). Therefore, for sustainable stakeholder engagement in innovation, it is important to understand the enabling environment in which they work best, and clear roles and responsibilities should be assigned to each of them.

2.2.5 Breeding, multiplication, and promotion of high-yielding, pests and disease-resistant matooke hybrids (2007-2016): The NBRP's initiatives to control banana disease (especially Black Sigatoka) were intensive from 2007 to 2016 through breeding, evaluation, multiplication, and promotion of *Matooke* hybrids which were resistant to the disease. In addition, the *Matooke* hybrids were high-yielding and resistant to nematodes and banana weevils which are also a threat to banana production especially in central Uganda (Akankwasa et al., 2016). After evaluation, the preferred varieties were multiplied and promoted in Northern, Eastern, Central, and Mid-western parts of Uganda (Akankwasa *et al*., 2013). However, despite the promotional efforts, these varieties are not yet visible to many farmers and their demand is still low in markets compared to the local varieties in Uganda, which Sanya *et al*. (2017) attribute to the little or lack of involvement of key stakeholders such as farmers during the first stage of setting research agenda to develop the hybrids. Effective stakeholder involvement enables the utilization of their capacities and creates favorable policy and institutional environments for innovation and adoption of technologies to take place (Anandajayasekeram & Gebremedhin, 2009). Capacity development for innovation in an agricultural value chain is discussed below in detail.

2.3 Capacity development for innovation in an agricultural value chain and adoption of banana technologies

There is an increasing interest from the international communities to support value chain development where smallholder farmers are directly linked to other market stakeholders (Kilelu et al., 2017; Devaux et al. 2018; Ssennoga, et al., 2019; Horton et al. 2022). This is in recognition of the smallholder farmers' potential to become more innovative, entrepreneurial and expand their enterprises to engage in other profitable aspects along the value chain (Babu et al., 2015). This necessitates that the farmers possess the capacity to identify opportunities for growth, not only in the local but also in regional and global markets. In addition, the farmers must be in a position to work in an integrated and coordinated manner with other stakeholders such as input suppliers, service providers, funding agencies, and retailers in order to facilitate access to modern technologies and services that boost agricultural productivity (Devaux et al., 2018). Mayanja et al (2013) also suggest that not only the relationships between value chain stakeholders should be strengthened, but so should the standards, regulations, and policies to create a favorable environment for the growth and development of agricultural markets. Thus, the manner in which stakeholder relationships are managed is key to enabling an effective flow of resources, commodities, and knowledge needed to innovate at every node of the value chain including on-farm adoption of technologies (Trienekens, 2011). Proper management ensures the complementary and synergistic utilization of stakeholder capacities while innovating together. This then implies that the current capacities and challenges of each stakeholder should be analyzed in addition to the roles they play in the value chain innovation system. This facilitates proper engagement of stakeholders during engagements for innovation activities. In a quest for proper engagement and management of stakeholders in the banana value chain innovation activities, this study identified the current challenges faced, the current capacities they possess and the capacity development needs.

In Uganda, bananas are mainly sold in spot markets characterized by low prices and weak relationships between the farmers and other chain stakeholders. Although there is a potential to access international markets, banana farmers do not have capacities to respond effectively to the demands of such markets (Mayanja et al., 2013). Thus, the intermediaries in international markets and processors are frustrated by the high transaction costs, small volumes, non-uniformity in the quality of supplies which limit their operations (Ssennoga et al., 2019). In this study, the capacity needs were identified which when addressed could improve innovation for improved relationships and interconnections among stakeholders in the banana value chain which reduces such frustration.

Capacity development has three dimensions: the individual, organizational, and enabling environment which are also subject to political and socioeconomic factors (FAO, 2012; Babu et al 2015). The three dimensions are interdependent and mutually reinforcing to influence the overall impact of the capacity development intervention (Tropical Agriculture Platform, 2016). Planning for capacity development commences with the identification of the needs required at all dimensions in order to facilitate innovation.

Thus, capacity development needs at the individual dimension are analyzed in the context of the required skills, behaviors, practices, and attitudes among individual stakeholders such as the farmers, traders, processors, extension agents, and input suppliers, among others (FAO, 2012). The identified needs act as a basis for designing capacity development strategies to improve innovation. CD strategies at individual dimension are designed to impart technical and or functional capacities. Technical capacities are needed to enable successful innovation in a specific field such as processing and agronomy; while functional capacities are required to enable connections for the innovation to perform effectively, for example, effective collaboration to facilitate learning, and engagement in strategic and political processes (Global Food Security Strategy (GFSS), 2017). Babu et al. (2015) recommend that individuals at all nodes of the value chain must have the technical and functional capacities to enable them to apply modern and efficient technologies and practices that boost productivity. This stresses the need to identify and address individual capacity gaps to enable active engagement in innovation activities.

Capacity development at the organizational dimension focuses on improving the overall functioning of an organization along with strengthening the interactions among the organizations (FAO, 2012). Babu et al (2015) noted that the organizational and managerial capacity to bring together the farmers, the public, and the private sector into agribusiness innovations is still low in several African countries. The low organizational capacity is also reflected in the Ugandan banana value chain where Kiconco et al (2022a) observed the low cohesiveness among stakeholders in the banana value chain, which limited information exchange and service delivery for innovation and adoption of technologies. Capacity development of organizations often leads to changes in organizational mandates, systems, and priorities (FAO, 2012) in order to respond to stakeholder linkages for innovation. The enabling environment influences how innovations take place at the organizational and individual dimensions. Enabling environment refers to the norms, customs, laws, regulations, policies, international trade agreements, and public infrastructure in which innovation and adoption take place (GFSS, 2017). Competent individuals and capable organizations can never be effective in an environment that does not effectively support them. Capacities in the enabling environment dimension may involve policy reform in the agricultural sector, prioritization, changes to incentive systems, or cultural changes among others (FAO, 2012). Such capacities should strengthen the stakeholder linkages and facilitate the flow of information between agricultural research, extension, and producers and also strengthen and promote coordination between public and private research institutes to support innovation (Babu et al, 2015).

Most of the previous studies on the banana value chain in Uganda aimed at identifying the stakeholders, and their gender roles and quantifying how much of the bananas flow through different market channels for example (Ariho *et al.*, 2015; Marimo *et al.*, 2019; Ajambo *et al.*, 2020). In addition to this, some other studies measured the costs and revenues to estimate how much value is added at every node of the value chain (Ngambeki, et al., 2010; Nalunga *et al.*, 2015; Kikulwe *et al.*, 2018). Little and less exhaustive research on capacity development for innovation and adoption of technologies has been conducted. Ariho *et al.* (2016) for example assessed the enabling environment for the development of the banana value chain in Uganda; while Kiconco et al (2022a) covered information exchange and service delivery among banana value chain stakeholders. The summary of recent studies on the banana value chain in Uganda is presented in Table 2.1. Therefore, it is essential to conduct a comprehensive study in order to identify the capacity development gaps to enable innovation for efficient and resilient banana value chain development.

Table 2.1: Overview of the previous studies on banana value chain

Authors	Title	Subject covered	Main finding	Recommendation
Ngambeki, Nowakunda and Tushemereirwe, (2010)	The extent and causes of banana market distortions in Uganda	The extent to which the middlemen in upcountry banana markets affect farmers' prices	• 70% of the farmers market their bananas through middlemen • Some farmers sell in informal groups earning 44% of wholesalers' price at the nearest loading center • 19% of the farmers organized into collective marketing groups	None
Nowakunda et al (2010)	Increasing small scale farmers' competitiveness in banana production and marketing	Small-scale farmers' competitiveness in banana production and marketing	• Working through farmer network groups including other organizations enabled them to: develop and maintain a market-information system; access wholesale markets; bulk purchase of inputs; access extension services; improve pest disease management; and in-field fruit-quality.	None
Ariho *et al.*, (2015)	Assessment of innovative market access options for banana value chain in Uganda	Major options for banana farmers and other stakeholders to access markets	• The major innovative market access options for bananas are group marketing, contract farming, mobile phone platforms, value addition and supermarkets. However, they are underutilized.	• There is need to develop a banana value chain development strategic framework to tap into innovations among value chain stakeholders and facilitate their diffusion among major banana growing areas in Uganda.
Nalunga *et al.*, (2015)	Structure of the cooking banana value chain in Uganda and opportunities for value addition and postharvest losses reduction	key stakeholders in banana value chain, presentation forms of bananas in markets, banana sorting and grading among stakeholders, use of weight-based banana marketing system and post-harvest losses along the value chain	• The producers, brokers and wholesalers sell bananas in bunches and sacks of unpeeled fingers • Exporters sell banana clusters to European markets and bunches to the regional markets • Supermarkets sell in clusters • Banana retailers sell bunches, fingers and clusters but bunches are most preferred • The producers, brokers, bicycle traders and wholesalers grade their	None

			bananas by visual inspection of bunch size which presents risks for unfair marketing transactions • The stakeholders in trading bananas face high postharvest losses because of short green life of bananas and damage from poor post-harvest handling	
Ntale *et al.*, (2015)	Stakeholders influencing successful inclusion of smallholder farmers in modern value chain in African-Caribbean-Pacific (ACP) countries: lessons from pig, banana and fish value chains in Uganda	Smallholder inclusion in the value chain	• Farmers have access to a variety of buyers including local traders, local markets and urban traders • No standard for grading bananas, prices are determined arbitrary based on bunch size	None
Ariho *et al.*, (2016)	Assessment of existing policy and legal framework for banana value chain development in Uganda	Assessing enabling environment for development of banana value chain in Uganda.	• No specific policy for banana subsector	• Adequate financing and human capital development are required to empower existing institutions towards promotion of banana value chain.
Mayanja, Mudege and Nanziri (2016)	Gender situational analysis of the banana value chain in western Uganda and strategies for gender equity in postharvest innovations	Gender strategies to enhance uptake and utilization recommended improved technologies and practices along the value chain	• Constraints faced by farmers are: lack of equipment, fertilizer and manure; lack of market, price fluctuations and low prices, lack of access to agricultural and women friendly credit; lack of access to quality suckers • Constraints faced by traders are: constraints related to mobility, little knowledge on postharvest and marketing innovations	• Use of the proposed gender strategy to enhance uptake and utilization of recommended improved technologies and practices along the value chain
Kikulwe *et al.*, (2018)	Postharvest losses and their determinants: a challenge to creating a sustainable cooking	Magnitude, distribution and determinants of postharvest losses of bananas	• Major postharvest losses are experienced at retail node • At farm level, female headed households suffer more losses than male headed households	• Call for a comprehensive and gender responsive postharvest loss reduction strategies

	banana value chain in Uganda		• Household headship, household size, proportion of land allocated to banana production and monthly banana production are the principal determinants of postharvest losses at farm level • At retail level, postharvest losses are determined by the sex of the vendor and group membership	
Tinzaara *et al.*, (2018)	Challenges and opportunities for smallholders in banana value chains	challenges and opportunities for smallholder farmers at pre-production, production, post-harvest management and marketing stages of the banana value chain	• Opportunities along the value chain (pre-production, production, value addition, marketing) for increasing banana production	• More research focusing the enabling environment for production, processing and marketing of bananas
Ssennoga, Mugurusi and Oluka (2019)	Food insecurity as a supply chain problem. Evidence and lessons from the production and supply of bananas in Uganda	Food insecurity as a result of supply chain problems	• Farmers do not benefit from increased food prices due to insufficient market information. • Infrastructural limitations and limited collaboration and coordination among smallholders greatly affect countrywide supply of bananas.	• Provide prospects for farmer cooperative unions to control information. • Cooperative unions should play a lead role in collection and distribution of information on banana production, marketing and distribution to enable smallholder farmers become active members in the value chain. • Invest in physical infrastructure to support postharvest handling of bananas and transportation • Establish strong linkages between regulated sources of information such as cooperative unions with government agricultural extension services as an opportunity to share

				production and marketing information.
Ajambo *et al.* (2020)	Gender roles and constraints in the green cooking banana value chain: evidence from southwestern Uganda	Men and women engagement in cooking banana value chain	• Social norms and banana business entry requirements pose constraints to women participation in banana value chain. • Women mainly participate at retail node (70%) and are absent at wholesale node. • Retail node registers the highest post- harvest losses and the lowest profit margins. • The main source of financial assistance to are informal sources such as farmer groups which do not require collateral.	• Develop financial products such as loans which respond to the needs of women farmers.
Akankwasa et al. (2020)	The East African highland cooking bananas ‘Matooke’ preferences of farmers and traders: implications for variety development	Matooke trait preferences for farmers and traders	• characteristics which drive trait preferences among farmers and traders were agronomic (big bunch, big fruits) and quality (soft texture, good taste, good aroma, yellow food).	• Quality characteristics should be well defined for the breeding programs to incorporate from the beginning in order improve adoption and impact of new banana varieties
Kiconco et al. (2022a)	Agricultural information exchange and service delivery within social networks: evidence from Uganda’s banana value chain stakeholders	Value chain stakeholder linkages for exchange of information and services which facilitate adoption of banana technologies	• There is low cohesiveness among stakeholders in banana value chain with the utilization of only 30% of potential linkages for information exchange and service delivery • Farmer groups and regulatory bodies are the most influential stakeholders for facilitating information exchange although they are more of recipients rather than determinants of information or services exchanged	• Extension, research and practitioners should take advantage of existing farmer networks for information exchange and service delivery as the means to expand and sustain their last mile reach.

2.4 Determinants of adoption patterns and intensity for multiple banana technologies

2.4.1 Banana production technologies in Uganda

Banana is one of the essential crops for food security in Uganda and attracts various stakeholders in the market, research, government agencies, and the private sector (Ntale et al., 2015). Bananas in Uganda are produced on individual small subsistence farms with sizes ranging from 0.2-1.6 hectares (Gold *et al.,* 2002). It is a perennial crop and can be continuously grown on the same piece of land thus, necessitating rigorous management in order to achieve and sustain high yields. The longevity of banana plantations ranges from as low as four years in Central to over 50 years in Southwestern Uganda where it is a household asset inherited from one generation to another (Katungi, 2007). Over the years, traditional banana management practices have been subjected to adjustments and modifications in order to cope with the new productivity challenges.

The high number of banana practices and specific details of how each of them should be implemented reflects how complex they are and the level of knowledge required in banana management (NARO, 2019; Tushemereirwe et al., 2003). Consequently, it is more likely that farmers will choose to implement a combination of technologies in a step-wise manner depending on the convenience of using them, similar resource requirements, and complementarity in their use (Byerlee & Polanco, 1986). Thus, the establishment of the patterns in which the households choose to implement the technologies and the number of technologies that can be implemented at a time provide insights into technological packaging to facilitate adoption. This is useful in guiding further scaling of banana technologies. Due to the complexity and knowledge requirement for implementing banana technologies and practices, Katungi (2007) recommended that the promotion of such technologies should be conducted through social networks in which individuals learn from one another while implementing sub-components until the full technological package is implemented. The technologies and practices can be categorized as soil and water conservation practices, pests and disease control practices, and mat management practices (NARO, 2019). A collection of these practices and technologies was promoted under the Banana Agronomy project (2017-2020) as part of deliberate efforts to promote various technologies in order to tackle simultaneously a myriad of challenges faced in on-farm banana production. The technologies and practices are described in the following subsections.

2.4.1.1 Soil and water conservation practices

a) Use of organic manure from animals: Tushemereirwe et al. (2003) in a banana production manual recommended that manure should be applied around the mat at least once a year at the onset of the rainy season. They suggest first forking before pouring one to two basins of manure two feet away from the mat in order to allow extended root growth.

b) Use of inorganic manure: This is an input intensification technology intended to curb nutrients lost in banana fruits to the city centers. In addition, animal manure has become scarce and distances from banana growing areas to cattle-keeping areas for cow dung further increase the costs.

c) Mulching: This is a traditional practice where bananas are mulched with residues from old banana leaves, sheaths, and split pseudo stems. However, due to the increased decline in soil fertility and extended dry seasons, other sources of mulch are recommended in order to improve the microclimate. Such sources are papyrus reeds, crop residues such as maize stovers, bean trash, and sorghum. Tushemereirwe et al (2003) recommended that mulch should be placed 50 cm away from the mat and it should be done during the dry season.

d) Construction of trenches and desilting them: Trenches are dug across the gradient of the plantation in order to reduce surface runoff and facilitate efficient absorption of rainwater into the soil.

e) Construction of basins and desilting them: Basins are constructed in between the four neighboring mats on a flat terrain. They also capture rainwater for the banana mats.

2.4.1.2 Pests and disease management practices

a) Use of clean planting materials (pared suckers and tissue culture banana plantlets): While tissue culture plantlets are free from pests and diseases, sucker paring controls weevils and nematodes. It is done in a banana plantation where banana suckers are obtained.

b) Chopping pseudo stems and weevil trapping: Chopping fastens the drying and decaying of banana pseudo stems after harvesting. In this way, it reduces the breeding ground for banana weevils.

c) Male bud removal: This is one of the traditional practices promoted to control *Banana Xanthomonas wilt* (*BXW*). It reduces the movement of insects from one male bud to another, spreading the disease (Kubiriba & Tushemereirwe, 2014).

Sterilizing tools with Sodium hypocholite or fire: This is one of the sanitary practices recommended to control *BXW*.

d) Use of hybrid banana varieties: This is one of the input intensification practices aimed at promoting hybrid banana varieties which are high-yielding and resistant to *Black Sigatoka* disease and nematodes. NBRP has been promoting these varieties in banana-producing areas of the country since 2007. The major distributed varieties are M9, M2, M14, M25 (cooking types), and FHIA 17 (dessert type) (Akankwasa et al., 2013).

2.4.1.3 Mat/ stool management practices

a)De-suckering: This is a traditional practice of removing excess suckers in order to reduce competition for water, light, and nutrients on a stool. It is recommended to leave three plants per mat with one from each successive generation that is mother, daughter, and granddaughter (Tushemereirwe et al., 2003).

b) De-trashing: This is the removal of old leaves and sheaths from banana pseudo stems. This practice provides traditional mulch and controls pests and diseases. However, some farmers sometimes reduce green leaves too in order to reduce wind effects.

c) Corm removal: This is the removal of the corm from a mat where banana fruit has been harvested. This disrupts the weevil life cycle, thus reducing the incidence.

2.4.2 Factors affecting the adoption of multiple agricultural technologies

Technologies are essential in agricultural production and have shaped the history of farming over time and everywhere. Adoption of new or improved technologies such as new varieties or fertilizers is highly regarded as the most feasible pathway to improve agricultural productivity and food security (AGRA, 2022). The farmers' decisions to adopt technologies including the speed of adoption are influenced by a number of household socioeconomic, physical farm characteristics and as well as access to agricultural support services.

Among the socioeconomic characteristics, the gender of the household head affects the adoption of technologies in various ways. In most communities, women do not have access to and or control over resources such as land, labor, and capital which are essential for the adoption of technologies (Abunga et al., 2012; Obisesan, 2014). Thus, in most cases, female-headed households are less likely to adopt new technologies. In other instances, women are associated with the adoption of technologies based on labor benefits associated with them. For example, the herbicide-tolerant maize variety in South Africa (Gouse et al., 2016) which requires less weeding was adopted by more women than men. In addition, women compared to men usually adopt technologies biased toward food security. For example, more women than men in Uganda adopted banana hybrid varieties (Sanya et al., 2020) because of their traits of high yielding and food security benefits.

Household size is linked to the availability of labor to partake in the implementation of the additional new technology. This is especially so in SSA where family members are directly involved in providing labor for agricultural activities. For example, large family size was associated with the adoption of labor-intensive practices such as planting trees, soil conservation, and mixed cropping in Nigeria (Ndiritu et al., 2014). Similarly, Kiconco, et al. (2022b) also found that family size was associated with the adoption of trenches for soil and water conservation and the adoption of hybrid banana varieties for pests and disease management among banana farming communities in Uganda.

With regards to physical farm characteristics, land accessibility and allocation to banana production: Feder et al. (1985) highlight that there is minimum land size requirement below which no new technologies can be adopted. Wubeneh & Sanders (2006) reaffirm that households with more land are more likely to devote portions of their land to experiment with the new technology. Thus, in this study, households with more land are likely to adopt technologies which require opening up new areas such as the use of hybrid banana varieties. However, with the increase in the land allocated to bananas such technologies are likely not to be adopted but instead favor adoption of all other technologies which are practiced in already established plantations such as mulching, sterilizing tools, among others (Kiconco et al., 2022b).

Ecological conditions and soil fertility status: The physical farm environment such as good soil and sufficient moisture content increases the expected utility of income from modern production and hence increases the probability of the farmer to adopt a new technology (Feder et al., 1985). However, for this study, households located in dry corridor are likely to adopt a number of technologies, especially those associated with soil and water conservation.

Access to support services such as credit positively influences the farmer's adoption behavior through increasing risk-bearing ability associated with the adoption of new technologies (Mujeyi et al., 2020). Access to credit lowers the income constraints of the farmers, which then enables them to access inputs or new technologies such as fertilizers (Awotide et al., 2016). Thus, farmers with access to credit are more likely to adopt technologies than those without credit access.

Access to agricultural extension services enables farmers to get exposed to information about the use of technology. It creates awareness of technology availability, thereby paving the way for its adoption (Mujeyi et al., 2020). Therefore, farmers who access agricultural extension services are more likely to adopt technologies than those who do not have access to such services.

Membership in the farmer group enhances social capital (Katungi, 2007), trust and information sharing with regard to new technologies (Kiconco et al., 2022b). Thus, the farmers who belong to farmer groups are more likely to adopt technologies than those not in farmer groups.

2.4.3 Approaches for measuring adoption

There are various approaches used in understanding what influences the adoption decisions of agricultural technologies. Among them, dichotomous choice models (logit, probit, and tobit) and multiple response models (multinomial logit or multivariate probit) have been widely used (Isgin et al., 2008; Sharma et al., 2011; Teklewold et al., 2011; Kassie et al., 2015; Zeweld et al., 2018; Aryal et al., 2018). A dichotomous regression model is usually applicable when the data used is qualitative and only explains the probability of adoption or non-adoption (Wooldridge, 2012). On the other hand, a multinomial response model is used when there are three or more alternative responses assuming the Independent Irrelevant Alternative (IIA) (Greene, 2003). Tobit model is also used when the data set for the dependent variable is censored and when the effects of the independent variables on the dependent variable are continuous. This model is usually applied when estimating the joint effects of the factors that influence the probability and intensity (area of expansion) of adoption (Wooldridge, 2012). The weakness of the above models is that they assume the independence of error terms of different technologies, thus; they can yield biased results if applied where a decision to adopt a technology is influenced by adoption decisions of other technologies used (Teklewold et al., 2011; Sharma et al., 2011). Under such conditions, the Multivariate probit (MVP) model is the appropriate one to be applied. The MVP allows for the interrelationships among the various technologies, which helps in determining possible complementarities (positive correlation) and substitutability (negative correlation) between the technologies (Kassie et al., 2015; Aryal et al., 2018). This model is appropriate for understanding multiple adoption decisions of banana technologies because the decision to adopt one practice influences the adoption of several other technologies and vice versa.

To estimate the adoption intensity of various banana technologies, the ordered probit model was used with the number of technologies adopted as the dependent variable. The adoption intensity of agricultural technologies is usually based on the proportion of land covered by the technology (Aryal et al., 2018). However, in cases such as the adoption of various banana technologies, the exact area under each technology is always challenging to assess. Therefore, the intensity of adoption is estimated by the number of technologies adopted by each household (Greene, 2003). In addition, the use of the number of technologies as a dependent variable looks to be count data, justifying the use of Poisson regression models. However, Poisson regression assumes an equal probability of adopting each alternative technology (Wooldridge, 2012). Therefore, this assumption is not applicable to this study since the likelihood of adopting one technology might differ from that of adopting the second and so on; and with the adoption of the first practice, the farmer is exposed to information about all other technologies (Greene, 2003).

2.5 The theoretical and conceptual frameworks

2.5.1 The innovation system theory

The innovation systems theory is an evolving theory that has attracted the attention of various researchers and development practitioners in different sectors and value chains (Anandajayasekeram & Gebremedhin, 2009; Lundvall, 2005). The theory provides the context for understanding the coordination of innovation activities at the national level through policies, governance, and institutional strengthening (Rajalahti, 2012). To apply the theory to specific components of the national innovation system, the sectoral innovation system was developed to offer a multidimensional view of various sectors in an economy (Malerba & Mani, 2009). The sectoral innovation system is made of various agents who generate and distribute products through market and non-market interactions, networks, institutions, and platforms, among others. Each of the sectoral innovation systems differs from one another in terms of agents, inputs, and interaction platforms; which affect the nature and structure of the sectors (Onumah et al., 2022). Therefore, the application of the innovation systems concept to development challenges requires a sector-specific analysis, for example, the agricultural sector, which in this case becomes the agricultural innovation system (AIS).

The AIS is a framework that recognizes the multiple collaborative arrangements among organizations, enterprises, and individuals focused on bringing about institutional, technical, and managerial changes in the agricultural sector (Anandajayasekeram & Gebremedhin, 2009; Suchiradipta & Raj, 2015). Thus, the AIS is a network of individuals, organizations and enterprises which bring existing or new products, processes and forms of organization into social and economic use in the presence of supporting institutions and policies (World Bank, 2006). Thus, innovation takes place when new or existing products, processes and forms of organization are put into social and economic use. The innovation comes from interactions among multiple stakeholders in an agricultural system who, according to Rajalahti et.al (2008) fall under 5 AIS domains: (i) the demand domain such as consumers whose preferences induce creation of innovations by (ii) the supply domain such as research, NGOs, Universities; (iii) the enterprise domain such as the farmers, processors who are the users of knowledge supplied to fulfil the demands of consumers; (iv) the intermediary domain such as extension, media who link all other domains; and (v) the support domain such as financial services, marketing systems which support the smooth functioning of all other domains. Based on the innovation systems theory, specifically the AIS framework, this study analyzed the collaborative nature of the existing relationships among stakeholders in the Ugandan banana value chain as sources of innovation for adoption of technologies and improved banana productivity.

More to the AIS, this study is embedded within the Capacity Development for Agricultural Innovation Systems (CDAIS) framework proposed by TAP, (2016). The CDAIS framework builds on the Agricultural Innovation Systems (AIS) framework and provides a context in which to develop the scientific and non-scientific skills and competencies required for the AIS to perform effectively. Thus, CD is implemented to strengthen the components of AIS so as to reach its full potential.

2.5.2 The conceptual framework

Innovations in agriculture usually occur out of open interactions among stakeholders of different backgrounds and levels in both formal and informal settings. The various stakeholders are the sources of knowledge and competencies that facilitate innovation to take place (Rajalahti, 2012). It is recognized that the innovative ability of any sector such as the agricultural sector depends on the nature of collaboration among stakeholders along and beyond the value chain and the available opportunities to utilize the innovations (Onumah et al., 2022). Effective collaboration enables the use of available stakeholder capacities to innovate and adopt the innovations. Capacities can be assessed at individual, organizational, and enabling environment dimensions which re-enforce one another (Tropical Agriculture Platform, 2016).

Also, to note is that innovations do not occur in isolation. It is then better to analyze them in the context in which they occur (Anandajayasekeram & Gebremedhin, 2009). Thus, the AIS provides such a context for the analysis of agricultural innovations. In this study, the AIS provided the conceptual framework for analyzing stakeholder interactions and capacity development for innovation and adoption of agricultural technologies and practices within the banana value chain.

Figure 2.1 demonstrates that interactions among stakeholders such as input suppliers (seed, organic and inorganic fertilizers, pesticides), research, extension, processors, community-based organizations (CBOs), media, and financial providers can improve the performance in generating, accessing, and adopting banana technologies and practices such as soil and water conservation and pests and disease control practices. As earlier discussed in the theoretical framework, Figure 2.1 further emphasizes that in order to facilitate effective innovation to take place, it is important to identify and address capacity development needs for innovation at individual, organizational, and enabling environment dimensions. In other words, Figure 2.1 illustrates that stakeholder interactions can be enhanced by addressing CD needs at individual, organizational and enabling environment to further facilitate innovation. This suggests the need to recognize the nature of interdependencies among stakeholders at all dimensions and their capacities to play certain roles in the innovation process.

Figure 2.1 further shows that although stakeholder interactions create a favorable environment for innovation and eventually adoption of technologies, the adoption is also influenced by household characteristics, physical farm characteristics, and access to agricultural extension and support services (Kiconco, et al., 2022a).

This study contributes to not only understanding the stakeholder interactions for innovation and adoption of technologies in the banana value chain but also establishes the capacity development requirements by the individuals, organizations, and enabling environment to effectively interact and innovate to increase the adoption of technologies.

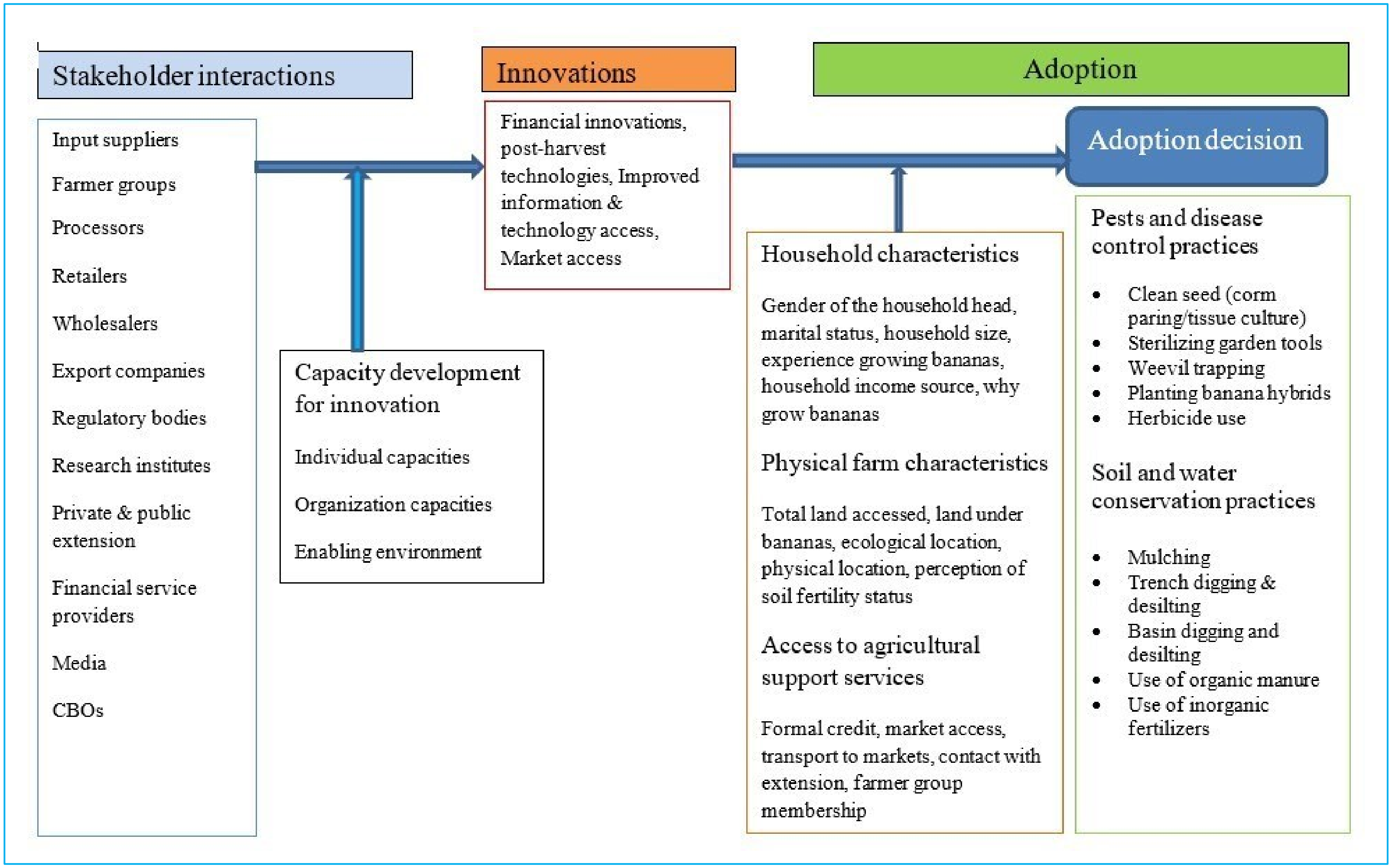

Figure 2.1: The conceptual framework of the study

Source: Adapted from Onumah et al (2022

Chapter 3: Methodology

3.1 Introduction

This chapter is divided into seven short sections in which methods and materials for data collection and analysis are described. The first section summarizes the study area followed by the research design and sampling procedures in the second and third sections respectively. The fourth section contains data collection procedures and then details of data analysis and econometric models where applicable. Finally, concerns in econometric estimations and how they were addressed in this study were discussed together with ethical procedures followed.

3.2 Description of the study area

The study was conducted in low-land, highland, and mid-highland agroecological zones in Uganda; specifically, in Nakaseke, Bunyangabu, and Isingiro districts respectively. From the respective districts, Nakaseke, Rwini, and Birere sub-counties were considered for the study (Figure 3.1). The districts were purposively sampled because they represent the historical banana-producing and consuming areas in the country where banana productivity has been gradually declining (Gold et al., 1999). Consequently, NARO and partners have been promoting various technologies in these areas to improve banana productivity which was hitherto generally low. Furthermore, there are a number of stakeholders in the area who are engaged in banana activities. They are; farmer groups, export farmers, traders, processors, research, extension, and community-based organizations (CBOs) who could potentially contribute to improving banana productivity in these districts (Ngambeki et al., 2010).

3.2.1 Isingiro district

Isingiro lies at 00^0 50^0S, 30^0 50^0E, and 1800m above sea level. Some parts of the district are characterized by steep hills and deep valleys while others are gentle slopes and low land areas. The largest part of the district possesses a deep loamy well drained soil type that supports banana production. The area receives an average rainfall of 1200mm and temperatures normally range from 17ºC to 30ºC. There are two main rainy seasons - March to April and September to November. Close to 98% of the population in the district is dependent on agriculture for their livelihoods, with about 70% entirely dependent on bananas as their sole economic activity. The average size of land under banana production is currently 0.4 hectares per household, compared to 1 hectare more than 5 years ago. The average banana production per hectare per annum is 3 330 bunches and each bunch weighs approximately 50kg (Kuteesa *et al*., 2018). Banana prices in this area are very unstable and vary by more than 50%. During 2017 for example, banana prices in Isingiro declined from 2.78 USD per bunch (off-peak season price) to 1.11 USD per bunch (peak season price) (National Agricultural Research Laboratories (NARL), 2018). Other food crops grown in the Isingiro district include sweet potatoes, potatoes, beans, maize, and cassava (Kuteesa et al., 2018).

3.2.2 Bunyangabu district

Bunyangabu lies at 00^0 29^0N, 30^0 12^0E and 1300m to 3800m above sea level. The district is located 330km west of Kampala Capital City. According to the Uganda Bureau of Statistics (UBOS) (2016), Bunyangabu district has a population of 171 292 people with 83% engaged in banana production. The district has rugged mountainous terrain (Rwenzori Mountain) and undulating slopes towards the lowland. It is characterized by mountainous highly fertile soils that support the growth of a wide range of crops including bananas, maize, onions, cassava, potatoes, coffee, and beans among others. It receives a bimodal rainfall ranging from 1200mm to 1500mm, fairly distributed throughout the year. Temperatures range from 20ºC to 25ºC, but in some parts, they fall below 19ºC. The climate is attributed to mountain Rwenzori and the many surrounding forests like Kibaale and Semuliki Game Park. The district has 29,063 plots of bananas grown in pure stands, while 21,819 plots of bananas exist as mixed stands. The common crops mixed with bananas include coffee, beans, and vanilla. The average size of land under banana production in Bunyangabu is currently 0.2 hectares per household. The average prices of banana bunch vary between 2.22 USD per bunch during the peak season and 4.17 USD per bunch during the off -peak season (NARL, 2018).

3.2.3 Nakaseke district

Nakaseke is located at 00^0 44^0N, 32^0 25^0E and 1200M above sea level. Crop farming is the main economic activity and majorly includes the cultivation of bananas, coffee, maize, vegetables, and fruits. It is a common practice in Nakaseke that coffee and bananas are intercropped. The vegetation cover is largely of a savannah type (Nakaseke District Local Government, 2012). Close to 64% of households in Nakaseke are engaged in banana growing, with an average plot size of 0.2 hectares. Banana prices also fluctuate between 1.39 USD for an average bunch size during the peak season and 2.78 USD during the off-peak season (NARL, 2018). The district receives two rainfall seasons with the main one from March to June and the second from August to November. The mean annual rainfall is between 1450mm to 1500mm, but sometimes it may become irregular. The variations in temperature are insignificant, with a mean annual maximum temperature between 27.5ºC to 30ºC and a minimum temperature of 15ºC and 17.5ºC.

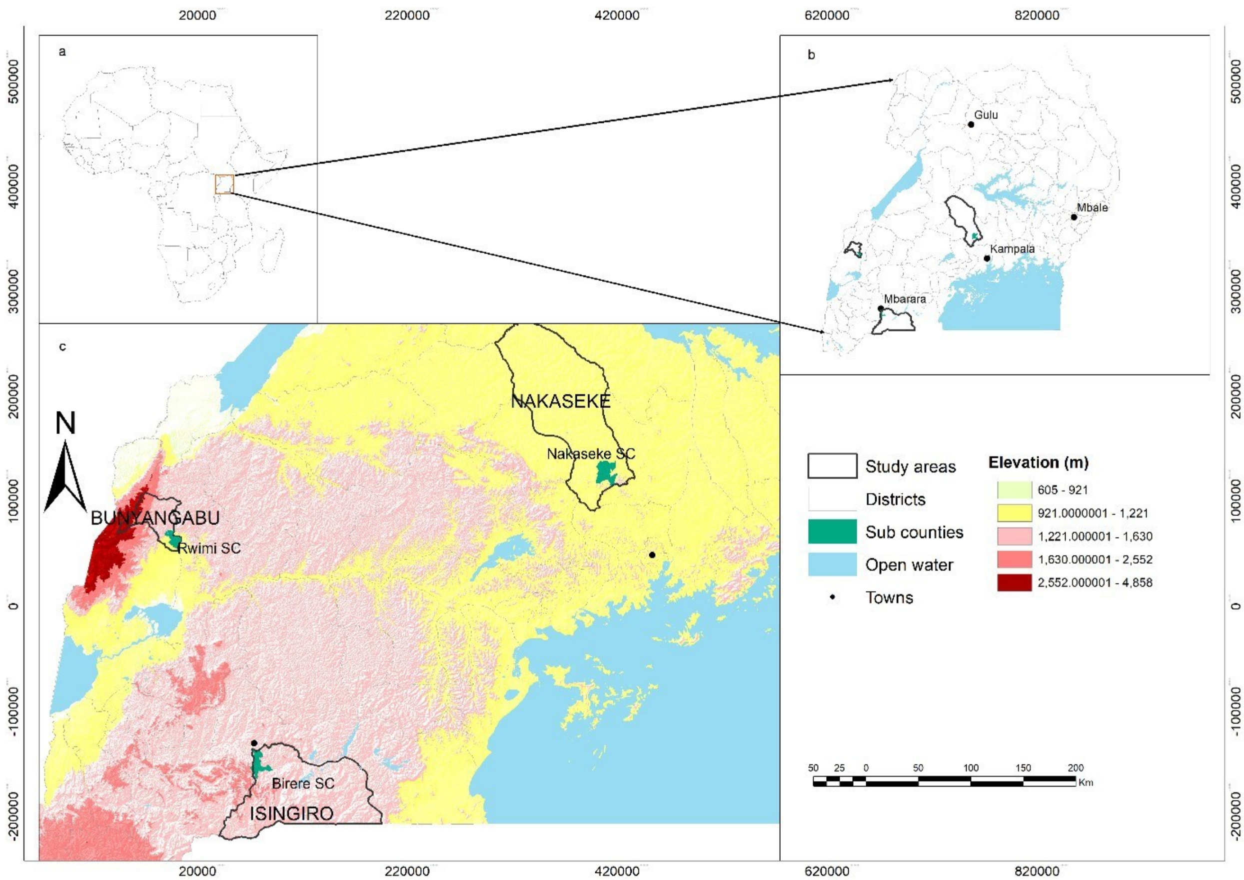

Figure 3.1 Map of Uganda showing target districts for the study

3.3 Research design

The design of this study was a mixed methods design. The study involved the use of qualitative and quantitative methods as complements in collecting and analyzing primary data which was collected from December 2019 to March 2020. The qualitative method used was the exploratory case study design (Yin, 2012) covering three banana-growing districts. This design was appropriate because of the study's emphasis on a comprehensive understanding of stakeholder interactions and relationships for supporting innovation and adoption of technologies in each of the districts. Thus, each of the districts was treated as a case. Focus group discussions (FGDs) and key informant interviews (KIIs) were conducted with a number of stakeholders in the banana value chain in each of the districts in order to collect qualitative data. Qualitative data was used to address objectives one and two. Quantitative data was obtained by conducting a household survey with banana farmers in order to assess on-farm technology adoption status. Data from the household survey was used to address objective three.

3.4 Sampling procedure

To select sample households for this study, a multi-stage sampling procedure was applied. Stage one involved the purposive selection of three different agroecological zones and respective districts where bananas are traditionally produced. Stage two involved the purposive selection of one sub-county per district given that there have been deliberate efforts of NBRP and partners to promote banana technologies in those sub-counties. The three selected sub-counties were Nakaseke, Rwimi, and Birere located in Nakaseke, Bunyangabu, and Isingiro districts. The total number of banana farming households in each of the sub-counties were 2 789, 3 230 and 3 132 for Nakaseke, Birere, and Rwimi respectively which gave a total of 9 151 (National Agricultural Research Laboratories (NARL), 2018). This total makes the sampling frame. In the final stage, a simple random sampling approach to select the households was applied using Yamane's (1967) sample size estimator as expressed in equation (1).

$$n = \frac{N}{(1+N(e)^2)} \qquad \text{equation (1)}$$

Where n= sample size

N= Total number of banana households in the three sub counties i.e 3 132+3 230+2 789 = 9 151

e = Margin of error (5%)

Therefore, the sample size, $n = \frac{9151}{9151(1+9151(0.005^2))}$

= 383 households

The number of respondents per sub-county to make a total of 383 depended on the probability proportional to the number of banana farming households in each. (Table 3.1). Lists of banana farmers per sub-county were obtained from the inventory of banana farmers provided by NBRP. The actual respondent households were selected using skip counting until the intended total number was attained.

The sampling procedure for export farmers, research agents, extension agents, CBO representatives, and processors was purposive based on whether they were operational in the study area (Suen et al., 2014). Stratified random sampling was used to select participant traders for KIIs and FGDs. The strata among traders were bicycle/motorcycle banana traders, wholesalers, and retailers. Thus, the procedure ensured the representation of all groups of traders in the selected sample (Acharya et al., 2013). Respondents from each of the strata were selected by lottery method from the lists of traders provided by the chairpersons of banana markets (Suen et al., 2014). The sampling procedure for banana farmers who participated in KIIs and FGDs was systematic random sampling from farmer lists provided by the chairpersons of banana farming groups (Acharya et al., 2013). The summary of the sampling procedure and the total number of respondents per category of the respondents is presented in Table 3.1.

Table 3.1: Summary of data collection methods, categories and number of respondents and sampling procedure followed

Data collection method	Categories of stakeholders Interviewed	No. of respondents per district			Total respondents	Sampling procedure
		Nakaseke	Bunyangabu	Isingiro		
KIIs	Research/ CBOs	2	2	2	6	Purposive
	Public extension	2	2	2	6	Purposive
	Processors	0	6	6	12	Purposive
	Export farmers	0	3	3	6	Purposive
	Banana wholesalers	6	6	6	18	Simple random
	Bicycle/ Motor bike banana traders	6	6	6	18	Simple random
FGDs		**No. of FGDs per district**			**Total FGDs**	
	Banana traders	2	2	2	6	Simple random
	Banana farmers	2	2	2	6	Simple random
Household survey		**No. of farmers per district**				
	Banana farmers	117	131	135	383	Multistage

3.5 Data collection

This study used primary data which was collected using KIIs, FGDs, and a household survey.

3.5.1 Key Informant Interviews (KIIs)

Key informant interviews were conducted with the representatives of research, extension and CBOs, processors, banana traders, and export farmers. Checklists of questions were used to guide the interviews and collect data with regards to who the key stakeholders in the banana value chain are, the exchange of information and services among them, innovation activities they were engaged in, the innovation capacities they possessed and those they needed to actively participate in the banana value chain, and the current nature of the innovation environment. Data from KIIs was used to address objectives one and two.

3.5.2 Focus group discussions (FGDs)

Focus group discussions were conducted with banana farmers and traders in each of the districts. Checklists of questions similar to those used in KIIs were used to guide the FGDs. This was intended for triangulation purposes. The farmers and traders who participated in FGDs had not participated in the survey and KIIs. During FGDs, open discussions were allowed among the participants (Onwuegbuzie et al., 2009).

3.5.3 The household survey

The household survey was conducted to collect data for addressing objective three. Data were collected using a semi-structured questionnaire from 383 sampled households. The questionnaire contained a mix of structured and open-ended questions that covered the characteristics of farmers which eventually drive their farming decisions. Only one adult was interviewed in each household to avoid pseudo-replication (Forstmeier et al., 2017). The data collected include; (i) banana technologies that were implemented on-farm such as: de-trashing; male bud removal; use of organic manure; use of inorganic fertilizers; use of clean seed; digging of trenches and basins and desilting them; use of hybrid varieties; de-suckering; corm removal; (ii) household socioeconomic status in terms of: gender of the household head; marital status; number of years in school; family size; major income source of the household; household banana growing experience and total land owned; (iii) Access to agricultural support services in terms of: membership to farmer groups; household access and receipt of credit, and contact with agricultural extension; (iv) Physical farm characteristics such as farmer perception of their farm soil fertility status (low, medium, high) and physical location of the farm whether it is located on a flat, medium, or steep slope. The questionnaire was first pretested to examine the appropriateness of the questions to collect the intended data (Hilton, 2017). Based on the result of the pretest, some questions were modified, others were added and yet more others were deleted before the actual data collection in the study area.

3.6 Data analysis procedure

3.6.1 Qualitative data analysis

Qualitative data analysis was conducted for objectives one and two while objective three was analyzed using quantitative methods. To address objective one, stakeholder interactions in terms of information exchange and service delivery in the banana value chain were analyzed using the Social

Network Analysis (SNA) approach. The SNA approach involved mapping out stakeholder linkages using Gephi 0.9.2 software (Grandjean, 2015). Stakeholder linkages were established based on whom they exchanged information and services with. Although data were collected from individual stakeholders and agents of organizations, analysis was conducted by aggregating individual stakeholders into groups. This was intended to identify which groups held similar positions across the districts. The identified groups were: input suppliers, farmer groups and associations, export farmers, export companies, local banana traders, processors, cooperative unions, CBOs, regulatory bodies, media, research, extension, and financial service providers. Therefore, the groups were regarded as stakeholders during data analysis. Each stakeholder was represented as a node while the joining lines (ties) represented linkages (relationships) among them to form network maps for each case study.

The maps were essential to visualize the strength of stakeholder linkages whether weak or strong. The strength of relationships is usually based on the number and frequency of interactions, and the interchange of services among stakeholders (Hanneman & Riddle, 2005; Sykes et al., 2009). However, in this study, the strength of relationships was measured based on the extent to which the ties were reciprocated which reflects the extent to which the stakeholders mutually exchanged information and services. Strong linkages on network maps were illustrated as red double arrows while weak linkages are in black single arrows. As a form of triangulation, there were common questions for KIIs and FGDs such that data from KIIs was helpful to establish the linkages which were not mentioned during FGDs. Therefore, if a linkage was said to exist, it must have been mentioned at least once during data collection.

SNA quantitative indicators that were used to describe the exchange pattern of information and services among stakeholders are degree (in- and out-degree) and betweenness. Degree centrality shows the number of ties directly connected to each stakeholder. The ties can either be inbound or outbound in which case are called in-degree or out-degree, respectively (Borgatti et al., 2009). The direction of a tie shows whether a stakeholder is influential and can supply information or provide a service to other stakeholders, or is a passive recipient of information and services. Therefore, in-degree shows popularity while out-degree shows the influence of a stakeholder. In this study, the influence of a node was visualized by its size such that the bigger the size, the more influential the stakeholder was in facilitating the exchange of information and services in the banana value chain.

Betweenness centrality is the number of times a stakeholder links with other stakeholders in the social network using the shortest paths between them. In other words, there is no direct linkage observed between the two stakeholders except through the third one (Freeman et al., 1979). Betweenness measures the ability of the node to control information flow or the capacity to link together unconnected nodes (Borgatti et al., 2009; Crespo et al., 2014). In this study, relative betweenness was computed and used in order to make comparisons of stakeholders across the three districts. The relative betweenness ranged from 0-1, with 0 representing the lowest while 1 represented the highest betweenness score.

Network density was used as a measure of solidity and cohesion, implying trust relationships among the stakeholders (Crespo et al., 2014; Filippini et al., 2020). It can also indicate the network's closeness as a completely connected network, less open to the inclusion of new members capable of bringing new information (Crespo et al., 2014).

The analysis of objective two involved the transcription of data from KIIs and FGDs for thematic coding and analysis (Onwuegbuzie et al., 2009). The inductive approach was used to assign open codes to individual narratives, which were then grouped into classes. The various classes later constituted two broad themes: (i) the current innovation capacities possessed by the banana stakeholders together with the enabling environment and challenges faced; (ii) capacity development needs for the individuals, organizations, and enabling environment for banana innovation and adoption of technologies.

3.6.2 Quantitative data analysis

Quantitative data analysis was conducted for objective three. Data were entered and cleaned for statistical analysis using Microsoft Excel. Data cleaning involved checking for completeness and outlier responses which resulted in the elimination of data from 50 households out of 383 initially considered. Thus, the analysis for this study was based on reliable and complete data from 333 households. The clean data was then imported into Stata 14 and analysis was conducted to produce descriptive and econometric results. The econometric models used were the Multivariate Probit (MVP) and Ordered probit models.

3.6.2.1 The Multivariate Probit (MVP) Model

The Multivariate Probit (MVP) model was used to analyze the patterns and drivers of adopting multiple banana technologies. The MVP model is appropriate for estimating multiple adoption decisions in the presence of adoption interdependence (Kassie et al., 2015). The model recognizes the correlation in the error terms of the adoption equations (Wooldridge, 2008). Given that implementing banana technologies is not mutually exclusive, the decision to adopt one of the technologies may influence the decision to adopt other technologies. The application of MVP to analyze adoption patterns and drivers of multiple interrelated technologies was more appropriate compared to the estimation of univariate logit, probit, and multinomial regressions. Such models assume independence of error terms thus, exclude relevant information on interdependent and simultaneous adoption patterns (Kassie et al., 2015; Teklewold et al., 2013; Ehiakpor et al., 2021). The correlation is a result of the same unobserved characteristics of a household which could influence the adoption of different technologies. Estimations without considering the synergies (complementarities) and trade-offs (substitutability) of banana technology adoption would produce inefficient and biased estimates of the determinants of adoption patterns.

The variables used in this analysis were selected based on the past empirical adoption literature (Feder et al., 1985; Singh et al., 1986; Aryal et al., 2018; Zeweld et al., 2018; Akankwasa et al., 2013; Akankwasa et al., 2016; Lusty & Smale, 2002; Sanya et al., 2020; Gold et al., 1999; Katungi, 2007). A set of nine technologies namely, mulching, use of herbicides, organic manuring, use of the clean seed, use of trenches and basins and desilting them, use of sterilized tools, weevil trapping, and use of hybrid banana varieties were chosen as the dependent variable for MVP estimation in this study. The other technologies (de-trashing, corm removal, de-suckering, and male bud removal) were regarded as basic technologies because they were implemented by almost all banana farming households and those implemented by very few farmers (application of inorganic fertilizers) (NARO, 2019) were excluded from the MVP model. The exclusion was because these extreme number of households once included in the model would produce biased results (Greene, 2003). Details of the variables used are presented in Table 4.1. To fulfill the assumption of normality, total land accessed, total area under bananas, and cost of transport to the input and output markets in major towns were transformed before using them in model estimation (Gujarati, 2006).

It was hypothesized that a farming household is more likely to adopt a particular banana technology if the benefits of its adoption are higher than those obtained without adoption (Feder et al., 1985). Consider the i^{th} farming household (i= 1, 2,….. N) that face the decision on whether to adopt a j^{th} banana technology on its farm. Let U_0 and U_j represent the benefits to a farmer without and with the adoption of a particular banana technology. A household will adopt the j^{th} banana technology if the net benefits (B^*_{ij}) with its adoption are higher than without its adoption i.e., $B^*_{ij} = U_j - U_0 > 0$. In this case, the net benefits of adopting banana technologies are taken as a latent variable, which is determined by the observed household socioeconomic status, access to support services, and physical farm characteristics (X_i) and the error term or unobserved characteristics ε_i as presented in (2) below:

$$B_{ij}^* = X_i'\beta_j + \varepsilon_i \qquad \text{(j= banana technology)} \qquad (2)$$

Equation (2) can be presented in terms of an indicator equation where the unobserved preferences in equation (2) translate into the observed binary outcome equation for each banana technology as follows:

$$B_{ij} = \begin{cases} 1 \; if B_{ij}^* > 0 \\ 0 \; otherwise \end{cases} \qquad \text{(j = banana technologies)} \qquad (3)$$

In the MVP model, the error terms jointly follow a multivariate normal distribution with zero means and variance normalized to unity (0, Ω). Thus, the covariance matrix (Ω) is given by:

$$\Omega = \begin{bmatrix} 1 & \varepsilon_{12} & \varepsilon_{1j} \\ \varepsilon_{21} & 1 & \varepsilon_{2j} \\ \cdots & \cdots & \cdots \\ \varepsilon_{1j} & \varepsilon_{2j} & 1 \end{bmatrix} \qquad (4)$$

3.6.2.2 The Ordered Probit Model

Following (Greene, 2003), the intensity of adoption was analyzed by taking the number of technologies adopted by the households as the dependent variable. The study assumed that: (i) provided a household derives greater utility from the last adopted technology, there is no limit to the number of technologies adopted; (ii) adoption decision of the farming household for any one agricultural technology does not rule out the adoption of the other available technology since the effects of certain technologies could be complementary; (iii) adoption of some technology components could be independent due to variable needs and conditions of producers (Isgin et al., 2008; Teklewold et al., 2011; Zeweld et al., 2018; Sharma et al., 2011; Kassie et al., 2015; Aryal et al., 2018).

Intensity of adoption is measured in terms of a count variable representing the number of technologies adopted (Mengistu & Assefa, 2019). The number of technologies adopted were categorized i.e., 0-4 were regarded as low-level adopters, 5-8 as mid-level adopters, and > 9 as high-level adopters. The categories were assigned integer values 1, 2, and 3 respectively and used as the dependent variable in the ordered probit model (Gujarati, 2006).

Therefore, level of adoption (Y_j) is given by:

$$Y_j = \begin{cases} 1\ if\ 0 < y_j \leq 4 \\ 2\ if\ 4 < y_j \leq 8 \\ 3\ if\ 8 < y_j \leq 12 \end{cases} \quad \text{(y is the number of technologies adopted)} \quad (5)$$

Since the dependent variable was measured as an integer which is considered count data, Poisson regression models were deemed appropriate. However, the study did not assume an equal probability of adoption of each alternative banana technology but rather assumed that the likelihood of adopting the first practice might differ from that of adopting additional others (Teklewold et al., 2019).

3.7 Concerns in the estimation of econometric models and how they were addressed

The concerns in the estimation of econometric models were applicable to objective three only. These are endogeneity and heteroskedasticity.

(i) *Endogeneity:* According to Wooldridge (2012), endogeneity occurs when the independent variable is correlated with the error term in a regression model. If not corrected, endogeneity bias leads to inconsistent econometric results. Endogeneity is caused by a number of factors such as mis-specifying the model by including an irrelevant variable or excluding a relevant variable from the model. In other cases, the omitted variable could be a function of another explanatory variable in the model (Baser, 2011). In such circumstances, the estimation would be inconsistent such that the measured independent variables would be correlated with the error term. In this way, one of the independent variables becomes endogenous. Therefore, Greene (2012) suggested four different ways to overcome endogeneity caused by mis-specification of the model or omitted variables including: (a) ignoring the problem and getting inconsistent estimators; (b) using of suitable proxy variable for the unobserved variable; (c) when using panel data, and face the omitted variable problem, it can be assumed that the omitted variable does not change over time, thus; the use of fixed effects or first differentiating methods could deal with the problem; and lastly, (d) the use of instrumental variable approach.

In this study, endogeneity was corrected by choosing model variables based on the past related adoption studies in which the use of such variables did not indicate endogeneity problems (Feder et al., 1985; Singh et al., 1986; Aryal et al., 2018; Zeweld et al., 2018; Akankwasa et al., 2013; Akankwasa et al., 2016; Lusty & Smale, 2002; Sanya et al., 2020; Gold et al., 1999; Katungi, 2007).

(ii) Heteroskedasticity: Literature (Wooldridge, 2008; Wooldridge, 2012) shows that heteroskedasticity occurs when the variance of unobserved stakeholders changes across different segments of the population. This happens naturally in data sets with a large range of observed data values. Wooldridge (2002) suggests that although heteroskedasticity does not cause the bias of coefficient estimates, it makes them less accurate which increases the likelihood that the coefficient estimates are further from the correct population value. The common ways of fixing heteroskedasticity include: (a) transforming the dependent variable such as taking the log of the dependent variable; (b) redefining the dependent variable such as using the rate of the dependent variable; and (c) the use of the weighted regression. However, the three common methods are not applicable to this study given the nature of the dependent variable. Therefore, the effects of heteroskedasticity were fixed by carefully choosing the variables to include in the model based on the previous similar studies.

3.8 Ethical considerations

3.8.1 Ethical considerations in Uganda

Data collection was sponsored by the National Agricultural Research Organization (NARO), a government body entrusted with conducting authentic agricultural research. Before conducting interviews and FGDs in communities, permission was sought from the relevant District and Sub-County leaders. During interviews, a consent form containing the purpose, procedures, use and sharing of data was first read out to each of the participants and agreed to the terms before signing the consent form. Permission from the participants was also sought before taking photographs and audio recording. During reporting of the results, the names were anonymized to ensure privacy and confidentiality of the interviewees.

3.8.2 Ethical considerations at the University of Pretoria

After the approval of the proposal, application for ethical clearance process was initiated at University of Pretoria. There were no issues which contradicted with ethical conduct in South Africa. Therefore, the research was approved with clearance number NAS303/2022. (Appendix 1).

Chapter 4: Stakeholder interactions for information exchange and service delivery to support innovation and adoption of technologies

4.1 Introduction

This chapter presents and discusses the current nature of interactions among stakeholders in the banana value chain, with emphasis on information exchange and service delivery to support innovation and adoption of technologies. The chapter discusses the first objective of the thesis: how do the stakeholders in the banana value chain interact and support one another to innovate and adopt technology? The study findings of this chapter were published in *The Journal of Agricultural Education and Extension* in 2022 (Kiconco et al., 2022a). The chapter comprises two sections. The first section describes data sources and methods of data analysis followed by the results section in which the stakeholders in the banana value chain and interactions among them were identified, strengths of relationships and network density are also presented, and the position of each of the stakeholders in information exchange and service delivery within the banana value chain.

4.2 Data source and methods of data analysis

This chapter used primary data which was collected by conducting KIIs with the agents of research, extension and CBOs, processors, banana traders, and export farmers. A total of 16 KIIs in Nakaseke, 25 in Bunyangabu, and 25 in Isingiro district were interviewed. The chapter also used data collected through FGDs with farmers and traders. A total of 6 FGDs with farmers and 6 FGDs with traders were conducted. The SNA approach was used to analyze stakeholder interactions for information exchange and service delivery to innovate and adopt banana technologies.

Results

The results revealed the current stakeholders, relationships among them, strengths of relationships, and the influence of each of the stakeholders in information exchange and service delivery.

4.2.1 Banana value chain activities and stakeholders involved

Banana is a major crop enterprise in Uganda, supporting the majority population as a source of food and income. The major banana varieties grown in Uganda are the East African Highland cooking varieties which are harvested when they are still green and cooked. Much of the bananas produced are consumed at household level (65%) and only an average of 30% is taken to the market (Nalunga et al., 2015). Banana markets in Uganda are in major towns located at 150-400 kilometers from the farming communities (Ngambeki et al., 2015).

Production: At production level, the stakeholders who perform production functions are traditionally the farmers. The manner in which they do production affects their participation in other value chain activities. The farmers include both small scale and largescale producers with land holdings under bananas ranging from 0.10 to 2.4 hectares in Bunyangabu, 0.06 to 3.20 hectares in

Isingiro and 0.04 to 3.52 hectares in Nakaseke. A percentage of 91% of farmers sell their bananas at farm gate to the middle men, mainly the bicycle and motorcycle banana traders. Some of the farmers are organized into farming groups and primary cooperatives which subscribe to the Uganda Banana Cooperative Union. The primary aim of forming the groups in the districts was to improve production and access banana markets collectively. Most of the farmers in these groups sell their bananas to the identified wholesalers or banana collection centers.

Banana export farmers and agents: These were identified in Bunyangabu and Isingiro and were not available in Nakaseke districts. Some of the exporters were individual farmers, mainly selling to the neighboring countries such as DRC, South Sudan, Kenya and Rwanda. They mainly sold roasting banana type *Gonja* to DRC.

Banana export agents: These were farmers who bought bananas from fellow farmers on behalf export companies such as KK foods ltd, Dasha foods ltd who sell to the Middle East and European markets. They pay keen attention to quality in order to meet consumer attributes. The preferred varieties for European markets were identified as Kibuzi and Musakala cooking bananas because of their big finger sizes and the apple bananas for dessert. The agents described banana export a very profitable venture as one of agents from Isingiro narrates: *"I have been in export business for 12 years with my two trusted business partners who export matooke to Sudan, UK, German and America. They take 40% from my plantation and 60% from other individual farmers from this area. The farmers sell to me bunches cheaply, I cut clusters and weigh them, package them in boxes, transport them to Entebbe airport. Buying bunches selling in kilograms is the source of the profits."* Another export agent from Bunyangabu had this to say: *"With export markets, I cut bunches into clusters and package them in specialised boxes. In this way, you sell every banana regardless of the bunch size. There are farmers we gave money to produce bananas on our behalf because during the months of September and December we cannot sustain the demand."* From such narratives, it is observed that the high value export markets use a weighing system compared to the cheating bunch system used locally.

Trading: Across the three districts, the trading function was conducted by various categories of traders, buying and selling the bananas at different scales. A number of them are briefly described;

The *banana wholesalers*: These buy bananas in large quantities transport them from farming areas to the major urban centres Uganda located 400-500km from the farms. While in urban centres, they sell to the banana wholesalers and retailers in these towns. They mainly buy from motorcycle and bicycle banana traders who bring bananas from the farmers to the village banana collection centres where these wholesalers load from. Some of the wholesalers buy directly at farm gate from largescale banana producers and few farmer groups. Some wholesalers buy bananas through *village agents*. They give money to such agents in advance and agree upon the dates on which to come and harvest the bananas. It was revealed in FGDs that some of the agents have established trust with the farmers and connect them to the buyers from Kampala. This arrangement was common in Isingiro and Bunyangabu and not available in Nakaseke.

The *banana loaders*: They mainly operate at village collection centres, packaging bananas brought by bicycle and motorcycle banana traders on to the wholesalers' lorries. According to Ariho *et al* (2015) and Ngambeki *et al* (2010), such lorries have capacities of 2- 25 tonns carrying 60- 800 bunches respectively. The loaders also do post-harvest handling of bananas by plucking the fingers off the bunches, package them into sacks and load them. The wholesalers said in this form, they are easy to transport and that it is a better way to market small banana bunches which do not attract high market value.

Motorcycle and bicycle banana traders: These buy bananas from farmers at farm gate and transport them to the collection centres, local restaurants and other markets. They connect farmers from remote villages inaccessible by the trucks to the markets. They offer minimum prices per bunch depending on the daily market trends set by the wholesalers in the area. This group of traders are the majority and each bicycle or motorcycle can be loaded with 6-8 bunches of bananas at once. A small number of farmers take their own bananas to the local markets or collection centers using bicycles.

The *wholesalers in major towns (WMT)*: These are common in Nakaseke and the towns near this place. In one of the FGDs with traders in Nakaseke market, the traders revealed that in most cases, the bananas sold in Luwero and Nakaseke are sourced from Isingiro and Bunyangabu. They receive fresh bananas from lorries of wholesalers from upcountry markets or banana collection centres. The WMT then distribute bananas to the retailers, motorcycle and bicycle banana traders in these towns. The motorcycle and bicycle traders distribute the bananas to the restaurants and individual consumers in major towns. Some of these traders also collect bananas from farmers in Nakaseke and distribute them to the major towns in and near Nakaseke district.

Retailers: They are found in village and urban markets where they sell small amounts of bananas to the final consumers. The consumers buy a single bunch, fingers or clusters which are provided by the wholesalers. In KIIs it was revealed that the retailers sometimes buy bunches, pluck them into bunches and fingers in order to serve a wide range of customers.

Processing: Results from key informant interviews revealed that banana processors are dealing in producing a number of products such as banana wine, flour, juice, cakes among others. However, they still use rudimentary methods during processing and the products are consumed locally. Only a few processors such as Buka foods cottage ltd and Rwabagome enterprises (RE) in Bunyangabu; and Rockhill winery in Isingiro were registered with Uganda National Bureau of Standards (UNBS), the quality assurance mark in Uganda. A few farmer groups such as Kikunyu farmers' cooperative were venturing into banana flour production and associated products. This presents a potential for alternative use of bananas in the area in order to minimize losses especially during the bumper harvests of bananas. There were no processors identified in Nakaseke district.

The information and services provided by each of the value chain stakeholders were also regarded as the innovation capacities they possessed (Table 4.1). The capacities range from production, transportation, marketing, financing value chain activities, generation and promotion of technologies and information, among others. Such capacities could be utilized to enhance one another for innovation to take place.

Table 4.1 Summary of stakeholders in banana value chain, categories, AIS domains and the current innovation capacities

Stakeholder	Category	AIS domain	Current innovation Capacities
Grain pulse	Input supplier	Enterprise	Produces and supplies inorganic fertilizers to banana farmers through NARO and IITA.
ANEBU farm supply	Input supplier	Enterprise	Stocks and supplies inorganic fertilizers in Isingiro district through extension.
Kasunganyanja banana farmers' cooperative	Farmer group	Support	Produce bananas, bulk them from member plantations for sale to the wholesalers and exporters in Bunyangabu.
Kasanda banana farmers	Farmer group	Support	Produce bananas, bulk them from member plantations for sale to the wholesalers and exporters in Bunyangabu.
Kibiito modern farmers' Association	Processor	Support	Produce bananas, process them into other products such as juice, wine and flour for baking.
Rugaaga banana farmers' cooperative	Farmer group	Support	Produce bananas, bulk them from member plantations for sale to the wholesalers and exporters Isingiro.
Kikunyu banana farmers' cooperative	Farmer group	Support	Produce specific banana varieties (Kibuzi, mpologoma), bulk them from member plantations for sale to the wholesalers and exporters in Isingiro.
Export farmers	Export farmers	Enterprise	Produce bananas in large quantities, sell to local markets and neighboring countries such as DRC, South Sudan, Kenya and Rwanda. They were found in Isingiro and Bunyangabu

Village agents	Trader	Enterprise	They are the natives of communities and are the agents of wholesalers and or export companies. They bulk bananas from individual farmers and bicycle banana traders on behalf of wholesalers and or export companies.
Motorcycle and bicycle banana traders	Trader	Enterprise	They buy bananas at farm gate and transport them to the wholesalers at collection centers, local restaurants and other markets. Each bicycle or motorcycle can be loaded with 6-8 bunches of bananas at a time.
Wholesalers	Trader	Enterprise	Buy bananas in large quantities and transport them from farming areas to the major urban centers in Uganda located 400-500km from the farms. While in urban centers, they sell to other wholesalers and retailers in these towns.
Kwagalana Traders' group	Traders' group	Support	This is a group of banana wholesalers in Bunyangabu district. They buy and transport bananas from village markets to the markets in major towns of Uganda
Wholesalers in major towns	Traders	Enterprise	They are common in Nakaseke and nearby towns. They receive fresh bananas from lorries of wholesalers from upcountry markets (Isingiro and Bunyangabu among others). They then distribute them to the retailers, motorcycle and bicycle banana traders in these towns.
Retailers in major towns	Traders	Enterprise	Buy bananas from wholesalers then re-sell the bananas to the consumers in quantities they can afford that is; clusters, fingers and a single bunch.
Dasha foods ltd and KK foods ltd	Export companies	Demand	They buy bananas from export farmers and farmer groups and export them to Middle East and European markets. They are keen to quality and variety in order to meet customer attributes.
Local government (e.g town council)	Regulatory bodies	Support	Give trading licenses, set laws governing the market and collect revenue from the traders
Uganda National Bureau of Standards (UNBS)	Regulatory bodies	Support	This is a government body which establishes whether products are to the recommended standards
Local council	Regulatory bodies	Support	They work hand in hand with extension and research to enforce by-laws concerning the control of Banana Bacterial Wilt (BBW) at the village level. They also arbitrate conflicts between traders, village agents and the banana farmers

ESKY Winery, Rockhill winery, Ankole foods, Silver winery, Excel hort consult	Processor	Enterprise	These are processors of bananas wine from banana juice in Isingiro. There are many other upcoming banana wine and juice Processors
Rwabagoma enterprise	Processor	Enterprise	They are processors of bananas wine from banana juice in Bunyangabu
NARO, IITA, Bioversity International, CABI	Research	Supply	They generate and promote banana technologies. They provide knowledge and experimental materials
Public Extension	Extension	Intermediary	They provide the necessary knowledge and information to the various actors.
Mirambi SACCO, HOFOKAM Microfinance	Financial service providers	Support	They are formal sources of credit in Bunyangabu
Farmer revolutionary groups, Individual money lenders, Village savings groups	Financial service provider	Support	They are informal sources of credit in Bunyangabu
Muhame SACCO, Centenary bank, Ankole SACCO, Pride microfinance	Financial service provider	Support	They are formal sources of credit in Isingiro
Individual money lenders, Village savings groups	Financial service provider	Support	They are informal sources of credit to the banana farmers in Isingiro
KRC	CBO	Supply	Supports banana farming and processing
RUHEPAI	CBO	Supply	Supports farmer group formation, banana farming and household Sanitation
Uganda Banana Farmers' Cooperative union		Support/ intermediary	Supports formation of primary cooperatives, helps them and individual largescale banana farmers to access finances, banana inputs and technologies
Radio west, Tv West	Media	Intermediary	They provide platforms where researchers, extension, NGOs, CBOs and other actors in Isingiro relay banana knowledge and related information. Through these platforms, farmers too communicate their concerns
Voice of Kamwenge	Media	Intermediary	They provide platforms where researchers, extension, NGOs, CBOs and other actors in Bunyangabu relay banana knowledge and information
CBS FM, Radio Musana,	Media	Intermediary	They provide platforms where researchers, extension, NGOs, CBOs and other actors in Nakaseke relay banana knowledge and Information

The stakeholders were categorized into ten groups, that is; the farmer groups, input suppliers, export companies, export farmers, processors, traders, financial service providers, regulatory bodies, research, extension, media, and CBOs (Table 4.1).

4.2.2 Stakeholder interactions in the banana value chain

Stakeholder interactions in each of the districts were treated as a case. Therefore, three case studies according to the districts were discussed.

4.3.2.1 Case 1: Stakeholder interactions in Bunyangabu

The results revealed that there were both strong and weak interactions/relationships for exchanging information and services among 12 stakeholders in the Bunyangabu banana value chain. Out of these, only processors, CBOs, and traders had strong relationships with the farmer groups while research, extension, media, financial providers, export farmers, and regulatory bodies had weak relationships with the farmer groups (Figure 4.1). Research too had strong relationships with extension, regulatory bodies, and input suppliers. Granovetter (1973) suggests that the nature of social ties whether weak or strong affects the quality and the process of information flow within social networks. Therefore, the strong relationships of farmer groups with CBOs, traders, and processors reflect reciprocated information and service delivery regarding on-farm production and marketing of processed and non-processed banana products. Such relationships are an important source of information and knowledge exchanged through informal social learning networks such as processors-farmers, farmers-traders, and CBOs-farmers (Stevens & Letty, 2014). This implies that farmers in Bunyangabu, through such networks, have access to information and services to enable them to innovate, upgrade, and participate in other value chain activities such as processing and trading. It also reflects farmers' awareness of the qualities of products that are acceptable on markets and for processing purposes. This could be an indicator that the farmers are likely to adopt technologies related to such.

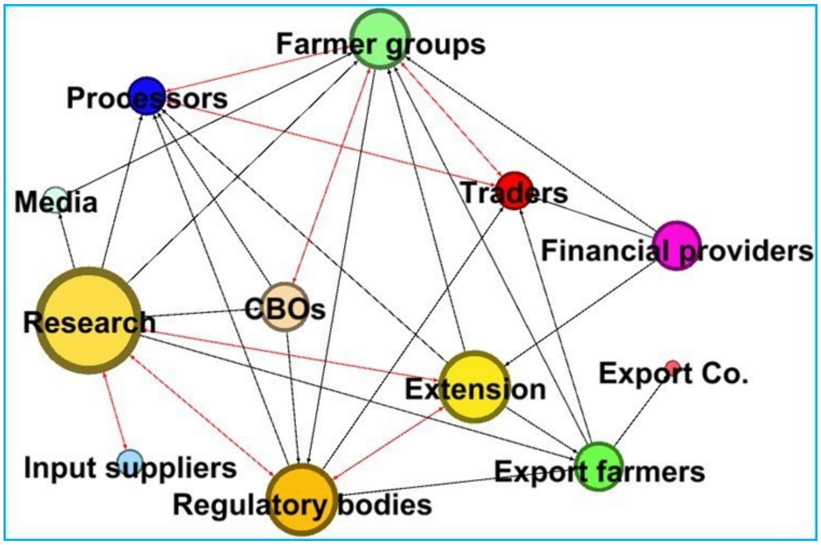

Figure 4.1 Stakeholder interactions in Bunyangabu

Key: ⟷ Reciprocated linkage (strong relationship)

⟶ One-way relationship

Thus, in order to improve the farmer group's position in the value chain network, it is important to build the capacity of farmer groups to enable them to articulate their needs with which the service providers align themselves (Chindime et al., 2016). On the other hand, extension and research, the traditional sources of agricultural information, were weakly connected to the key value chain stakeholders such as the farmer groups and processors, and not at all with the traders (Figure 4.1). The position of research and extension reflects a one-way communication characterized by limited involvement of the key stakeholders in technology generation and dissemination processes. Such processes are more likely to produce irrelevant technologies with low receptibility among the end users.

4.3.2.2 Case 2: Stakeholder interactions in Isingiro district

Our results show that the Isingiro banana value chain consisted of 13 stakeholders with fairly distributed ties and connected to the farmer groups. Compared to Bunyangabu and Nakaseke cases, the farmer groups in Isingiro were connected to the most stakeholders in banana value chain. The farmer groups had strong relationships with Uganda Banana Producers' Cooperative Union, traders, processors, financial service providers, CBOs and regulatory bodies (Figure 4.2). This implies farmers' access to vast information and services. Farmer groups' strong wide network in Isingiro could be attributed to the cooperative union which is operational in the area. Cooperatives are historically known to play a critical role in agricultural value chain development by improving access to markets and other essential services (Devaux et al., 2018). Indeed, the Uganda Banana Farmers' Cooperative Union's agenda is to institutionalize banana farmers' position among other stakeholders in the banana value chain. Thus, with the improved coverage of the Union countrywide, it is expected to improve and sustain access to information and services to enable innovation and adoption of technologies.

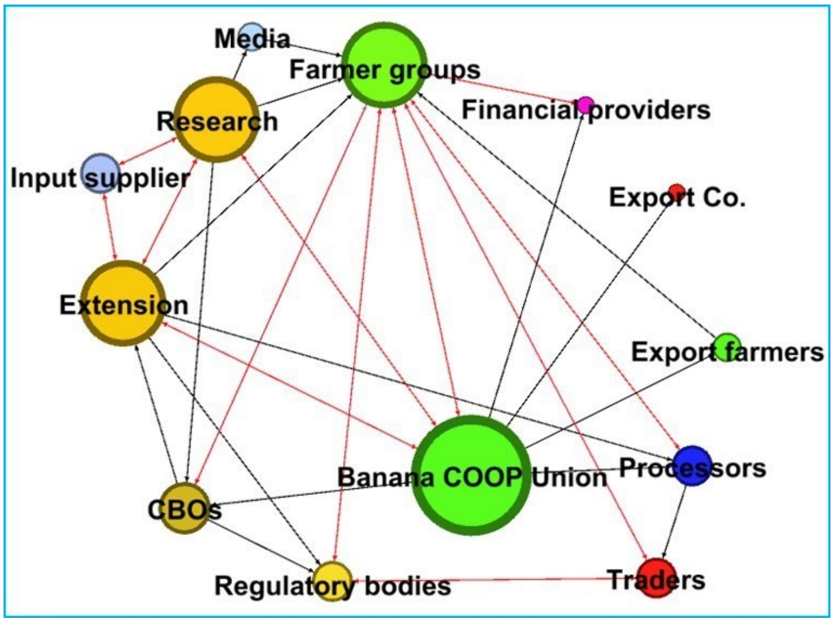

Figure 4.2: Stakeholder interactions in Isingiro district

It is also worth noting that farmer groups in Isingiro had weak relationships with key stakeholders such as research, extension, export farmers, and media with unidirectional ties (Figure 4.2). The results show that research and processors are not at all connected to each other, indicating that processors hardly receive information on new technologies such as the availability of new varieties and their characteristics, which possess a constraint to the receptivity of technologies.

4.3.2.3 Case 2: Stakeholder interactions in Nakaseke district

Compared to the two other case studies, the Nakaseke banana value chain consisted of the least number of stakeholders (only eight) of which farmer groups were strongly connected to the financial service providers only. The results show that research, extension, traders, and CBOs had weak relationships with the farmer groups. Compared to other sites, some value chain stakeholders such as processors, export farmers, and companies were missing in Nakaseke (Figure 4.3). In addition, Nakaseke's location enables farmers to access cheaper substitutes of bananas such as maize flour on the market

(Bagamba, 2007) thus, there could be less labor allocated to banana production in this area.

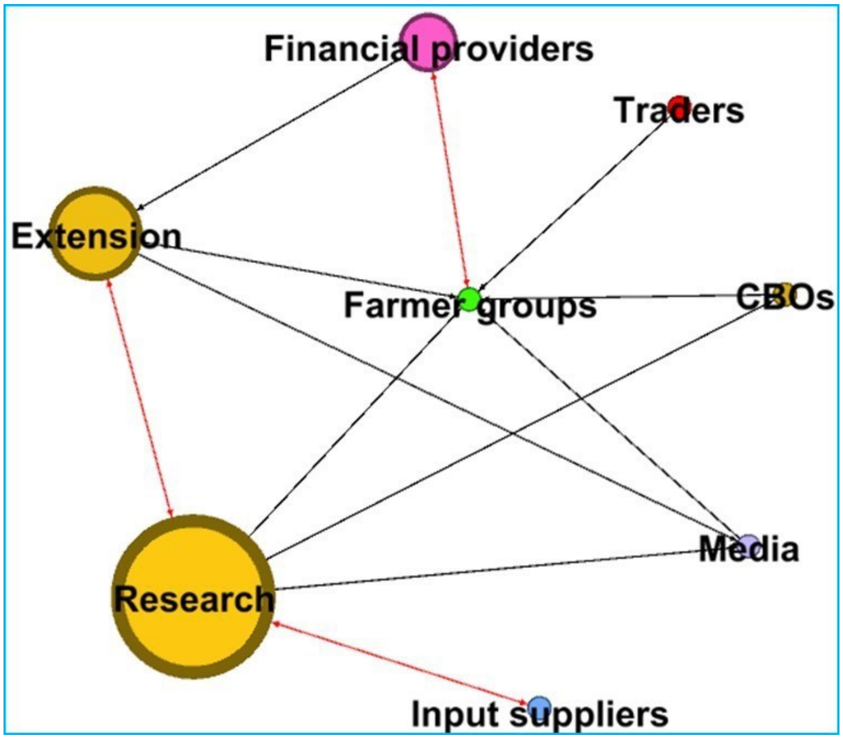

Figure 4.3: Stakeholder interactions in Nakaseke district

Aguilar-Gallegos et al. (2015) and Thuo et al. (2014) suggest that the linkages within and beyond network boundaries create engagements with external agencies to obtain useful resources to facilitate adoption and network support. Therefore, the situation of Nakaseke reflects a lack of diversity in value chain information networks for farmers' reference. In addition, Nakaseke is located near major urban centers where the non-farm sector is widely developed, therefore; farmers' strong connections with financial providers and few stakeholders imply that the potential farm labor force could be allocated to other self-employment activities other than farming.

The linkages among stakeholders in each of the case studies indicate which ties need to be strengthened to create a cohesive and interactive network, especially regarding feedback on the different banana technologies and practices promoted. In all three cases, research had strong linkages with extension and input suppliers indicating technical support of one another in terms of information and resources for experimentation with farmers.

However, the weak linkages of farmer groups with extension and research show a lack of feedback from the farmers to inform the technology development and promotion process. Similarly, the lack of direct connection between farmers and input suppliers shows that farmers have limited information and are not yet using such inputs on farms. The farmers only access them through extension and research for research and experimentation purposes only.

4.2.3 Strengths of relationships and network density

The strengths of relationships and network density indicate the speed with which information flows among the stakeholders in the network (Borgatti et al., 2009).

4.2.3.1 The strengths of relationships

Results show that there were 28 connections among 12 stakeholders in Bunyangabu, 28 connections among 13 stakeholders in Isingiro, and 12 connections among 8 stakeholders in Nakaseke district. Of these, the percentages of reciprocated connections were 28.57% in Bunyangabu, 42.86% in Isingiro, and 25.00% in Nakaseke district (Table 4.2). Reciprocated connections are regarded as strong relationships, implying the dependency of stakeholders on one another for information and other services (Borgatti et al., 2009).

At the same time, Fritsch & Kauffeld-Monz (2010) described strong ties as beneficial and associated with an exchange of complex knowledge. Hansen et al. (2020) also suggest that strong relationships reflect the presence of social attributes such as cooperation, trust, exchange of opinions, and power balance among the stakeholders. Therefore, the situation of a small percentage of reciprocated connections in the three districts reflects the dominancy of a one-way communication characterized by limited discussions, cooperation, and feedback among the stakeholders in the value chain. However, for the Isingiro network, the percentage of strong connections were relatively higher which implies that there is an improved distribution of information and resilience in the Isingiro network compared to the two other cases (Table 4.2).

4.2.3.2 Network density

The results across the three case studies revealed that network densities among the value chain stakeholders were 0.283, 0.256, and 0.268 in Bunyangabu, Isingiro, and Nakaseke districts respectively (Table 4.2). This suggests that of all the potential relationships that could be present, only 28.3% were actually present in Bunyangabu, 25.6% in Isingiro, and 26.8% in Nakaseke. These results indicate the existence of very weak relationships among banana value chain stakeholders and that many of them were working in isolation, which limits the possibility of innovating together.

Table 4.2: The number of connections and network density

	Districts		
Network measure	Bunyangabu	Isingiro	Nakaseke
No. of stakeholders	12	13	8
No. of existing connections	28	28	12
Percentage of strong connections	28.57	42.86	25.00
Network density	0.280	0.256	0.268

According to Sanya et al (2018), information and knowledge move more accurately and timely in networks where there are intense and direct linkages among the stakeholders. Therefore, the situation of weak linkages among value chain stakeholders in the three districts portrays the underutilization of potential relationships for the dissemination of valuable knowledge, information, and services necessary for generating and adopting relevant banana technologies for improved productivity.

4.2.4 The position of stakeholders in information exchange and service delivery within the banana value chain

The position of each of the banana stakeholders in the exchange of information and services was determined using centrality measures that are betweenness, in-degree, and out-degree. Betweenness indicates the ability of a stakeholder to act as a bridge to other stakeholders in a network. For this study, the term relative betweenness was used in order to compare stakeholders with similar positions across the three case studies. In-degree shows the ability of a stakeholder to receive information, services, inquiries, and feedback from all other stakeholders in the network; while out-degree indicates the ability to reach out and influence other network stakeholders by providing information, services, and answers to inquiries among others (Filippini et al., 2020).

4.2.4.1 Case 1: Bunyangabu

The SNA results show that the most central stakeholders were regulatory bodies with a relative betweenness of 1, followed by research, extension, and farmer groups (Table 4.3). These results suggest that regulatory bodies are the major stakeholders facilitating the flow of information and services in the Bunyangabu banana value chain. Leeuwis & Aarts (2011) suggest that innovation requires a network approach that allows the engagement of different stakeholders in the process. Thus, since the regulatory bodies' inherent role is not agricultural information dissemination, their position in the banana value chain as indicated by the study results is relevant in order to create a favorable environment for the other stakeholders to successfully facilitate the exchange of information and service delivery in Bunyangabu. The local council as a regulatory body was key in enforcing the implementation of by-laws, leading to the successful application of information and technologies for the control of *Banana Xanthomonas Wilt (BXW)* which was threatening the country's banana production in the previous years (Kubiriba et al., 2016). The key role of the local council and other stakeholders in *BXW* control was revealed during FGDs with the farmers in Kaina parish, Rwimi Sub County as one of them narrates: "…*the local council and extension workers work hand in hand to enforce laws for controlling BXW in this area. If any of the local council authorities see a diseased banana plant in your garden, they ask you to pay a fine yet, these days money is never readily available. In the fear of paying this expensive fine, we all clean up our plantations of the diseased plants….the disease is no longer a threat here in our area."* Such results indicate that the active involvement of locally based stakeholders such as the local council in agricultural development initiatives is always essential in order to overcome the local hurdles to the application of information and technologies.

The results also show that research and extension were also highly connected stakeholders in Bunyangabu with relative betweenness of 0.918 and 0.207 respectively (Table 4.3). The results further show that research and extension had very low in-degree results of 0.083, similar to that of export farmers. This suggests that only 8.3% of existing ties direct their requests for information and services with regard to banana innovations to research and extension. This small percentage could be attributed to their low accessibility. For example, the extension-to-farmer ratio in Uganda is at 1: 5000 compared to the global benchmark of 1:500. Besides, NARO, the public agricultural research body does not have logistical support to reach every corner of the country (Rwamigisa et al., 2017). Therefore, research and extension may not be in a position to reach out to the farmers and other stakeholders directly for professional guidance and assistance. Under such circumstances, given the growing trend in agricultural research and extension to partner with the private sector, collaboration with stakeholders such as the local government who are well positioned and locally embedded would enhance information exchange among stakeholders in the Bunyangabu banana value chain.

Whereas the banana processors, traders, and financial service providers are key stakeholders with a potential to innovate and finance some of the value chain activities, they had very low relative betweenness indicating that they were mainly operating at the periphery of the value chain network. This was re-affirmed during KIIs with the traders at the Kakooga trading center as one of the wholesalers remarked when asked which stakeholders, he shared banana information or services with: *"I share information with fellow traders. As wholesalers, we sit every week, discuss the available market opportunities, and decide on prices to impose on the farmers and/or bicycle and motorcycle banana traders."* According to this statement, it seemed to be a common practice for the traders to dictate farm gate banana prices. It reflects existing asymmetries in power and influence in accessing banana markets in Bunyangabu. However, more results show that traders are not central in information exchange and service delivery, alleging that their strong relationships with farmer groups depicted in Figure 4.1 could be due to fair services (access to large volumes of bananas in one place and good prices) received from one another. However, agricultural interventions in this area should aim at providing opportunities that improve farmers' bargaining power and profitability at the farm gate. This can influence the extent to which the farmers are commercially or subsistence-oriented (Nakasone, 2014).

4.2.4.2 Case 2: Isingiro

Results from the SNA revealed that research, farmer groups, banana cooperative unions, and extension were the most central stakeholders for information exchange in Isingiro as indicated by their high relative betweenness. The farmer groups had overall the highest relative betweenness of 1, the highest in-degree of 0.231, and a high out-degree of 0.154 (Table 4.3). The relative betweenness result implies that the farmer groups are the major stakeholders for bridging information and services, the highest in-degree stresses that they are very prominent, and 23.1% of queries about banana innovations in the value chain are directed towards the farmer groups.

The high out-degree result compared to that of other stakeholders implies that farmer groups are better positioned to introduce technological innovations in Isingiro. Such results portray the prominence of farmer-to-farmer extension in a situation where extension is constrained to reach out to a number of stakeholders. Because farmer-to-farmer extension is locally based, there is trust, reduced risk, easy access, and compatibility of information and services among stakeholders (Weyori et al., 2017) leading to the quicker embrace and ownership of technologies.

Table 4.3: Centrality of stakeholders across the case studies

Stakeholders	Measures of Centrality per district								
	Bunyangabu			Isingiro			Nakaseke		
	Relative betweenness	In degree	Out degree	Relative betweenness	In degree	Out degree	Relative betweenness	In degree	Out degree
Extension	0.207	0.083	0.139	0.261	0.103	0.154	0.947	0.133	0.200
Research	0.918	0.083	0.222	0.283	0.077	0.154	0.842	0.133	0.333
Traders	0.036	0.139	0.056	0.008	0.077	0.051	0.000	0.000	0.067
Processors	0.044	0.167	0.056	0.018	0.077	0.051	0.000	0.000	0.000
Regulatory bodies	1.000	0.111	0.139	0.018	0.103	0.051	0.000	0.000	0.000
Banana COOP Union	0.000	0.000	0.000	0.653	0.077	0.205	0.000	0.000	0.000
Export Co.	0.000	0.028	0.000	0.000	0.026	0.000	0.000	0.000	0.000
Input supplier	0.000	0.028	0.028	0.000	0.051	0.051	0.000	0.067	0.067
Media	0.000	0.028	0.028	0.000	0.026	0.026	0.000	0.133	0.067
Financial providers	0.000	0.000	0.083	0.000	0.051	0.026	0.947	0.067	0.133
CBOs	0.000	0.056	0.083	0.087	0.051	0.077	0.000	0.067	0.067
Farmer groups	0.891	0.194	0.111	1.000	0.231	0.154	1.000	0.400	0.067
Export farmers	0.342	0.083	0.083	0.000	0.051	0.026	0.000	0.000	0.000

The position of farmer groups in Isingiro could be attributed to the banana cooperative union which is spearheading the wide establishment of farmer groups as primary cooperatives and linking them to a number of service providers. However, KII results with banana cooperative union management in Isingiro revealed that some stakeholders were not responding to the call for collaboration with farmers as indicated in the narrative; "*Some stakeholders such as traders do not respond to such calls for collaboration because they fear their profits are going to be reduced.*" Such results indicate that although the banana traders are strongly linked to the farmer groups, they are not at all linked to the banana cooperative union. As is the case in Bunyangabu, the traders' direct linkage with farmers could be a reflection of opportunistic behavior which reduces farmers' profitability from banana harvests. Low profitability from agricultural investments discourages farmers from investing in the adoption of new technologies and innovations for increasing on-farm productivity.

Magnan et al. (2015) suggest that out-directed ties indicate the stakeholders who may introduce improved technologies into the network. Therefore, the results showing that the banana cooperative union has the overall highest out-degree of 0.205 suggest that it is the overall most influential in facilitating the exchange of information and services among stakeholders in Isingiro. This was further emphasized during KIIs with the cooperative leadership where one of them revealed that the cooperative played an active role in mobilizing various stakeholders to identify challenges and areas of collective intervention in the banana value chain as noted in the quotes: "As *banana cooperative union, we recommend some farmer groups and primary cooperatives to access financial services as a group; for example; we recently recommended Kikunyu Banana farmers' cooperative and Rugaga banana cooperative to access loans from Centenary Bank."* Such facilitated linkages to funding opportunities help farmers access services leading to the adoption of technologies that require initial capital investments such as the use of fertilizers and clean seed.

The results further show that research and extension, with relative betweenness of 0.283 and 0.261 respectively were among the key bridges for information and services in Isingiro (Table 4.3). However, some stakeholders criticized the approach of research and extension to engage the farmers only while neglecting the rest of the stakeholders in the value chain. This was revealed during KII with one of the motorcycle banana traders in Isingiro, Kaberebere market as expressed in the narrative: "*These days, NARO, like any other organization is operating in this area but it is more concerned with farmers' increase in banana productivity but for us, the traders we are left out. They should for once think about us traders and train us in issues like business management, how to access quick loans not from money lenders, and how to make profits."* The results from KIIs with public extension agents in the district affirm such a disconnection and suggest the need to engage entire value chain stakeholders and wholesomely look at information and service delivery among them as a way to improve the adoption of banana technologies. This was expressed by one of the public extension agents in the following narrations: *"Most of our partners in extension and research promote on-farm productivity of bananas so in this area, we have no problem with banana* *productivity. Farmers in this area produce a lot of bananas; we are instead faced with a lack of banana markets."* The Isingiro district commercial officer too had this to say: "*We have one extension worker per sub-county to promote productivity but information on value addition is scarce among the extension workers. They also need to be trained in such aspects as banana wine processing in order for them to regularly monitor such developments among banana farmers and processors in this area."* Such statements from the extension agents and banana traders show the need for the dissemination of technologies and information among stakeholders across entire value chain as a way to improve technology adoption and productivity. This affirms the need to shift from the linear agricultural development approaches to the innovation systems approaches which target outreach to the various stakeholders as users and collaborators in the generation and promotion of technologies and innovations. Extension and research in Isingiro need to take advantage of established farmer structures and the banana cooperative union to reach out to, but also receive feedback from a number of stakeholders in order to improve farmer profitability and maintain high productivity level.

4.2.4.3 Nakaseke

The results from Nakaseke show that farmer groups, as is in Isingiro had overall the highest relative betweenness of 1 indicating that they are the major intermediaries for facilitating the exchange of information and services among stakeholders in the Nakaseke banana value chain. Financial service providers and extension, with a relative betweenness of 0.947 each, and research with 0.842 were also potential intermediaries (Table 4.3). However, farmer groups' low out-degree of 0.067 indicates that they were less influential compared to research (0.333), extension (0.2), and financial service providers (0.133) (Table 4.3).

The position of financial providers indicates that farmers in Nakaseke could be benefiting from financial institutions compared to other cases. Additionally, Nakaseke's proximity to a number of research institutions make it well positioned as a place for farmer field trials for banana innovations. Therefore, this allows research to play a temporary role of extension agents in the area.

4.3 Summary

According to the study findings, farmer groups in Bunyangabu possess strong relationships with processors, traders and CBOs. This indicates reciprocated information exchange and service delivery regarding on-farm production and marketing of processed and unprocessed banana products. It indicates dependency of one another for information and services. Regulatory bodies in this area occupied the central position in the value chain network. Such stakeholders, whose traditional role is not related to agricultural development creates a favorable environment for innovation and adoption of technologies, for example, the local council in Bunyangabu district. Therefore, such stakeholders should be carefully identified and engaged for maximum service delivery in agricultural development. The results further show that although research and extension were relatively central across the three case studies, they had weak or missing connections with the key stakeholders such as the processors, traders, and farmer groups. This loose connection depicts that research and extension are mainly focused on technology development and information dissemination ignoring feedback for their own learning from other stakeholders in the value chain. The likely outcome is the generation and promotion of technologies that are not acceptable among end users. Thus, the position of key stakeholders such as farmers, traders and processors in the value chain network can be improved by building their capacity to articulate their needs with which the service providers align themselves. Research and extension should also seek feedback in order to increase their influence in innovation and adoption of technologies.Having discussed the key stakeholders and the roles they play in facilitating the exchange of information and services in the banana value chain, this chapter provides the foundation for analyzing the capacities the stakeholders need to fully participate in banana value chain innovation activities (chapter 5) and later on analyze the on-farm adoption patterns and intensity for the multiple banana technologies (chapter 6).

Chapter 5: Capacity development needs for improving innovation and adoption of technologies in the banana value chain

5.1 Introduction

This chapter discusses capacity development (CD) needs which indicate gaps required to be filled at individual, organizational, and enabling environment dimensions in order to actively participate in innovation activities and adopt technologies. As a basis of this analysis, the current stakeholder capacities were identified and discussed in the previous chapter section 4.3.1. This chapter discusses the second objective: what capacity development needs are required in the banana value chain to improve innovation and uptake of banana technologies? The chapter presents the summary of data collection and analysis methods, the stakeholders and three dimensions they belong to, challenges faced and capacity development needs for innovation and adoption of technologies.

5.2 Data source and methods of data analysis

This chapter used data that were collected through KIIs with the agents of research, extension and CBOs, Processors, Banana traders and Export farmers, and FGDs with banana traders and farmers. Checklists were developed to guide KIIs and FGDs to capture data on: the innovation capacities each stakeholder possessed as depicted from the information and services they shared with others; and the CD needs by the stakeholders in order to participate in innovation activities. Data were transcribed for thematic coding and analysis. The inductive approach was used to assign open codes to individual narratives, which were then grouped into classes. The various classes later constituted three broad themes: (i) the actors in the banana value chain and CD dimensions; (ii) challenges faced in the banana value chain; and (ii) CD needs for the individuals, organizations, and enabling environment to participate in innovation activities and adoption of technologies.

5.3 Results

5.3.1 Stakeholders in the banana value chain and CD dimensions

The stakeholders in the banana value chain were categorized and the CD dimensions in which they fall were listed (Table 5.1). The dimensions of CD (individual, organization, and the enabling environment) reinforce one another for innovation to take place. The CD conducted at the individual level requires favorable conditions at an organizational level and enabling policy environment to be successful. At the same time, organizations require an enabling environment to perform the additional responsibilities that come with enhanced capacities (TAP, 2016).

Table 5.1 Stakeholder categories and dimensions in the banana value chain

Stakeholder	Category	CD dimension
Grain pulse	Input supplier	Organization
ANEBU farm supply	Input supplier	Organization
Kasunganyanja banana farmers' cooperative	Farmer group	Organization
Kasanda banana farmers	Farmer group	Organization
Kibiito modern farmers' association	Farmer group & processor	Organization
Rugaaga banana farmers' cooperative	Farmer group	Organization
Kikunyu banana farmers' cooperative	Farmer group	Organization
Export farmers	Export farmers	Individual
Village agents	Trader	Individual
Motorcycle and bicycle banana traders	Trader	Individual
Wholesalers	Trader	Individual
Kwagalana Traders' group	Traders' group	Organization
Wholesalers in major towns	Traders	Individual
Retailers in major towns	Traders	Individual
Dasha foods ltd and KK foods ltd	Export companies	Individual
Local government (e.g town council)	Regulatory bodies	Enabling environment
Uganda National Bureau of Standards (UNBS)	Regulatory bodies	Enabling environment
Local council	Regulatory bodies	Enabling environment
ESKY Winery, Rockhill winery, Ankole foods, Silver winery, Excel hort consult	Processor	Organization
Rwabagoma enterprise	Processor	Organization
NARO, IITA, Bioversity International, CABI	Research	Organization
Public Extension	Extension	Organization
Mirambi SACCO, HOFOKAM Microfinance	Financial service providers	Organization
Farmer revolutionary groups, Individual money lenders, Village savings groups	Financial service provider	Organization
Muhame SACCO, Centenary bank, Ankole SACCO, Pride microfinance	Financial service provider	Organization
Individual money lenders, Village savings Groups	Financial service provider	Individual
KRC	CBO	Organization
RUHEPAI	CBO	Organization
Uganda Banana Farmers' Cooperative union	Farmer group	Organization
Radio west, Tv West	Media	Organization
Voice of Kamwenge	Media	Organization
CBS FM, Radio Musana,	Media	Organization

Source: Data from FGDs and KIIs, February 2020

Key: NARO: National Agricultural Research Organization; IITA: International Institute of Tropical Agriculture; CABI: Centre for Agriculture and Bioscience International; SACCO: Savings and Credit Cooperative Organization; HOFOKAM: Hoima Fort portal Kasese Microfinance; KRC: Kabarole Research and Resource Centre; RUHEPAI: Rural Health Promotion and Poverty Alleviation Initiative; CBS: Central Broadcasting Service

The results from KIIs and FGDs revealed the challenges that limit innovations taking place in the banana value chain. The challenges are presented in subsection 5.3.2.

5.3.2 The challenges faced in the banana value chain

The challenges faced in the banana value chain affect stakeholders' participation in innovation initiatives for improving productivity, profitability, food, nutrition, and income insecurity among banana-growing communities and beyond. Results from KIIs and FGDs showed the challenges faced in the banana value chain at three dimensions: the individual dimension (farmers, traders, and processors) who face technical and functional challenges (Table 5.2) and the challenges faced by organizations and the enabling environment (Table 5.3) while some of the details are discussed in subsections 5.3.2.1, 5.3.2.2 and 5.3.2.3.

5.3.2.1 Challenges faced in the banana value chain at individual dimension

Farmers: Results from FGDs with farmers revealed that the major challenges they face mainly limit them from adopting technologies for increased banana productivity. The results show that such challenges are associated with the lack of markets and low prices offered at farmgate (Table 5.2). One of the respondents from the farmers' FGD in Isingiro had this to say: *"NARO has been in this place promoting technologies to improve banana production and actually for us who acted, we produce big banana bunches these days. But where is the market?….you see, as farmers, in most cases we contact bicycle banana traders to transport our bananas and sell them on our behalf at collection centers. You give 6 bananas to a bicycle trader and agree that he should sell each at 10000 ugx only to come back with 5000ugx shillings per bunch….."* This statement shows the usual information asymmetry with regard to market prices and the prevailing mistrust between the farmers and market players. Another farmer added: "…*in addition, we pay much levy per bunch of banana taken to the market…yet the government has not helped in any way to work on the roads to enable wholesalers to come to our gardens…therefore our bananas usually end up ripening because we cannot eat it all…. when we produce bigger bunches of bananas but prices remain the same as for medium and small, we get disappointed for investing to produce bigger bunches without the* *matching profit gain.*"

The results further show that there were attempts to practice contract farming where medium to large-scale banana farmers produced for specific wholesalers who gave advance payments to the farmers and would come at an agreed time to harvest. However, with time, the contracts between the farmers and traders were not honored which created conflicts between them. This was exposed during FGDs with the traders at Kaberebere market in Isingiro when one of the respondents said: *"Earlier on, we the traders used to give farmers some money in advance and later come back to harvest bananas at an agreed time. But later there were misunderstandings where farmers would disappear with traders' money…but on other occasions, some of the traders would want to harvest more bananas than earlier agreed, offering little money per bunch than the earlier agreed upon price…this created conflicts between the parties involved."* This statement portrays that there were no formally written contracts between the traders and farmers which prompted either of the parties to act contrary to what was agreed upon verbally. Therefore, innovations in market access by banana farmers in this area should aim at familiarizing traders and farmers with making written contracts to minimize future disagreements and conflicts.

Export farmers: On the other hand, export farmers expressed that the seasonality of bananas was the major challenge they faced as it affected their supplies to the export markets and companies. This was revealed during KIIs with one of the export farmers in Kakooga village, Bunyangabu district who had this to say: *"I belong to a group of farmers who export most of their matooke. During the time of scarcity especially the months of December and September, we cannot sustain the supply so we buy from other farmers, which reduces our profits."* This depicts the need for mechanisms to ensure continuous banana production and productivity as a means to satisfy such markets. This implies the supply and adoption of improved banana technologies as a lasting solution.

Processors: Results from KIIs with banana processors show that the banana fruit can be processed into various products such as wine, flour for various purposes, juice, crisps, and local alcohol among many others. However, they expressed that the problem at hand is a lack of standard machinery, resorting to the use of rudimentary processing methods which undermine the quality of the products. As a result, the products are of low quality and are less popular even in local markets. In most cases, the processors were groups of banana farmers with an interest in finding the alternative uses of their bananas especially in the peak production seasons when there is abundant production. The use of rudimentary methods and lack of proper machinery limits the processors' innovation initiatives into the alternative uses of bananas. When asked about the challenges they face, one of the key informants in Bunyangabu district, Kakooga village had this to say: "*peeling and drying is very difficult for it needs constant sunshine otherwise the bananas change the color to black producing poor quality flour.*

Table 5.2 Challenges faced by individual stakeholders in the banana value chain

	Individual stakeholders		
Challenges	**Farmers**	**Traders**	**Processors**
Technical	• Pests & diseases (Banana Bacterial wilt) • Expensive organic manure • Low soil fertility • Low rainfall • Lack of seed for hybrid varieties • Short plantation life span • Lack of land for expansion • Low yields • Expensive/ lack of inorganic fertilizers • Expensive herbicides • Ripening of bananas especially in peak production season • Prolonged drought conditions	• Quick ripening of bananas • Damages to banana bunches during transportation	• Lack of recommended containers for banana wine • Banana flour does not last longer- only kept for 60 days • Peeling and drying is very difficult • Lack of machinery for peeling, drying & drying bananas • No preservative for flour
Functional	• Poor road network • Long distances to access manure • Many practices are involved in banana production • Lack of correct market information because of brokers • On farm theft of bananas • Buyers reject our small banana bunches • Mulches are expensive • Lack of markets for bananas • Very low prices • Banana farmers are not united • Minimal extension visits • Traders buy bananas on credit and do not pay • Traders set banana prices (no negotiation)	• High transport costs from farms to the market- reduced profits • High market levy- reduced profits • No electricity- no working for long hours • Lack of cooperation with council-we sell our bananas to other markets in nearby districts	• Low prices of our products • No registration- fear to advertise and supply to super markets • Few buyers of our products • Rain disrupts drying of bananas & they become black

Traders: The results from KIIs with traders showed that they faced challenges related to infrastructural developments and the deteriorating relationship with regulatory bodies. KII with one of the banana traders had this to say: "*We have one market here in Kaberebere but because the town* *council is against us, some traders and farmers end up taking their bananas to Mbarara market... Here, the levy is so high to the extent that each bunch is charged 200ugx which is too much compared to 100ugx in Mbarara……moreover, there is no electricity to enable us to work for long hours.*"

Similarly, results from FGDs with the traders in Bunyangabu revealed that in addition to high market levy charges, they faced challenges related to accessing finances and poor services from the regulatory bodies. During the discussions at Kadindima market in Rwimi Bunyangabu, one of the banana traders had this to say on the challenges they faced: "*Money lenders are a problem to us, we even don't trust them because they are so disappointing…. They give money at high interest rates and put you under pressure to pay back and in worst cases they take your property. We also don't engage in SACCOS because of too much membership fees*." Another respondent interjected:

…….this levy we pay is like a donation to the market because we do not see its purpose, for example, we cannot even be allowed to leave behind our Matooke in case we do not sell on a particular day". Another respondent had this to say: "*We get less profits from bananas because of high transport costs, bad roads, long distances to the city markets.*" In Nakaseke, the traders in FGDs revealed a lack of trustworthiness between them and their customers, and the perishability nature of the bananas affected their business; "*Sometimes customers do not pay us back when we sell to them on credit*". Another respondent interrupted: "*During the bumper harvest season, we do not sell much and most of them ripen before they are sold*."

5.3.3.2 Challenges faced in organizational and enabling environment

The KIIs were conducted with the district commercial officers, district agricultural officers, sub-county extension workers, agents of CBOs, and research organizations to establish the current status of the enabling environment and challenges faced by the organizations. The results show that the major challenge faced is the limited knowledge of the alternative uses of bananas among the agents of organizations (Table 5.3). An interview with a commercial officer in Isingiro had this to say: "*the level of value addition in this district is very low…first there are very few processors moreover using very low-level technology… generally, banana production in this area has increased so the next step should be commercialization/markets… so now, the future of the banana industry lies in getting various ways of preserving bananas because on-farm production has increased.*" The results further show that partnerships among organizations involved in banana improvement are not yet well exploited for example public extension complained of the added workload of partnerships while the Uganda banana farmers' cooperative union says some actors such as traders are not willing to participate in partnerships.

Table 5.3: Challenges faced at organizational and enabling environment dimensions of CD

	Challenges
Organizational	• The knowledge of banana value addition is still low among the agents • Sometimes partnerships with other organizations add workload on our agents/staff but it is manageable • Some actors such as traders are not interested in partnerships and dialogues
Enabling environment	• Most formal financial service providers charge very high interest rates not affordable by individual stakeholders • Lack of cold chain transportation of bananas • Export potential for matooke bananas is not yet well exploited

KII with the Isingiro district agricultural officer revealed that the available formal options for financing agricultural activities in the area are not affordable by the stakeholders because of the high interest rates. This discourages the stakeholders from investing in value chain innovations which require high capital investments.

5.3.3 Capacity development needs

Creating resilient agricultural value chains requires building different kinds of capacities among multiple interlinked stakeholders (Babu et al., 2015). Capacity development within a value chain can improve its performance and strengthen value chain linkages through the development of agro-enterprises. It facilitates linkages among producers and other market actors (local and international) which also facilitates the movement of food products from the farms to areas of scarcity, facilitating access to the food by such communities.

5.3.3.1 Capacity development needs by the individual actors

Capacity development needs by the farmers were revealed from the results of household surveys and FGDs with them (Table 5.4). The results show farmers' desire to engage in activities which span the entire value chain. The banana farmers expressed the need to develop capacities in processing. Given the perishability nature of bananas, processing helps in turning bananas into several other diverse products.

Product development has been found to be key in facilitating the adoption of technologies, for example, Papa Andina's experience where the development of various products from local potatoes led to the adoption and increased production of potatoes which improved farmers income (Devaux et al., 2018).

Table 5.4: Capacity development needs by the individual actors in the banana value chain

	Individual actors		
Capacities	**Farmers**	**Traders**	**Processors**
Technical	• Early pests and disease identification and control • Soil and water conservation • Value addition to reduce perishability • Planting of new high yielding varieties • Researchers should give us feedback on research results	• Alternative options for trading bananas eg use of weighting system than banana bunches • Value addition-how to make flour from bananas for local and international markets • Improve banana productivity-produce big and desirable bunches	• Producing quality wine which is competitive among international brands • Production of various banana products
Functional	• Provide a cold store for matooke at collection centers/ markets • Improve road network • Banana marketing strategies • Group formation and maintenance • Financial and banana business management • Provide credit at low interest rates	• Record keeping • Financial management- how to get loans and make profits from using the loans • Getting direct links to international markets	• Registration and quality assurance mark • Connection to markets

5.3.3.2 Capacity needs by the organizations and enabling environment

Results from KIIs with the district agricultural officer in Isingiro show that to some extent, they have enough human capacity but it is limited by a lack of information beyond that of on-farm production of bananas: *"we have extension workers at grassroots communities, for example, one extension worker per sub-county but they have less information on agro-processing… so they need to be trained at least in winemaking so that they are able to pass on the information to the interested farmers."* This shows the desire for public extension to shift from focusing on the promotion of on-farm production to include other aspects of value chain improvement as a way of ensuring sustainable production at the desired levels.

Table 5.5: Capacity development needs by the organizations and enabling environment

	Capacity development needs
Organizational	• Train extension workers in agro-processing so they can teach other actors
Enabling environment	• Finance agriculture at low interest rates • Need for irrigation equipment • Provide cold storage facilities for bananas

5.4 Summary

The challenges faced at individual, organizational and enabling environment were identified as the basis for the capacity development gaps. At the individual dimension, the challenges faced by the key stakeholders (farmers, processors and traders) were identified. From the results, the key CD concerns at all dimensions are; value addition, marketing and financial access and management. Therefore, interventions for banana development should be directed towards banana value addition, improving marketing systems and availability of funding at low interest rates affordable by the value chain stakeholders.

Chapter 6: Determinants of adoption patterns and intensity for multiple banana technologies in Uganda

6.1 Introduction

This chapter presents and discusses the on-farm patterns and intensity of adopting multiple banana technologies in Uganda and what influences them. The observations in adoption patterns, intensity, and determinants provide guidance to the practitioners on how to package the multiple technologies together and factors to consider in order to promote and adopt such technologies. The chapter presents the third and last objective of the thesis: what determines household adoption patterns and intensity for multiple banana technologies in Uganda? The results presented in this chapter were published in *Sustainability 14 (23) 1-14* (Kiconco et al., 2022b). The chapter comprises two sections. The first section describes data sources and methods of data analysis followed by the results section where various subsections are discussed. The subsections covered under results are; farm and household characteristics, the technologies promoted, adoption relationships among multiple technologies, adoption patterns and determinants, and finally the determinants of adoption intensity of multiple banana technologies.

6.2 Data sources and analytical methods

This chapter used data which was collected through a household survey covering 383 households in three agroecological zones historically known for growing bananas. Data were first cleaned resulting in the use of reliable and complete data from 333 households for descriptive and econometric results in response to the research objective. The econometric models used were the multivariate probit model to determine what influences adoption patterns (complementary and substitute technologies) and the ordered probit model to investigate what influences adoption intensity (number) of multiple banana technologies that can be adopted at a time. The households were first categorized depending on the number of technologies adopted. The categories are; 0-4 technologies (low-level adopters), 5-8 (mid-level adopters), and > 9 (high-level adopters). The categories were assigned integer values 1, 2, and 3 respectively, and used as the dependent variable in the ordered probit model (Gujarati, 2006).

6.3 Results

6.3.1 Description of the farm and household characteristics (Independent variables)

The study results show that the average family size for low and mid-adopter households was six (6) household members compared to high-adopter households which consisted of seven (7) members.

This indicates the availability of labor associated with the adoption of more new technologies (Menozzi et al., 2015). Although the majority of households across adopter categories reported farming as their major source of income, less than 50% of them grew bananas for commercial use. For example, 36% of low-adopters 44% of mid-adopters, and 49% of high-adopters cultivated banana for commercial use. It is expected that high-adopter households that grow bananas for commercial use will adopt more yield-enhancing technologies such as the use of hybrid banana varieties. The study findings also show that low-adopter households accessed more land (1.87ha) and allocated a smaller proportion of 0.43ha to banana production (Table 6.1) compared to other adopter categories. This implies that they could be engaged in other livelihood economic activities other than agriculture or banana production. The majority (68%) of high-adopter households were located in the dry corridor of Nakaseke and Birere compared to 62% of mid-adopters and 64% of low-adopters. The high adoption intensity among households in the dry corridor could be associated with the uptake of many technologies especially those related to soil and water conservation compared to Birere whose conditions are not prone to drought conditions.

Similarly, 33% of high-adopter households perceived the fertility status of their soil as high (Table 6.1). The highest percentage (67%) of high-adopter households had access to formal sources of credit compared to 56% of mid-adopter and 30% of low-adopter households. Access to credit facilitates the acquisition and adoption of technologies that require high capital investment (Feder & Slade, 1984). The results further reveal that only 29% of high adopters, and 18% of mid-adopters and low-adopters were able to access markets apart from farm-gate or local markets. The results further show that only a handful of households belonged to farmer groups, for example, 9% of low-adopters, 37% of mid-adopters, and 50% of high-adopter households (Table 6.1).

6.3.2 Description of banana technologies used by the farming households (dependent variables)

The results show that basic banana technologies (de-trashing, de-suckering, corm removal, and male bud removal) were implemented by over 80% of low-adopters, 97-100% of mid-adopters and 100% of high-adopters. Conversely, the use of inorganic fertilizers and banana hybrids were new technologies and implemented by none of the low-adopters, a maximum of 7% among mid-adopters and only 14% of high-adopters. Other than sterilizing tools, the rest of the technologies were implemented by less than 10% of low-adopters, above 15% of mid-adopters, and a minimum of 40% of high-adopters (Table 6.2).

6.3.3 The nature of adoption relationships among multiple banana practices

Adoption relationships (complementarity and substitutability) among multiple banana technologies were determined using the MVP model. The study results from MVP analysis indicate that households adopted numerous banana technologies simultaneously, suggesting associations among them. This was tested using pair-wise correlation coefficients across the residuals of MVP model. Of the 36 pairs among nine banana technologies, 15 pairwise correlation coefficients were statistically significant. The results support the hypothesis that error terms of the multiple adoption decision equations are correlated. The likelihood ratio test (Chi^2 (36) = 184.274; Prob > chi^2 = 0.000) rejects the null hypothesis of zero covariance of the error terms across the equations. Such results indicate that banana technologies are adopted as complements and substitutes as indicated by the 15 significantly correlated pairs. It also implies that households may adopt a combination of input intensification and low external input banana technologies. This is in agreement with other studies which recognized the interdependence of adoption decisions of multiple agricultural technologies (Teklewold et al., 2013; Aryal et al., 2018).

Table 6.1: Household and farm characteristics

	Variable description	Low adopters (n= 33)		Mid adopters (n=208)		High adopters (n=92)		Expected sign
		Mean	SD	Mean	SD	Mean	SD	
Socioeconomic characteristics								
Gender of household (hh) head	1 if female 0 if male	0.15	-	0.11	-	0.08	-	+/-
Marital status of the hh head	1 if married 0 otherwise	0.79	-	0.79	-	0.82	-	+/-
Household size	No. of people in household	6	2.90	6	2.60	7	3.30	+/-
Hh experience growing bananas	No. of years growing bananas	22.52	15.94	17.49	13.38	18.30	11.96	+/-
Hh income source	1 if farming 0 otherwise	0.82	-	0.93	-	0.90	-	+
Why grow bananas	1 if subsistence 0 if commercial	0.64	-	0.56	-	0.51	-	+
Physical farm characteristics								
Total land accessed	Total land operated by the household (ha)	1.87	2.94	1.59	2.16	1.64	1.45	+
Total land under bananas	Total land where bananas are planted (ha)	0.43	0.37	0.65	0.59	0.70	0.57	+
Ecological location	1 dry corridor if Nakaseke and Birere and 0 if Rwimi	0.64	-	0.62	-	0.68	-	+
Physical location	1 if hilly and 0 if flat or valley	0.61	-	0.50	-	0.51	-	+
Soil fertility status1	1 if high soil fertility and 0 if medium or low soil fertility	0.18	-	0.25	-	0.33	-	+/-
Soil fertility status3	I if medium and 0 if high or low	0.48	-	0.44	-	0.46	-	+/-
Access to agricultural support services								
Access to formal credit sources	1 if formal (banks, SACCOs, VISLAS) and 0 otherwise	0.30	-	0.56	-	0.67	-	+
Input/output market access	1 if major towns and 0 if farm gate / local markets	0.18	-	0.18	-	0.29	-	+

Distance to the market	Distance to the nearby market	4.16	4.14	5.88	5.20	5.05	4.71	-
Cost of transport to the market	Cost of transport to input/output markets	2364	2013	3204	2166	2842	1910	-
Contact with extension	1 if yes and 0 otherwise	0.88	-	0.96	-	0.97	-	+
Membership to a farmer group	1 if yes and 0 otherwise	0.09	-	0.37	-	0.50	-	+

Source: survey data, 2020

Table 6.2: Description of banana technologies used by the households

		Percentage households using the practice		
Basic mat maintenance practices	**Variable description**	**Low adopters (n= 33)**	**Mid adopters (n=208)**	**High adopters (n=92)**
De-trashing	1 if practiced and 0 if not	0.91	0.99	1
De-suckering	1 if practiced and 0 if not	0.85	0.99	1
Corm removal	1 if practiced and 0 if not	0.82	0.97	1
Male bud removal	1 if practiced and 0 if not	0.94	1	1
Pests and disease control practices				
Clean seed (corm paring/use of tissue culture plantlets)	1 if practiced and 0 if not	0	0.06	0.43
Sterilizing garden tools	1 if practiced and 0 if not	0.15	0.67	0.88
Weevil trapping	1 if practiced and 0 if not	0	0.35	0.7
Planting banana hybrids	1 if practiced and 0 if not	0	0.07	0.46
Herbicide use	1 if practiced and 0 if not	0.03	0.15	0.40
Soil and water conservation practices				
Mulching	1 if practiced and 0 if not	0.09	0.39	0.65
Trench digging and desilting	1 if practiced and 0 if not	0	0.47	0.86
Basin digging and desilting	1 if practiced and 0 if not	0	0.16	0.43
Use of organic manure	1 if practiced and 0 if not	0.03	0.39	0.83
Use of inorganic fertilizers	1 if practiced and 0 if not	0	0.02	0.14

Source: survey data, 2020

6.3.4 The determinants of adoption patterns for banana technologies

The results from MVP analysis show that household size was positively and significantly associated with the adoption of trenches ($P < 0.05$), and the use of banana hybrid varieties ($P < 0.1$) (Table 6.3). This indicates that households with a larger number of members were more likely to adopt the use of trenches and banana hybrid varieties. These technologies are often labor intensive, hence, the increased probability of being adopted by larger households given the high dependency on family labor in the study area. According to Okuthe (2014) and Akankwasa et al (2016), family size plays a significant role in enhancing the adoption of labor-intensive agricultural technologies.

The findings also show that farming, as a major source of income, positively and significantly influenced the use of trenches ($P < 0.05$), and negatively influenced the use of clean seed ($P < 0.01$) and banana hybrid varieties ($P < 0.1$). This implies that households whose major source of income was farming were more likely to adopt the use of trenches but less likely to take up the use of clean seed and banana hybrid varieties at the same time. This could be associated with the competing costs and labor requirements to implement the three practices. Other studies (Abeje et al., 2019; Ellis & Bahiigwa, 2003), found that farming as a major source of household income is not enough to provide capital investment into the timely purchase of farm inputs such as clean seed, hybrid varieties, and hiring labor. Given the restricted resources, such households prioritize investment in soil and water conservation measures (trenches) using family labor rather than disease control practices such as clean seed and hybrid varieties which require more cash investments. The study further revealed that a unit increase in land access significantly influenced the household's negative decision to adopt the use of organic manure ($P < 0.1$), basins ($P < 0.1$), and sterilizing tools ($P < 0.1$) (Table 6.3). This suggests that households who access more land could be involved in other farming activities other than banana production and where banana farming is practiced, they could only be focused on implementing the basic mat maintenance technologies. Expectedly, a unit increase in land allocated to bananas significantly increased the probability of adopting a package of several banana technologies more so those targeting soil and water conservation such as mulching ($P < 0.05$), use of organic manure ($P < 0.01$), use of trenches ($P < 0.05$) and basins ($P < 0.05$). An increase in the size of the banana plantations also increased the household's probability of using sterilizing tools ($P < 0.01$). Banana technologies are applied in already established plantations. Therefore, the more the size of the plantation available, the more the number of technologies applied as shown in the results. On the contrary, a unit increase in the land allocated to bananas was significantly and negatively associated with the adoption of hybrid banana varieties ($P < 0.01$). This suggests that while the rest of the practices are applied in already established plantations, the use of hybrid varieties requires opening up new gardens which may no longer be available.

Households located in the dry corridor (Nakaseke and Birere) were more likely to adopt a package of input intensification (herbicides ($P < 0.01$), clean seed ($P < 0.01$), hybrid banana varieties ($P < 0.01$)) and low external input technologies (organic manure ($P < 0.05$), basins ($P< 0.05$)). This could be due to the fact that households in these areas are commercially oriented focusing on banana enterprise and in most cases easily access the market. In Birere for example, banana has been the sole cash and food crop for a long time (Kuteesa et al., 2018) because of its tolerance to drought conditions (Nansamba et al., 2021) while Nakaseke's strategic location near major towns in Uganda offers a ready market for the produced bananas (Bagamba, 2007). Therefore, they are motivated to take up many more banana technologies to improve greatly and maintain banana productivity. On the other hand, households in this area were less likely to use mulch ($P < 0.01$) because of the presence of termites that destroy the organic mulches in a short time. They also indicated that being in a dry corridor predisposes their plantations to fire hazard thus they choose not to mulch.

Household membership to a farmer group was positive and significantly ($P < 0.05$) related to the adoption of mulches, herbicides ($P < 0.01$), and trenches ($P < 0.05$). This could be a result of formal and informal interactions among the group members which enable them to exchange information and services, harmonize their beliefs and attitudes, and overcome resource constraints related to the adoption of technologies (Zeweld et al., 2018). In addition, some farmer groups are initiated by development organizations to ease the process of technology and information dissemination (Okuthe, 2014; Chindime et al., 2016). Thus, banana farming households with membership to farmer groups have access to adequate information with regard to the use of banana technologies to enable them to adopt a package of banana technologies.

The study also shows that access to formal sources of credit has a significant ($P < 0.05$) positive effect on the use of input intensification technological packages involving clean seed and hybrid varieties ($P < 0.1$).

Table 6.3: Determinants of adoption patterns for banana technologies

	Banana technologies (n = 333)								
Independent variables	**Mulch**	**Herbicide**	**Manure**	**Clean seed**	**Trench desilt**	**Basin desilt**	**Sterile tools**	**Weevil trapping**	**Hybrid varieties**
Socioeconomic characteristics									
Gender of household (hh) head	-0.060 (0.265)	0.372 (0.323)	-0.255 (0.244)	0.086 (0.334)	0.002 (0.245)	0.258 (0.292)	-0.374 (0.255)	0.432* (0.245)	0.077 (0.279)
Household size	0.027 (0.027)	0.000 (0.030)	0.027 (0.027)	0.056 (0.036)	0.062** (0.027)	0.002 (0.031)	0.020 (0.026)	-0.010 (0.026)	0.059* (0.031)
Hh experience growing bananas	-0.011 (0.007)	-0.008 (0.007)	-0.008 (0.006)	0.003 (0.008)	-0.021*** (0.006)	0.003 (0.006)	0.006 (0.006)	0.003 (0.006)	-0.004 (0.007)
Hh income source	0.264 (0.289)	0.320 (0.315)	0.047 (0.280)	-0.897*** (0.316)	0.599** (0.280)	0.041 (0.298)		0.367 (0.266)	-0.511* (0.282)
Why grow bananas	0.014 (0.162)	-0.014 (0.174)	-0.137 (0.153)	-0.169 (0.196)	0.096 (0.153)	-0.143 (0.171)		0.225 (0.147)	0.216 (0.179)
Physical characteristics									
Log land accessed (ha)	-0.157 (0.128)	-0.055 (0.140)	-0.222* (0.121)	-0.013 (0.156)	-0.130 (0.124)	-0.235* (0.142)	-0.203* (0.120)	-0.071 (0.121)	0.124 (0.141)
logTotal banana area (ha)	0.288** (0.144)	-0.100 (0.144)	0.388*** (0.130)	-0.024 (0.170)	0.324** (0.131)	0.337** (0.151)	0.370*** (0.128)	0.178 (0.129)	-0.384*** (0.146)
Physical location	-0.368** (0.155)		0.002 (0.147)	-0.282 (0.196)	0.130 (0.150)	-0.140 (0.166)	0.097 (0.149)	0.110 (0.143)	-0.108 (0.172)
Soil fertility status1	-0.124 (0.216)	0.338 (0.235)	0.227 (0.203)	0.772*** (0.279)	0.217 (0.202)	-0.488** (0.243)			0.253 (0.195)
Soil fertility status3	0.050 (0.185)	0.328 (0.203)	-0.008 (0.170)	0.399* (0.230)	-0.024 (0.170)	0.062 (0.186)			

Ecological location	-1.147***	0.577***	0.444**	0.822***	0.234	0.439**	0.030	-0.082	0.536***
	(0.175)	(0.193)	(0.172)	(0.241)	(0.163)	(0.194)	(0.156)	(0.155)	(0.202)
Access to agricultural support services									
Contact with		-0.134		3.989		-0.316		-0.069	
extension		(0.424)		(95.542)		(0.418)		(0.335)	
Membership to farmer	0.398**	0.541***	0.182	0.122	0.344**	0.171	0.060		0.098
group	(0.163)	(0.177)	(0.158)	(0.202)	(0.158)	(0.177)	(0.154)		(0.186)
Access to formal	0.153	0.191	0.062	0.526**	-0.017	-0.058	0.157	0.146	0.432*
credit sources	(0.166)	(0.187)	(0.156)	(0.214)	(0.158)	(0.178)	(0.156)	(0.147)	(0.194)
Type of input/output		0.378*	0.142	0.494**	0.083	0.008			0.314
market		(0.192)	(0.176)	(0.213)	(0.176)	(0.197)			(0.191)
Distance to the market			-0.004	-0.029					-0.023
			(0.015)	(0.021)					(0.017)
Constant	0.208	-3.093***	0.119	-10.005	-1.035	-0.786	1.006*	-1.297	-2.124***
	(0.704)	(1.173)	(0.659)	(191.088)	(0.665)	(1.154)	(0.601)	(0.908)	(0.733)

Log likelihood = -1506.09; Wald chi^2 (121) = 263.2; Prob > chi^2 = 0.0000. *, **, and *** indicate statistical significance at $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively; standard errors are indicated in parentheses.

Credit access provides the farmers with alternative cash sources to purchase clean seeds and pay for the labor requirements to grow banana hybrids. This conforms with the study by Okuthe (2014) who found that money availability and access to credit had a positive effect on the use of improved seed varieties and associated practices in integrated natural resource management.

Household access to input and output markets in major towns of Uganda was positively associated with the use of herbicides ($P < 0.1$) and clean seed ($P < 0.05$). These markets offer better prices and various options leading to the farmers' enhanced returns to invest in the adoption of technologies that require a relatively high capital investment. Thus, such households benefit from the favorable prices which would otherwise be impossible with the acquisition of inputs in local markets or the sale of bananas at the farm gate. A recent study by Mujeyi et al (2020) also reported that farmers were more likely to adopt technologies whose products have alternative markets to offer better prices and higher income earnings than they would be at farmgate.

6.3.5 Determinants of the adoption intensity of banana technologies

The maximum number of technologies adopted by a given household was twelve, indicating that none of the households had adopted all the 14 available banana technologies. Hence, there is still potential to increase the adoption intensity of banana technologies.

Household size, total banana area, soil fertility status, ecological location, household membership to a farmer group, access to formal sources of credit, input and output markets in major towns of Uganda had significant effects on the adoption intensity of banana technologies (Table 6.4). Worth noting, these effects were similar and negative among low-adopters (0-4 technologies) and mid-adopters (5-8 technologies), but positive among high-adopters (9-12 technologies). The magnitude of negative influence was higher among low-adopter households than in mid-adopters, while for high-adopters the positive influence was almost the summation of the magnitude of low and mid-adopters (Table 6.4). This implies that such variables favor the adoption of packages with more technologies. Teklewold et al (2011) noted that an increase in magnitude shows that the number of households adopting several technologies increases with the increasing number of technology options available. Therefore, with reference to the study results (Table 6.4), the increase in the magnitude of association with high-adopters indicates that the more the number of banana technologies available in a package, the more the increase in the number of households adopting many of them.

Table 6.4: Factors that influence the adoption intensity of banana technologies among the households

		Marginal effects		
Variables	**Coefficients**	**Low-level Adopters**	**Mid-level adopters**	**High-level adopters**
Socioeconomic characteristics				
Gender of household (hh) Head	0.225 (0.248)	-0.035 (0.039)	-0.033 (0.036)	0.068 (0.074)
Household size	0.047* (0.026)	-0.007* (0.004)	-0.007* (0.004)	0.014* (0.008)
Hh experience growing Bananas	-0.006 (0.006)	0.001 (0.001)	0.001 (0.001)	-0.002 (0.002)
Marital status of the hh head	-0.241 (0.200)	0.038 (0.032)	0.035 (0.029)	-0.073 (0.060)
Age of the household head	-0.002 (0.006)	0.000 (0.001)	0.000 (0.001)	-0.001 (0.002)
Why grow bananas	-0.055 (0.144)	0.009 (0.022)	0.008 (0.021)	-0.017 (0.043)
Physical characteristics				
Log land accessed (ha)	-0.087 (0.110)	0.014 (0.017)	0.013 (0.016)	-0.026 (0.033)
Log Total banana area (ha)	0.233** (0.115)	-0.036** (0.018)	-0.034* (0.017)	0.070** (0.034)
Soil fertility status1	0.420** (0.189)	-0.066** (0.030)	-0.061** (0.028)	0.127** (0.056)
Soil fertility status3	0.107 (0.160)	-0.017 (0.025)	-0.016 (0.023)	0.032 (0.048)
Ecological location	0.280* (0.158)	-0.044* (0.025)	-0.041* (0.023)	0.085* (0.047)
Access to agricultural support services				
Contact with extension	0.493 (0.323)	-0.077 (0.050)	-0.072 (0.049)	0.149 (0.097)
Membership to farmer group	0.433*** (0.147)	-0.068*** (0.024)	-0.063*** (0.023)	0.131*** (0.043)
Access to formal credit sources	0.266* (0.144)	-0.042* (0.023)	-0.039 (0.022)	0.080* (0.043)
Type of input/output market	0.318* (0.163)	-0.050* (0.026)	-0.046* (0.024)	0.096** (0.049)
Distance to the market	-0.024 (0.016)	0.004 (0.003)	0.004 (0.002)	-0.007 (0.005)
Log transport cost to the market	0.067 (0.053)	-0.010 (0.008)	-0.010 (0.008)	0.020 (0.016)
/cut1	1.150			
/cut2	3.242			

LR chi^2 (17) = 50.2; Prob > chi^2 = 0.0000). *, **, and *** indicate statistical significance at $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively; standard errors are indicated in parentheses.

Having a larger household increased the propensity to adopt more than eight technologies by 1.4%. This is attributed to the availability of relatively cheap labor. In addition, such households are motivated to take up more technologies to boost productivity and meet household food consumption requirements (Mujeyi et al., 2020; Teklewold et al., 2011). An increase in the household land allocated to bananas increased the tendency to adopt more than eight technologies by 7%. Other than a few technologies such as the use of hybrid varieties, most of the banana technologies are applied in an already established plantation. Therefore, the more the land covered by the plantation, the more the likelihood of using more technologies.

The household location in the dry corridor increased the propensity of adopting more than eight technologies by 8.5%. This could be attributed to the increased adoption of soil and water conservation technologies to reduce the effect of drought in the area (Nansamba et al., 2021). Membership to a farmer group increased the household's propensity to adopt more than eight banana technologies by 13.1%. This could be attributed to the ability of the groups to facilitate timely access to the necessary information, inputs, and labor requirements for the adoption of more technologies (Mujeyi et al., 2020).

Increased access to formal sources of credit increased the propensity to adopt more than eight technologies by 8%. This is due to the increased access to alternative financial support services to invest in the adoption of more technologies. Similarly, increased access to the input and output markets in major towns of Uganda increased the adoption of more than eight technologies by 9.6%.

6.4 Summary

Banana farming households adopted technological packages in patterns involving input intensification and low external input technologies as complements and substitutes. Complementarity implies that the promotion of such technologies as a package of options rather than in isolation is a better strategy that presents more options that can maximize the benefits from such synergies. For example, households in dry corridors are more likely to adopt a package a package of technologies including herbicides, clean seed, hybrid varieties, organic manure, basins and are less likely to use mulches at a time.

Adoption intensity results obtained from estimating ordered probit model revealed that farmers had a tendency to adopt more than four technologies. The maximum number of technologies that can be adopted at a time was 12 technologies. The propensity to adopt was bigger among high adopters (9–12 technologies) than in mid-adopters (5-8 technologies) and low-adopters (0-4 technologies). Household size, total banana area, ecological location, household membership to a farmer group, access to formal sources of credit, input and output markets in major towns of Uganda produced significant results with the MVP model and ordered probit model. This shows that the type and the number of technologies adopted are determined by similar factors which should be taken into account when designing adoption interventions for multiple agricultural technologies.

Chapter 7: Summary, conclusions and recommendations

This chapter summarizes the most important findings, providing the study conclusions, recommendations, and new knowledge contribution to the existing literature.

7.1 Summary

The major objective of this study was to examine the agricultural innovation arrangements in place to enable the stakeholders in the Ugandan banana value chain to interact and develop capacities for participating in agri-based networks, value chains and adopt technologies. Therefore, the interactions for the exchange of information and services among stakeholders in the banana value chain were examined; followed by the capacities possessed and those needed by the various stakeholders in the banana value chain to participate in innovation activities and adoption of technologies; and finally, the on-farm patterns and intensity for adoption of multiple banana technologies were also examined.

The study used a mixed methods research design employing primary data which was collected from December 2019 to March 2020. This data was collected from the three agroecological zones (lowland, highland, and mid-highland) specifically in Nakaseke, Bunyangabu, and Isingiro respectively which are traditionally known for growing bananas.

The overall results from the three case studies show that although there are various stakeholders in the banana value chain, many of them were weakly connected to one another, as indicated by the low network densities and the low percentage of reciprocated ties. This shows that most of the stakeholders were working in isolation which limits the possibility of innovating together. Particularly, research and extension had weak or missing connections with the key stakeholders such as the processors, traders, and farmer groups. This depicts the existing limited discussions, cooperation and feedback among them, with the likely outcome of generating and promoting technologies that are not acceptable among end users. In addition, the weak connections lead to the underutilization of potential relationships to disseminate valuable knowledge, information, and services necessary for the adoption of improved banana technologies. The results further indicate that capacity development at individual, organizational, and enabling environment dimensions in terms of value addition of bananas, improved and increased marketing options, and improved financial access and management can greatly contribute to innovation and adoption of technologies.

Results on adoption patterns and intensity indicate that farmers simultaneously adopted technologies as complements and substitutes. This was deduced from the MVP results. Complementarity implies that the promotion of technologies as a package of options rather than as a single technology is a better strategy that presents more options that can maximize the benefits from such synergies. Moreover, ordered probit results show that the propensity to adopt was more towards the packages of 9-12 technologies than lower technological packages. The results show that adoption patterns and adoption intensity of multiple banana technologies are influenced by similar aspects. Household size, total area under bananas, ecological location (dry corridor or not), household membership to a farmer group, access to formal sources of credit, and access to input and output markets in major towns of Uganda produced significant results with the MVP model and ordered probit model depicting adoption patterns and intensity, respectively. Thus, such socio-economic and institutional aspects should be taken into account when designing adoption interventions for agricultural technologies.

7.2 Conclusions

Based on the study results, it can be concluded that interactions among stakeholders in the Ugandan banana value chain are very minimal. There are various weak and/or missing linkages among essential value chain stakeholders and service providers, depicting their limited active engagement in banana innovation activities in Uganda. The missing linkages have been identified among research and extension and processors, financial service providers, and traders. If such linkages together with those of other stakeholders could be improved, this could improve information exchange, service delivery, innovation, and adoption of technologies, which eventually improves productivity.

The need for value-addition options for bananas; improved financial access and management; and an increase in banana marketing options were emphasized as major capacity development needs among the individuals, organizations, and the enabling environment for the banana value chain in Uganda. Moreover, farmer access to finance and markets was also found to significantly influence the adoption of multiple banana technologies.

From the study results, it can be concluded that farmers adopt technologies in patterns involving a mixture of low external and input intensification technologies. The farmers' intensity to adopt multiple banana technologies increases with an increase in the number of technologies (9-12 technologies) in a particular package. Therefore, in order to improve adoption and subsequent banana productivity, banana technologies should be promoted as packages of technologies rather than promoting each of the technologies in isolation. Promotion and implementation of agricultural technologies as a package helps farmers tackle multiple challenges and constraints that limit agricultural productivity.

7.3 Recommendations

Agricultural development interventions should aim at improving stakeholder interactions, whether physical or virtual in order to increase timely access to technologies and services such as marketing the produce and access to financial services which enhance technology adoption and innovation. There is a need to improve mutual interactions for information exchange and service delivery among research, extension, and other key banana stakeholders such as farmers, processors, traders, and financial service providers as a means to enhance innovations and adoption of technologies. Mutual interactions are sources of feedback to advise the development and promotion of banana technologies which are relevant for reducing the challenges and constraints faced by the end-users of technologies. Mutual interactions can be enhanced by building capacity of stakeholders to actively seek feedback and advice relevant for innovation and adoption ot technologies. In addition, banana extension options should include aspects that address the urgent need for market development and increase access to and management of finances to enable investment in technology adoption.

Exploration of other alternative ways of using bananas as one of the ways to augment increased production and marketing, especially during the peak banana production seasons. According to this study, improvement of the key stakeholders' capacities and equiping them with knowledge, skills, and competencies in terms of value addition, financial access, and management can facilitate innovation and adoption of technologies.

Lastly, since banana production is knowledge intensive involving implementation of various technologies, such technologies should be promoted in a step-wise manner. This involves packaging technologies which are complementary such as those identified by this study and introduce them to the farmers at different times. However, the farm and household characteristics should be taken care of for example; households in dry corridors are more likely to adopt a technological package which includes herbicides, clean seed, hybrid varieties, organic manure, basins and are less likely to use mulches at a time.

7.4 Limitations of the study and recommendations for future research

The major limitation of this study is that network analysis was conducted by aggregating individual stakeholders into groups such that network linkages focused on the group level rather than the individual stakeholder level. Although this was useful to enable relative comparisons of stakeholder connectivity across the study sites, it did not bring out individual stakeholder contributions to the network. Future research should focus on:

(i) network building at multiple levels such as within and between stakeholder groups;
(ii) assessing banana value chain stakeholder commitments to the continued collaboration;
(iii) factors that influence capacity development and utilization during interactions among stakeholders in the banana value chain
(iv) gender and adoption of climate-smart banana practices as a means to plan for inclusive and sustainable banana production.

7.5 Contribution to the knowledge

This study contributes to the literature on agricultural extension in Uganda by looking at the contributions of stakeholder interactions in informal value chain networks as conduits for the exchange of information and services, innovation, technology development, dissemination and adoption. This study, by answering the three research questions, provides a guiding framework for identification of appropriate technological packages, intervention zones and training topics as capacity development requirements to be fulfilled in order to facilitate innovation and adoption of technologies in the Ugandan banana value chain.

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15 March 2023

ETHICS SUBMISSION: LETTER OF APPROVAL

Mrs S Kiconco
Department of Agricultural Economics Extension and Rural Development
Faculty of Natural and Agricultural Science
University of Pretoria

Reference number: NAS303/2022
Project title: Stakeholder interactions and capacity development for innovation and adoption of agricultural technologies: the case of banana value chain in Uganda

Dear Mrs S Kiconco,

We are pleased to inform you that your submission conforms to the requirements of the Faculty of Natural and Agricultural Sciences Research Ethics Committee.

Please note the following about your ethics approval:

Please use your reference number (NAS303/2022) on any documents or correspondence with the Research Ethics Committee regarding your research.

Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, monitor the conduct of your research, or suspend or withdraw ethics approval.

Please note that ethical approval is granted for the duration of the research (e.g. Honours studies: 1 year, Masters studies: two years, and PhD studies: three years) and should be extended when the approval period lapses.

The digital archiving of data is a requirement of the University of Pretoria. The data should be accessible in the event of an enquiry or further analysis of the data.

Ethics approval is subject to the following:

The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

If Applications using GM permits: If the GM permit expires before the end of the study, please make an amendment to the application with the new GM permit before the old one expires

If Applications using Animals: NAS ethics recommendation does not imply that Animal Ethics Committee (AEC) approval is granted. The application has been pre-screened and recommended for review by the AEC. Research may not proceed until AEC approval is granted.

Comments:

Some focus on the decline of bananas as a result of consumer consumption decline may also be considered - it may well be that banana production decline is also as a result of declined consumption.

The data already been collected - the proposal indicates that data collection takes place between December 2019 and March 2022.

Post approval submissions including application for ethics extension and amendments to the approved application should be submitted online via the Ethics work centre.

We wish you the best with your research.

Yours sincerely,

Prof VJ Maharaj
Chairperson: NAS Ethics Committee

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