

**ACTOR INTERACTIONS IN THE DEVELOPMENT
AND UPTAKE OF NEW HYBRID BANANA
VARIETIES IN UGANDA**

BY

LOSIRA NASIRUMBI

REG. No: 2012/HD02/16U

B.A (Hons) SOCIAL SCIENCES; MSc AGRIC. ECON. (MAK)

**A DISSERTATION SUBMITTED TO THE DIRECTORATE
OF RESEARCH AND GRADUATE TRAINING IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD
OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN
AGRICULTURAL AND RURAL INNOVATION
OF MAKERERE UNIVERSITY**

DECEMBER, 2017

DECLARATION

I, Losira Nasirumbi, declare that the research reported in this dissertation titled "*Actor Interactions in the Development and Uptake of new Hybrid Banana Varieties in Uganda*", except where otherwise indicated, is my own original research, and to the best of my knowledge, it has never been submitted to any university or institution for any academic award whatsoever.

Signature: -----  -----

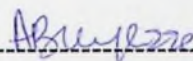
Date: ----- 6th DEC. 2017 -----

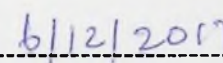
APPROVAL

This research dissertation has been submitted with the approval of the following supervisors:

Dr. Kyazze Florence Birungi,

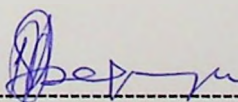
Department of Extension and Innovation Studies,
School of Agricultural Sciences,
College of Agricultural and Environmental Sciences,
Makerere University

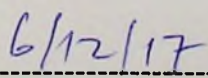
Signature: -----

Date: -----

Dr. Haroon Sseguya,

Department of Extension and Innovation Studies,
School of Agricultural Sciences,
College of Agricultural and Environmental Sciences,
Makerere University
and
International Institute of Tropical Agriculture (IITA),
Regional Hub for Eastern Africa, Dar es Salaam, Tanzania.

Signature: -----

Date: -----

COPYRIGHT STATEMENT

© Losira Nasirumbi, 2017. All rights reserved.

DEDICATION

This dissertation is dedicated to;
My dear husband Sanya Francis Mugeni,
Our children: Blessed Apio Sanya (RIP), Precious Abigail Sanya, and Praise Angel
Sanya,
&
My ever loving GNB Namachi family

ACKNOWLEDGEMENTS

Firstly, I want to thank the LORD GOD for enabling me to come this far in my Ph.D studies! I testify of His goodness, provision, grace and favour that have sustained me throughout this long journey. During my research, I received enormous support and encouragement from many institutions and individuals. I would like to take this opportunity to offer them my sincere gratitude.

First, I would like to thank the World Bank, through the Agricultural Technology and Agribusiness Advisory Services (ATAAS) project implemented by the National Agricultural Research Organization (NARO) for the financial support that has made this Ph.D study possible. I acknowledge NARO for all the support and time accorded to me as a doctoral student at Makerere University. I am grateful to the management and staff of Mukono Zonal Agricultural Research and Development Institute (MUZARDI) for all the support, input and contribution to this research. My special appreciation go to the former Director of Research – MUZARDI, Mr. Peter Lusembo, for providing me with different opportunities that eventually led me to this Ph.D path. You encouraged me to pursue PhD studies, and I don't regret the decision.

Secondly, this Ph.D research would have been impossible to accomplish without the tremendous and sustained guidance and mentorship of my dear supervisors, Dr. Florence Birungi Kyazze and Dr. Haroon Sseguya. My sincere gratitude go to you for the continuous support, motivation and immense knowledge you gave me. You have been a great resource throughout the research period right from conceptualization to writing of this dissertation. I could not have imagined having better advisors and mentors for my Ph.D study than you. Besides my supervisors, I would like to thank the rest of my Doctoral Committee members: Associate Prof. Paul Kibwika, Dr. Yona Baguma, Dr. Diiro Gracious, and Associate Prof. Gorettie Nabanoga, for your insightful comments, guidance and encouragement. My since appreciation also goes to the Professors and lecturers at the Department of Extension and Innovation Studies. You provided useful insights during the Friday seminars and my one-on-one interaction with many of you. I also wish to thank all the support staff of the department

particularly, Mrs. Harriet Walugembe (RIP), Ms. Deborah Ndagire and Mr. Kasujja Geoffrey for all the support rendered to me.

My sincere thanks also go to the Banana Research programme staff especially Drs. Barekye Alex, Akankwasa Kenneth and Tendo Reuben Ssali for your input and guidance throughout the research. I greatly appreciate the contribution of various actors in the banana technology development chain that provided and shared invaluable information without which, this study would have been impossible. I am also hugely indebted to Mr. Mulwana Felix who was my main point of contact in the field. I greatly appreciate your coordination role throughout the data collection process. I would also like to thank my research assistants, Olivia Bwire, Emmanuel Ngolobe, Doreen Mwanje, Christine Karungi and Polyx Adrian Musiitwa for the enthusiastic support. I especially thank Olivia Bwire for your role in data management.

I am glad to have walked this journey with other PhD colleagues. My special thanks to all the Ph.D in Agricultural and Rural Innovation (PARI) family members across Cohorts for the words of encouragement along the way. I particularly benefited from various review teams across cohorts. I particularly extend my gratitude to my peer review members Damalie B. Magala, Narisi Mubangizi, Godfrey Ssebagala Lusiba, Rebecca Mukebezi, Irene Tamubula, Sylvia Chindime, Sarah Akello Esimu, Rosemirta Birungi, Hon. Sebuliba Mutumba, Janet Achora, Pauline Birungi and Deborah Alio for the extra support. Damalie B., you have been a sister and friend throughout this journey. Narisi, thank you for always asking the tough questions. Your critical review and comments pushed me to think more systematically and frame the scientific contribution of my work.

My special thanks to my friends Dr. Pamela N. Muniina, Nalongo Florence Nakazzi and Dr. Dickson Baguma for the technical support. Further, my great appreciate to my friends of the N3 family - Cissy Nasana and Lydia Nandutu for the continuous encouragement. Pastor Mary Nambuya, you have been more than a friend, thank you for standing with me in prayer at all times.

Last but by no means least, I would like to thank my family. This PhD study would have been impossible to complete without a supportive family. I am grateful to the

entire Disan Namude - Mubende family for all the encouragement to soldier on and finish. Your inquiry of "how far" served to remind me that it was not just "my Journey but our journey". Special thanks to my family, The GNB Namachi family – Dad, mums, my brothers and sisters for being understanding, supportive and continuously praying with me. Auntie Mum Olivia, thanks for sacrificing everything to see that I accomplish my studies smoothly. Auntie Mum Hellen Aguttu, I can never forget the day Praise Angel referred to me as Auntie and you as mum. Uncle Kenneth Masiga, thanks for all the sacrifices to always step in when my Ph.D schedule would not permit me to be there. To my own - De Sanyas, many thanks for accommodating me throughout this journey with unwavering love, care and support that has been so visible. You have been my greatest inspiration throughout this Ph.D journey. My dear husband Sanya Francis Mugeni, you sacrificed your time to share this journey. For all the times you looked after the family, dropped me to school, stayed awake through the night to just be sure I am able to meet the deadlines and reviewed the different drafts, I greatly appreciate. You have been my prayer partner all the way and all I can say is, THANK YOU for being a caring and supportive husband always. To our children, Precious Abigail and Praise Angel (aka PARI), those little questions of whether I finished my homework made me realize that *homework could not take forever. I had to finish!* You promised to work hard and smart and be like mummy. I pray your dreams come true in Jesus Name.

Many thanks to each one of you. May God Bless you all!

Like Nelson Mandela (1918-2013) said, "It always seems impossible until it's done."

To God be the glory for this work through Christ my Lord and Savior. Amen.

TABLE OF CONTENTS

DECLARATION	ii
APPROVAL	iii
COPYRIGHT STATEMENT	iv
DEDICATION	v
ACKNOWLEDGEMENTS	vi
LIST OF TABLES	xi
LIST OF ILLUSTRATIONS/FIGURES	xii
LIST OF APPENDICES	xiii
LIST OF ABBREVIATIONS AND ACRONYMS	xiv
ABSTRACT	xvi
CHAPTER 1: GENERAL INTRODUCTION	1
1.0 Introduction	1
1.1 Background to the study	1
1.2 Banana production and its importance	3
1.3 Progress in the development of banana production technologies in Uganda	4
1.4 Problem statement	6
1.5 Research objectives and questions	7
1.6 Overview of the research methodology	8
1.7 Significance of the study	17
1.8 Theoretical and conceptual framework	18
1.9 Ethical consideration	22
1.10 Organization of the dissertation	23
References	25
CHAPTER 2: COMPLEXITY OF AGRICULTURAL TECHNOLOGY DEVELOPMENT: IMPLICATIONS OF PROCESSES AND ACTOR ROLES FOR UPTAKE OF NEW HYBRID BANANA VARIETIES IN CENTRAL UGANDA	31
Abstract	31
2.1 Introduction	32
2.2 The theoretical framework	34
2.3 Methodology	35
2.4 Results and discussion	37
2.5 Reflections on the process	51

2.6 Conclusions and Recommendations	53
References.....	56
CHAPTER 3: ACTOR DIVERSITY AND INTERACTIONS IN THE DEVELOPMENT OF BANANA HYBRID VARIETIES IN UGANDA: IMPLICATIONS FOR TECHNOLOGY UPTAKE	
Abstract	61
3.1 Introduction.....	62
3.2 Theoretical framework.....	63
3.3 Methodology	64
3.4 Results and discussion	67
3.5 Conclusions and implications	78
References.....	81
CHAPTER 4: DETERMINANTS OF UPTAKE OF NEW HYBRID BANANA VARIETIES BY SMALLHOLDER FARMERS IN CENTRAL UGANDA	
Abstract	84
4.1 Introduction.....	85
4.2 Methodology	88
4.3 Results and discussion	98
4.4 Conclusion and implications.....	113
References.....	115
CHAPTER 5: GENERAL DISCUSSION OF RESEARCH FINDINGS, CONCLUSIONS AND RECOMMENDATIONS	
5.1 Introduction.....	120
5.2 Overview and general discussion of research findings.....	121
5.3 General conclusions	123
5.4 General recommendations.....	126
5.5 Contribution of the research.....	130
5.6 Areas for further research	131
References.....	133
APPENDICES	134

LIST OF TABLES

Table 1.1:	Matooke hybrids released and their important attributes	6
Table 1.2:	Overview of data collection methods and tools	15
Table 1.3:	Summary of data analysis methods and tools	17
Table 2.1:	Scores for technical attributes in the selection of new HBVs.....	46
Table 3.1:	Elements of the Social Network Analysis used in the study	67
Table 3.2:	Categorization of Actors in the BTID process for new HBVs	69
Table 3.3:	Measures of network density for the BTID network	74
Table 3.4:	Comparison of cohesion measures for networks at different stages of BTID process	74
Table 3.5:	Descriptive Measures of Centrality in the BTID process	77
Table 4.1:	Number of farmers targeted for the study.....	90
Table 4.2:	Factor Loadings for varietal attribute preferences using a Factorial Analysis.....	92
Table 4.3:	Distribution of sample characteristics of banana farmers sampled	99
Table 4.4:	Socio-economic and demographic characteristics of sampled banana growing households by HBVs users and HBVs non-users.....	100
Table 4.5:	Main banana varieties grown.....	101
Table 4.6:	Source of planting materials for new HBVs	103
Table 4.7:	Areas that need improvement for the most important new HBVs.....	107
Table 4.8a:	Factors that influence farmers' decisions regarding adoption of new HBVs adoption: results of the Probit Model.....	109
Table 4.8b:	Factors that influence intensity of adoption of new HBVs: results of the Truncated Regression Model.....	111

LIST OF ILLUSTRATIONS/FIGURES

Figure 1.1: Framework for exploratory sequential mixed methods design.....	10
Figure 1.2: Main stages of a plant breeding program	19
Figure 1.3: Multi-level Technology Development Process	20
Figure 1.4: Conceptualization of the relationship between the social dynamics in BTD process and uptake of new hybrid banana varieties	21
Figure 1.5: Overview of the Organization of the Dissertation	24
Figure 2.1: The process of developing new HBVs: stages, activities and actors...	38
Figure 2.2: Venn Diagram showing the level of actor involvement in key activities of setting the research agenda	40
Figure 2.3: Evaluation and selection of new HBVs: Actors involved and criteria followed.....	45
Figure 2.4: Mean preference scores for the sensory attributes of cooked matooke	46
Figure 3.1: Actors involved at the different stages of the BTD process for new HBV.....	68
Figure 3.2: Network map for information and tangible resources between actors in the BTD process	70
Figure 3.3: Nature of the BTD Network structure	72
Figure 4.1: Conceptual model for factors influencing agricultural technology adoption and intensity of adoption	87
Figure 4.2: Venn diagram showing percentages of sampled households (n=242) using the different types of banana varieties	102
Figure 4.3: Aggregated average rating of production related attributes across local cultivars and new HBVs in central Uganda	105
Figure 4.4: Aggregated average rating of processing and consumption related attributes across local cultivars and new HBVs in central Uganda.....	105
Figure 5.1: A Multi-Dimensional Integrated Model for Technology Development	130

LIST OF APPENDICES

Appendix 1:	Map Showing the Study Area.....	132
Appendix 2:	Guide for Key Informant Interviews	133
Appendix 3:	Guide for Focus Group Discussion	137
Appendix 4:	Household survey instrument	140
Appendix 5:	Introduction letter from DEIS, Makerere University	165
Appendix 6:	Approval of the research study by the UNCST	166
Appendix 7:	Introduction and informed consent form	167
Appendix 8:	Hypothesized determinants of adoption and intensity of adoption decisions for new HBVs	170

LIST OF ABBREVIATIONS AND ACRONYMS

AIS	Agricultural Innovation Systems
ANT	Actor Network Theory
ARD	Agricultural Research and Development
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ATD	Agricultural Technology Development
BTD	Banana Technology Development
CAADP	Comprehensive Africa Agriculture Development Program
CGIAR	Consultative Group on International Agricultural Research
DEIS	Department of Extension and Innovation Studies
DSIP	Agriculture Sector Development Strategy and Investment Plan
EAHB	East African Highland Bananas
FAO	Food and Agricultural Organisation of the United Nations
FGD	Focus Group Discussion
FHIA	<i>Fundación Hondureña de Investigación Agrícola</i> in Honduras (Honduras Foundation for Agricultural Research)
HBVs	Hybrid Banana Varieties
IDI	In-depth Interviews
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
ISA	Innovation Systems Approach
KABANA	Kawanda Banana
KII	Key Informant Interviews
LVCAZ	Lake Victoria Crescent Agro-ecological Zone
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MDG	Millennium Development Goal
MUZARDI	Mukono Zonal Agricultural Research and Development Institute
PARI	Ph.D in Agricultural and Rural Innovation
NARO	National Agricultural Research Organisation
NARS	National Agricultural Research Systems

NBRP	National Banana Research Programme
NDP	National Development Plan
S3A	Science Agenda for Agriculture in Africa
SDGs	Sustainable Development Goals
SNA	Social Network Analysis
SNT	Social Network Theory
SSA	Sub-Saharan Africa
TD	Technology Development
TISs	Technological Innovation Systems
UBOS	Uganda Bureau of Statistics
UNCST	Uganda National Council of Science and Technology
UNDP	United Nations Development Programme

ABSTRACT

Low uptake of improved agricultural technologies is a major challenge to enhancing agricultural productivity and ensuring food security in developing countries. While a number of studies have analyzed technology use, less attention has been paid to the social context in which the Technology Development (TD) process is anchored. In this study, I analyzed how actor interactions in TD processes influence uptake of agricultural technology, with specific focus on cooking banana in Central Uganda. The study specifically (i) analyzed the process that led to development of new Hybrid Banana Varieties (HBVs); (ii) examined the diversity and inclusivity of actors and their interactions in the process and how these elements influence the uptake of new HBVs; (iii) established the determinants of uptake of new HBVs among smallholder farmers in Central Uganda. The study used an exploratory sequential mixed methods research design to explore the context that informed the development and uptake of new HBVs. Results indicate that the banana TD process involves many actors with diverse roles and interests. The process however is largely dominated by agricultural research institutions with limited integration of other actors, such as farmers, private sector actors and extension staff. Network analysis indicated a density of only 29.4%, implying a low existence of direct linkages between actors. Limited interaction between research oriented actors and end-users of the product consequently led to low use of the new HBVs among the study respondents. It is evident from the findings that less than 50% of the households in the survey used the new HBVs. Land allocated to banana production, access to relevant information and neighborhood effects were positively associated with the likelihood of technology use while household size and interactions with other actors significantly influenced the intensity of technology uptake. Further, both adoption and intensity of adoption are significantly spurred by production and consumption attributes associated with HBVs. Within the context therefore, the study provides insights in the diversity and position of actors in the BTDD process. The study further calls for a need to empower end-users of agricultural technologies through better organization so that they can influence technology development processes. In this regard, researchers, supported with appropriate policies, should engage more with actors in the intermediary, enterprise and support service domains for a more vibrant agricultural research system. Further, given that socio-cultural and gender-specific attributes remain critical in the uptake of banana varieties, breeding efforts should focus on generating varieties with multiple traits that meet end-user preferences and diverse needs.

CHAPTER 1: GENERAL INTRODUCTION

1.0 Introduction

Agricultural productivity is critical for economic growth and better livelihoods. Cognizant of the fact that increasing productivity is not possible without yield enhancing technological options, innovations and management practices from agricultural research and technology improvement programmes exist. However, uptake of such technologies and innovations that would otherwise contribute to reduction in poverty and food insecurity remain extremely low in Sub-Saharan Africa. While the current study provides knowledge on how the social dynamics in the Banana Technology Development (BTD) influence uptake of new Hybrid Banana Varieties (HBVs), this chapter describes the background of the study, statement of the problem, objectives, general research approach/methodology and justification of the study. It concludes with an overview of the structure of the dissertation.

1.1 Background to the study

The rapidly growing world population, projected to exceed 9 billion, by 2050, requires a significant increase in food production (Okyere & Jemaneh, 2012). Increasing agricultural productivity is key to increasing food availability and improving rural incomes thereby meeting the demand posed by the high population increase in Sub-Saharan Africa (SSA). Productivity increase can be achieved through expansion of the land cultivated (agricultural extensification) and/or by improving technology and production methods used (intensification) (Okyere & Jemaneh, 2012). The current increases in production experienced in SSA are mainly due to expansion of land under agriculture rather than use of improved technologies and practices. Increasing production through expansion of land under farming is no longer sustainable given the current population growth rate. Therefore, introduction of improved agricultural technologies and management systems remain fundamental to agricultural transformation. Though most agricultural production systems are characterized by low productivity and yields with little application of science and technology (United Nations Development Program [UNDP], 2012; World Bank, 2011), new technologies remain an important means of increasing food production (World Bank, 2008). Efforts have been therefore geared to agricultural research and development at both regional and national levels to sustainably increase productivity that meets food, nutrition and

income security. The post-2015 Sustainable Development Goals (SDGs) and the Comprehensive Africa Agriculture Development Program (CAADP), for instance emphasize the need for increasing investments in agricultural research, extension, and education systems to enhance innovations for improving agricultural productivity.

In Uganda, the agricultural sector occupies a strategic position in realizing food security, economic growth and poverty reduction goals. Agriculture is the most important sector of the Ugandan economy, contributing up to 22.2 % of the Gross Domestic Product (GDP), 40% of the total goods export earnings, and directly and indirectly employs approximately 75% of the country's labour force (Uganda Bureau of Statistics [UBOS], 2013; International Fund for Agricultural Development [IFAD], 2013). Despite its importance, the sector continues to face various challenges in production, processing, marketing and utilization of agricultural commodities (Ministry of Agriculture, Animal Industry and Fisheries [MAAIF], 2010). In regard to production, the sector has not achieved its full potential due to numerous factors that contribute to low productivity such as pests and diseases, decline in soil fertility, use of low yielding varieties, and harsh climatic conditions (MAAIF 2010; Shively and Hao, 2012).

Recognizing the importance of the agricultural sector, different frameworks such as the National Development Plan (NDP), Agriculture Sector Development Strategy and Investment Plan (DSIP) and currently Vision 2040 have been put in place to guide the National Agricultural Research Systems (NARS) towards addressing the challenges faced (MAAIF, 2010). In this regard, the National Agricultural Research Organization (NARO) has undertaken technological improvement as the most important and efficient pathway for increasing productivity and transforming agriculture (NARO, 2012). The aim is to develop and diffuse suitable yield enhancing agricultural technologies that can address the prevailing production constraints among priority commodities. Banana is one of the most important national priority crops valued for its potential contribution to food security and income for the majority of the rural poor that has benefited from such research and development (R&D) initiatives.

1.2 Banana production and its importance

Bananas (*Musa* spp.), including dessert and cooking bananas, is ranked the fourth most important food crop in the least developed countries based on total production and consumption. Uganda is the second largest producer of bananas and the world's largest producer of green cooking bananas (Kabahenda & Kaporiri, 2010). The country is also the largest banana producer and consumer in Sub-Saharan Africa with more than 50% of population depending on bananas for their livelihood (IITA, 2009). The crop is among the most important national priority crops grown as a major food staple, and for income. It is estimated that Uganda produces about 9.8 million tons of bananas and plantains annually which accounts for 7% of the total global production (FAOSTAT, 2012). The East African highland cooking bananas, locally known as *Matooke*, form the most important group of cultivars grown and consumed in Uganda (Karamura, Karamura and Tinzaara, 2012). *Matooke* occupies the greatest proportion (40%) of utilized agricultural land (UBOS, 2013). The crop is mainly grown in the southwest, central and eastern parts of the country by mostly smallholder farmers either for home consumption and/or for the local markets (Uganda Census of Agriculture [UCA], 2010). It is estimated that about 65 percent of the bananas produced are for home consumption with a smaller portion being sold to urban consumers who depend on the crop as their staple food (Smale & Tushemereirwe, 2007). The annual per capita banana consumption is estimated at 400 kg per person which is highest in the world (Karamura et al., 2012; FAOSTAT, 2013). On average, the crop provides about 30% of the caloric intake (FAO, 2002). Essentially, the crop is regarded a food security crop because of its perennial nature with all stages of the crop cycle occurring at any one time of the year thereby providing an extremely valuable food source and smoothening consumption during the *hunger season* (Eledu et al., 2004).

Despite the value of this crop, its productivity in Uganda has been on the decline over the years. The crop is increasingly affected by pests (banana weevils and nematodes), diseases (*Fusarium* wilt, bacterial wilt and black Sigatoka), soil fertility decline and drought stress (Gold *et al.*, 1994; Tushemereirwe *et al.*, 2003; Kubiriba *et al.*, 2013; Tushemereirwe *et al.*, 2014). These biotic and abiotic stresses coupled with socio-cultural and economic constraints limit production. Banana pests and diseases for instance can cause up to 80 percent yield reductions (Gold *et al.*, 1994; Tushemereirwe *et al.*, 2003; Smale & Tushemereirwe 2007). It is estimated that banana yields at farm

level have declined by approximately 45% across production regions (Barekye 2012; Smale and Tushemereirwe 2007).

The effects of these constraints particularly pests and diseases on banana production have been more severe in the Eastern and Central regions of the country that are located in the lowland areas at about 1200 masl (Tushemereirwe et al., 2003; Smale and Tushemereirwe 2007; Kikulwe et al., 2011; Karamura et al., 2016). The central region, the historical loci for banana growing, has registered the highest reduction in banana yields with annual yields falling from an average of 20 tha^{-1} to about 5 tha^{-1} as compared to the potential yield of 70-100t/ha (van Asten et al., 2005; Barekye, 2009). The decline significantly affects the livelihood of the farming communities in this region that depended on *Matooke* for their livelihoods till the early 1990s when production started shifting to Southwest Uganda (Gold et al., 1999; Tushemereirwe et al., 2003; Bagamba et al., 2004). Currently, the central region produces only 24.2 % of the total National banana crop (UBOS, 2012). Apparently, the region has become a banana deficit region, depending on the south-western region for supplies, despite being in the hub for banana consumption and marketing (Mugisha and Ngambeki, 1994; Bagamba, 2007). Addressing such constraints associated with decline in banana productivity can be achieved through development, transfer and use of improved yield enhancing technologies. Therefore, research efforts and investments have been geared towards development of technologies and innovations in the banana sub-sector.

1.3 Progress in the development of banana production technologies in Uganda

In a period when agricultural production is hampered by low yields, technological improvement offers potential solutions for farmers to increase productivity (World Bank, 2013). Development of improved varieties has been taken by NARO as one of the strategic interventions for increasing banana production. NARO, through the National Banana Research Programme (NBRP), has been at the helm of banana research in Uganda with the focus on development and transfer of banana technologies to farming communities. Globally, host plant resistance has been identified as the most feasible and sustainable intervention for pests and disease management for many smallholder farmers who grow the bulk of the banana crop (Ssali et al., 2010; Lorenzen et al., 2010). This prompted NBRP to conduct a banana breeding programme in 1994 aimed at generating improved varieties. A combination of approaches including

introduction and evaluation of accessions, conventional breeding, transgenic breeding and biotechnology have been exploited in breeding efforts to meet the end-users needs.

Following the outbreak of Black Sigatoka disease (*Mycosphaerella fijiensis*) and pests mainly nematodes (*Radopholus similis*) and weevils (*Cosmopolites sordidus*) in the early 1990s (Tushemereirwe et al. 1993), the NBRP introduced improved cultivars with resistance (Karamura et al., 2012). The cultivars developed at *Fundación Hondureña de Investigación Agrícola* (FHIA) in Honduras (Honduras Foundation for Agricultural Research) and hence referred to as FHIA hybrids were introduced through the International Musa Testing Program (Karamura et al., 2016). These hybrids with resistance to weevils, black sigatoka and Fusarium wilt were evaluated for several attributes and response against key pests and diseases (Nowakunda et al. 2000; Rosales, 2008). Studies indicate that the introduced FHIA hybrids did not meet the needs and preferences of end-users especially banana farmers and consumers in the lowland areas around the Lake Victoria crescent zone (Edmeades et al., 2007; NaCRRRI, 2007; Barekye, 2009; Karamura et al. 2016). This prompted the NBRP to intensify efforts towards development of new cooking banana (*matooke*) varieties with desirable attributes.

In collaboration with Consultative Group on International Agricultural Research (CGIAR) centers such as the International Institute of Tropical Agriculture (IITA), the NBRP embarked on a long term breeding programme (herein referred to as the Banana Technology Development [BTD] process) for new cooking banana varieties. Reports show that breeding efforts targeted resistance to black sigatoka and tolerance to nematodes and banana weevils that reduce yield and plantation longevity (Tushemereirwe et al., 2014; Ssali et al., 2010). Further, efforts were taken to integrate farmers' desired attributes as a strategy to enhance uptake (Barekye, 2009). The breeding efforts that started in 1994 led to new banana hybrids for food herein referred to as new Hybrid Banana Varieties (HBVs) or *matooke* hybrids. To-date, various *matooke* hybrids have been developed including; Kabana 6H (M9) and Kabana 7H (M2) that have been released and promoted for use to the farming communities (Table 1.1). The varieties are high yielding, resistant to black Sigatoka and Fusarium wilt and tolerant to weevils, nematodes and nutrient stress (Tushemereirwe et al., 2014; Nowakunda et al., 2015). These varieties targeted farmers mainly in Central Uganda

where growing of traditional cultivars had increasingly become difficult due to pests and disease pressure.

Table 1.1 Matooke hybrids released and their important attributes

Variety			Year of release	Key attributes
KABANA 'M9')	6H	(syn.	2010	• Tolerance to the banana weevils and Nematodes • Tolerant to black sigatoka • Big bunch size
KABANA 'M2')	7H	(syn.	2014	• Tolerance to the banana weevils and Nematodes • Tolerant to black sigatoka • Big bunch size • Early maturing

Source: Nowakunda et al. (2015)

1.4 Problem statement

Despite the existence of new HBVs developed with presumably farmers' desired attributes, low levels of uptake of these hybrids remain evident especially in central Uganda. Most farmers prefer to use their local cultivars with better cooking and market attributes rather than the exotics and hybrids. Reports indicate that the adoption is generally low, ranging between 5 - 15% nationally, and about 11.3% in central Uganda (Kagezi et al., 2012). The low adoption rates are indicative of failure of the new cultivars to match the end-users preferences. The scenario raises questions regarding how the processes to develop the new HBVs were implemented and the use of the agricultural innovation systems perspective to develop a holistic technology that meets the needs of the end-users. Although Akankwasa et al (2013) argue that farmers' involvement in banana varietal improvement and development is vital for meeting their preferences and could result into decisions for variety choice and potentially higher levels of use, the stage of the BTD process at which this involvement is critical is not known. Further, studies on other crops report that farmers' participation in crop variety breeding programmes is necessary for acceptance and eventual adoption (Sperling et al., 1993; Franzel, Hitimana, & Akyeampong, 1995; Ashby, 2009; Ceccarelli &

Grando, 2007). However, little is known about how this can be achieved and how the technology development process can be organised to better facilitate the uptake decision especially for a complex crop like bananas.

Previous studies on banana mainly focus on adoption factors ranging from technology attributes, farm and farmer characteristics and spatial factors (Bagamba, 2007; Katungi, 2007; Akankwasa, 2014). Doss (2006) and Knickel, Brunori, Rand, & Proost (2009) indicate that such studies lack an integrated approach that looks beyond socio-economic factors to understand the processes in technology development, dissemination and uptake. The social dynamics embedded in technological processes are still far too often overlooked in many gender and technology studies (Mayanja, Mudege & Naziri, 2016). In addition, limited empirical research exists to explain the dynamics in the BTD process in terms of (i) the processes that shape the development and uptake of new banana varieties, (ii) the nature of networks through which the new banana varieties are developed, and; (iii) determinants of uptake of new HBVs among smallholder farmers. The present study therefore adopted the Agricultural Innovation Systems (AIS) perspective to holistically examine the social dynamics in the BTD process and how they influence the uptake of the HBVs. The focus on social dynamics in the BTD process provides insights on whether and how approaches that integrate social aspects including gender in the process of banana breeding research can foster uptake.

1.5 Research objectives and questions

The overall objective of this study is to examine how social dynamics in the BTD process influence uptake of HBVs among smallholder farmers in central Uganda. The specific objectives are to:

1. Analyze the process that led to the development of new HBVs in Uganda
2. Examine the diversity of actors and their interactions in the BTD process and how these elements could influence uptake of new HBVs
3. Assess the factors that influence uptake of new HBVs among smallholder farmers in central Uganda

From these objectives, the following overarching research questions are derived that guided the different studies reported in chapters 2 to 4;

1. How do the key processes in banana technology development influence uptake of new HBVs among smallholder farmers in central Uganda?
2. How does actor diversity, linkages and interactions in the process influence the development and uptake of new HBVs?
3. To what extent do intra-household decision-making processes, institutional factors and varietal attributes influence uptake of HBVs in central Uganda?

In line with these broad questions, each chapter has its own set of specific guiding research questions and objectives.

1.6 Overview of the research methodology

This section describes the overall research approach elaborating on the scope, study area, research design and data (sources, collection and analysis). However, each of the empirical chapters provide specific details on the research methods and data analysis relevant to it.

1.6.1 Scope

The study examined the processes in technology development and its influence on uptake of new technologies. It uses the case of the new HBVs to analyze the dynamics involved in developing new banana varieties drawing on this case to analyze how these varieties were developed and how the process can explain the low uptake evident in central Uganda. Specifically, it focused on analyzing the process that led to new HBVs (objective 1), the diversity of actors and their interactions in the BTD process and how these shape the development and uptake of new HBVs (objective 2), and the factors that influence uptake of new HBVs at household level (objective 3).

1.6.2 Study area

The study was conducted in central Uganda region that covers the Lake Victoria Crescent Agro-ecological Zone (LVCAZ). Cooking banana form a major staple food crop in this region with bananas being refereed to locally as *emere*, literally to mean food. The crop is highly valued for its contribution to food security among households and high market value in the urban areas that dominate the central region. Statistics indicate that out of the 807, 000 agricultural households in the central region, 57.5% grow cooking bananas (UCA, 2010). The crop is grown on an estimated mean plot size

of 0.30 Ha which is the highest compared to all regions and the national level mean of 0.28 Ha (UCA, 2010). Most of the cooking banana plantations (64%) in the central region are largely grown in mixed stands with coffee, a practice that is considered to be more profitable and resilient production system to farmers (van Asten, Wairegi, Mukasa & Uringi, 2011). The central region is therefore characterized as a banana-coffee agro-ecosystem with banana and coffee as the main food and cash crop respectively.

The central region was chosen purposively for the study because of the drastic decline in banana yields. The region was once the main banana growing area in Uganda till the 1990s when pests and diseases became a major constraint to production of banana. The HBVs were developed by the National Banana Research Program (NBRP) of NARO to revamp banana production in the region. The first cooking hybrid banana evaluation trials were established in the region by the NBRP in 2008. Four districts namely; Nakaseke, Luwero, Wakiso and Mukono (Appendix 1) were purposively selected for this study based on their prior participation in the banana R&D activities during the development of the HBVs.

1.6.3 Research design

Research involves a quest for new knowledge conducted in scientific or systematic way. It aims to propose evidence based answers to questions implying that this process is guided by a 'research philosophy' which relates to the development of knowledge and the nature of that knowledge in relation to research. It provides an understanding of the reasons, mind and reality underpinning a systematic inquiry into a problem. The underlying philosophical underpinning to research is divided into two stances: ontological and epistemological categories. However, the ontological and epistemological issues tend to merge together, thus making it hard to keep them apart conceptually. Therefore, this study adopted a pragmatic philosophy that utilizes multiple view to best enable answering of the overarching research question. Since the study focused on a practical case, the pragmatic philosophy was useful to enable explore and integrate different perspectives with the aim of developing a technology development framework for increasing technology uptake.

A research design is a framework for the generation of evidence. Different research designs exist namely; experimental designs, cross-sectional designs, longitudinal designs, comparative designs and case study designs. From the characteristics and application of each of the designs, a case study design was selected based on the purpose and objectives of this research. The design is suitable when faced with the 'how' and 'why' questions in a study focused on a contemporary phenomenon within a real-life context (Yin 2013). It provides a holistic account of a case and in-depth knowledge of the specific case by utilizes different research methods to generate that evidence.

1.6.4 Research strategy

A research strategy is a general orientation to the conduct of research. Generally, there are three major research strategies namely: quantitative; qualitative; and mixed methods. The study used a mixed methods research (MMR) strategy employing both quantitative and qualitative methods (Creswell and Clark, 2011). MMR designs are largely classified based on timing in three ways: Concurrent, sequential or multiphase combination. This study used the exploratory sequential design (Figure 1.1) (Creswell, 2009; Creswell and Clark, 2011). According to Creswell and Clark (2011), an exploratory design begins with and prioritizes the collection and analysis of qualitative data in the first phase. Building from the exploratory results, a quantitative study is conducted in the second phase to test or generalize the initial findings. The qualitative methods were mainly used to collect data for objective 1 and 2 while the quantitative methods collected data for objective 3. Although the two studies were separate, they complemented each other in comprehensively answering the overarching research question.

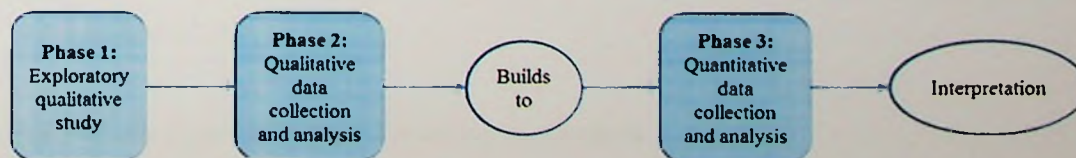


Figure 1.1 Framework for exploratory sequential mixed methods design

Source: Adapted from Creswell and Clark (2011, Pg. 69).

1.6.5 Research Methods

Research methods detail the forms of data collection, analysis and interpretation. Based on the research design and strategy adopted, both qualitative and quantitative methods were employed in this study. The different methods were useful to better understand the processes in banana technology development, but also to ensure reliability and validity through triangulation.

1.6.6 The research Process

The research was broadly carried out in three phases. Phase one of the study combined desktop review of relevant literature including project documents from the NBRP and exploratory meetings held with researchers in the banana programme. The aim was to identify the actors that were involved in the process and their contacts so as to guide phase two of the study. Phase two, was largely a quality study that aimed at a deeper in-depth understanding of the BTD process, specially the actors that were involved, their roles, interests in the process. This lead to the quantitative study in phase three that focused on uptake of new HBVs at farmer level. Data collection in phase three was implemented with help of five (5) research assistants that were selected and trained prior to the study. The study instruments were pilot tested and results of the pilot testing were used to modify the study instruments for the actual data collection.

After the data collection, data were assembled, analyzed and interpreted to guide the write up of the empirical chapters of the dissertation. Results of each empirical chapter were presented to the doctoral committee for their comments and approval. The results were also shared with some of the researcher in the banana programme for validation and also to enhance accuracy of the findings. The comments and feedback received was used to review the draft report which was later compiled as final dissertation for submission.

1.6.7 Study population and Sampling techniques

The study targeted different actors (individuals and organizations) involved in the BTD process for new HBVs including researchers from zonal, national and international research institutes, extensions agents, banana farmers, community leaders, policy agents and input suppliers among others. Pre-study exploratory visits and meetings were held with researchers to elicit information necessary for selection of study sites

and respondents. Both probability and non-probability sampling techniques were used to select study respondents (Oso & Onen, 2009).

Actors (including farmers) involved in the BTD process for new HBVs were listed in consultation with the breeders in the banana research programme of NARO. The breeders in the banana research programme of NARO also provided information about the level of involvement of different individuals from actor categories. Representatives of the different actor categories were then purposively selected based on the information about the level of involvement of different individuals obtained from the breeders in the banana programme. Preference was given to those that were most involved in the BTD process for the new HBVs.

A multi-stage sampling procedure employing both non-probability and probability sampling techniques was employed to select study sites and generate the sampling frame for objective 3. In terms of study sites, two districts of Nakaseke and Luwero were purposively selected due to their prior participation in banana research and development activities, and efforts by the NBRP to sustain banana production using the new HBVs in the two districts. In each district, one major banana growing sub-county that participated in research activities - Kasangombe and Makulubita sub-counties in Nakaseke and Luwero districts respectively was purposively selected. This was then followed by selection of only the participating parishes. Based on that procedure, Bukuuku, Bulyaake, Nakaseeta and Sakabusolo parishes were selected from Nakaseke district while Mawale parish was selected from Luwero district.

The non-probability sampling further involved purposive selection of banana farmers in each of the selected parishes. Banana farmers were purposively targeted because the study focused on HBVs and these were the farmers that were presumed to possess the information needed for the study. Therefore, with the help of community-based facilitators (CBF), names of all banana farmers in the selected parishes were compiled to generate the sampling frame with a total of 1,689 banana farmers. The total size of the sampling frame was then used to compute the sample size using Cochran (1977) and Krejcie & Morgan (1970) formula as detailed in chapter 4 of this dissertation.

1.6.8 Data collection methods and tools

To collect qualitative data used in this study, various methods including Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) were used. These methods are described below;

a. Key Informant Interviews

Key Informant Interviews (KIIs) are face-to-face in-depth interviews that aim at getting a deeper understanding of a given phenomenon by allowing for free flow of ideas and information (Parsons, 2008). Key informants were purposively selected based on their role, knowledge and experiences in the BTB process. Information about the key informants' roles and knowledge was obtained from breeders in the BTB process and other actors interviewed. Face-to-face interviews were conducted with key informants that included researchers, extension agents, community leaders, banana farmers, private tissue culture laboratory operators/entrepreneurs, and policy makers. These interactive sessions were guided by a KII guide to elicit information on the stages, actors, activities, roles and responsibilities, linkages, interactions, knowledge sharing, communication strategies, drivers of the research process and the weakest link in the process. The guide (Appendix 2) was organized in form of research topics which provided space for probing and prompting respondents thereby yielding detailed and in-depth data.

b. Focus Group Discussions

Focus Group Discussion (FGD) is a useful method in exploring and examining peoples' opinions and experiences about a given phenomenon, topic or issue (Krueger, 1994; 2002). An FGD is defined as "a group of people informally 'interviewed' in a discussion setting (Krueger, 2002). FGDs were conducted with Banana Farmer Research Groups (BFRGs) that were purposively selected. The size of the FGD ranged from seven to nine participants with an average of eight participants. This number of participants was based on recommendations in literature (Amin, 2005). Furthermore, this number of FGD participants was considered to be large enough to obtain a variety of perspectives in the time available. On average, each FGD took 2 hours to obtain information on farmers' opinions about and level of involvement in the BTB process. The FGDs also captured community views about level, experiences and drivers of uptake of new HBVs. In order to capture this information from the FGDs, a written

guide (Appendix 3) developed based on the objectives of the study and was used to facilitate and guide the discussions. The discussions were held in a conversation style where the researcher acted as the moderator and adopted a probing approach to clarify issues and get participants consensus.

c. Survey

This study used a cross-sectional survey that aimed to collect standardized quantitative data. A semi-structured questionnaire, with both open-ended and close-ended questions, (Appendix 4) was developed and pilot tested before actual data collection. A panel of five experts checked the study instruments for content validity. Prior to quantitative data collection, a pilot study was conducted to pre-test the survey instrument for reliability. The questionnaire was piloted with a total of 12 farmers. The purpose of pilot testing the tool was to check for consistency, sequence and follow of the questions. The pilot testing also aimed to establish the duration each interview would take and if this was acceptable. The information generated from the pilot testing was used to refine the final questionnaire before the actual survey. Adjustments were made for clarity and sequencing of questions. The pilot study was preceded by a two days intensive training for five research assistants that were involved in data collection. The survey targeted banana farmers at household level irrespective of their involvement in banana research activities. One-on-one interviews were conducted with a randomly selected sample of banana farmers. The survey was administered with the help of research assistants were recruited and trained. The interview collected data household socio-economic and demographic characteristics, banana production, yield and decision making for uptake of new HBVs. The survey interviews were supplemented with direct observation of artifacts in the natural social setting especially on the type of varieties grown and the acreage.

The primary data sources were complemented with secondary data sources including various documents such as project reports and publications, monitoring and evaluation reports; project datasets collected during on-farm trials; and national statistics from UBOS and FAO. Qualitative data were collected between November 2014 and December 2015 while the household survey was conducted in February 2016. Table 1.2 presents a summary of the primary data collection methods, tools used and type of data collected using each method.

Table 1.2 Overview of data collection methods and tools

Method	Tool	Number	Sampling strategy	Data collected
Key informants and in-depth interviews	Interview guide (Appendix 2)	20 Key informants comprised of different actors along the BTD process	Purposive	• Views on the organization of the BTD process; approach used, actors and their roles, linkages, and interactions. • Extent of gender-responsiveness of the BTD process. • Opinions and perceptions on the different dimensions of uptake, particularly acceptance and use of new HBVs • The weakest link in the BTD process and existing gaps that need to be strengthened and how this can be achieved.
Focus group discussion (FGD) with Banana farmers	FGD guide (Appendix 3)	5 FGDs (39 farmers in total)	Purposive	• Focused on exploring farmers' involvement and roles in the BTD process; – <i>Stages at which farmers are involved</i> – <i>Extent of their involvement</i> – <i>Interactions with other actors</i> – <i>Feedback and information sharing</i> • Data on barriers, constraints and motivating factors to uptake of HBVs • Farmer perceptions about HBVs • Gender issues related to uptake of HBVs
Household survey	Semi-structured Questionnaire (Appendix 4)	242 Households	Random	• Individual and household demographic and socio-economic characteristics • Farm characteristics • Institutional factors such as membership to groups, access to information and extension services • Varietal and trait/attribute preferences • Level of involvement in household decision-making for uptake of the new HBVs

Key informant and in-depth interviews were conducted face-to-face with the purposively selected actors in the banana research process. FGDs were held in a conversational style with banana farmer research groups consisting of 7-9 farmers. The FGDs were moderated by the researcher to ensure that each participant was given a chance to express their views while a rapporteur recorded notes to make sure that all participants' views were captured. A digital voice recorder was also used to back up the field note diaries (handwritten notes). A cross-sectional descriptive household survey was conducted to collect data from individual banana farmers in two districts of Nakaseke and Luwero.

1.6.10 Data Analysis

Qualitative data collected using a digital recorder were transcribed verbatim using express scribe transcription software (Ver 5.78). Where the local dialect (*Luganda*) was used during the interview, it was translated into English and transcribed for analysis. The transcripts were then imported into the QSR International NVivo software (Version 10.0) for thematic coding and analysis. NVivo qualitative data analysis package was preferred to other software packages because of its flexibility in coding the data. The analysis broadly followed a qualitative process focusing on content, thematic and interpretational analysis of the text or narrative data transcribed (Schutt, 2011; Merriam, 2009). Both deductive and inductive thematic analysis approaches were used in the coding of the data. Using an inductive approach, *open codes* were assigned to the individual narratives then grouped into *categories* which later constituted *themes* to guide presentation of results and discussions. Network analysis was done using UCINET6 6.584 and Network visualizer (*NetDraw 2.153*) was used to visualize the interactions in the BTD process.

Quantitative data were generally analyzed using STATA, Version 14 to generate descriptive and inferential statistics. Frequencies, percentages and means were generated. The t-test static and chi-square were used to determine the differences for continuous and discrete variables respectively. A double hurdle model was also estimated to determine the factors that influence adoption and intensity of adoption of the new HBVs at farmer level. While details of data analysis for each objective is

presented in the respective empirical chapters, Table 1.3 presents a summary of type of analysis by objectives.

Table 1.3 Summary of data analysis methods and tools

Objective	Type of data	Methods and tools	Output
1. Analysis of the BTD process for new HBVs	Qualitative data (KIIs & FGDs)	Thematic-content analysis using NVIVO software (Ver. 10)	- Emerging themes - Narrative and verbatim explanations
2. Examining diversity of actors and their interactions in the BTD process	Qualitative & Quantitative data (KIIs)	- Thematic-content analysis - Network visualizer (<i>NetDraw 2.153</i>) - Network analysis (UCINET6 6.584)	- Emerging themes - Network maps - Centrality measures (network degree, closeness and betweenness)
3. Assessing the factors that influence uptake of new HBVs	Quantitative data (Survey)	- Analyzed using STATA ver. 14 to descriptive and inferential statistics - Regressions analysis	- Frequencies, means, Chi-square and T-statistics - Double-hurdle model results for factors associated with use and intensity

1.7 Significance of the study

Banana is an important crop in central Uganda and beyond though its production is threatened by various constraints. Low uptake of new cultivars that have been developed impacts negatively on livelihoods. A number of socio-economic factors have been reported to influence the choice decisions but no evidence on the effect of social dynamics in banana technology development process exists. The study addressed the existing knowledge gap on how uptake of technological innovations can be improved. If such dynamics that affect uptake are not addressed, productivity will continue to decline in major banana production systems that are inherently characterized by various constraints. Low productivity will result into limited food and income from sale of banana that will culminate into hunger and poverty. This will grossly deteriorate living conditions of millions of smallholder farmers in banana production systems that depend on the crop for survival. Further, this study analyzed the banana technology development trajectory to elucidate the actors, their roles and interactions from a

systems perspective. It identifies implications for practice and policy as relevant strategies for increasing technology uptake which will in a way foster the role of science and technology in agriculture and rural development. The results of this study will guide current and future BTD process which is expected to result into increased uptake of new banana technologies as a key factor for sustainably increasing agricultural productivity and ultimately contributing to food and income security. This is vital for realization of the role of science in agricultural transformation as stipulated in Vision 2040 and reinforced in the Science Agenda for Agriculture in Africa (S3A).

1.8 Theoretical and conceptual framework

The study aimed at establishing the relationship between the social dynamics in BTD process and uptake of new HBVs. It was anchored in the Innovation Systems Theory (IST) and particularly the AIS framework in exploring this relationship.

Plant breeding (*also referred to as Technology Development (TD) in this study*) is a multi-stage process that involves different interlinked stages. Each stage of the process feeds into the next, and each cycle feeds into the next (Ceccarelli, 2009). Literature on crop improvement indicates that a typical plant breeding program involves five (5) stages (Figure 1.1). In this study, it was hypothesized that the way this process is organized influences uptake of the resultant technologies. Typically, a breeding process starts with setting breeding priorities through the technical breeding until release and dissemination of HBVs (Figure 1.2).

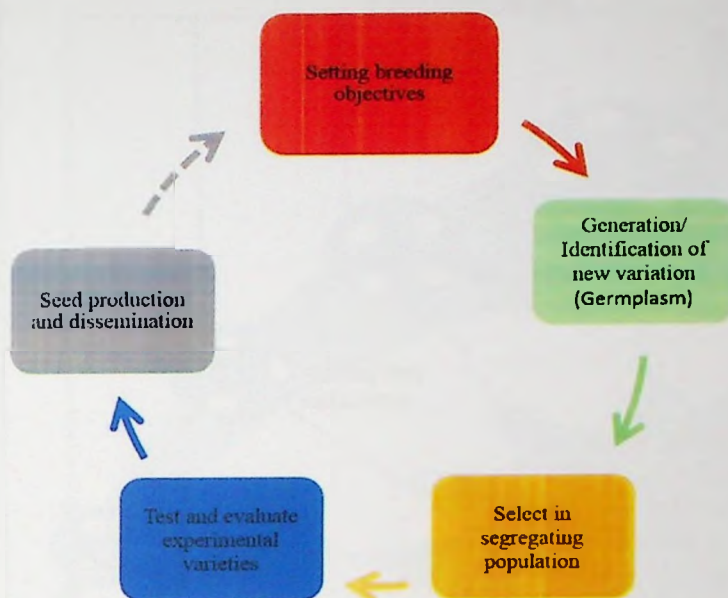


Figure 1.2 Main stages of a plant breeding program

Source: Adapted from Weltzien et al 2003

From the IST, particularly the AIS, different actors are expected to be involved at the different stages (Figure 1.3). Choice of actors, whether individual or organizations, to be involved in a breeding process could be influenced by their role and interests. The roles and interest in turn may determine the level at which they interact and or exchange knowledge and other resources for efficiency and effectiveness of the whole innovation process. This implies that positions and contributions of different actors are crucial in directing the process. Consequently, the extent and level of their involvement determine the ultimate outcome of the process. Therefore, the AIS provides an apt framework for analyzing the dynamics at each stage especially as diverse actors with different interests come on board and engage in the process. Issues of whose voice is heard and whose interests are served in the breeding process then arise. Consequently, this may result into power relations which influence and shape existing linkages, interactions and flow of information and resources in process of developing new technologies.

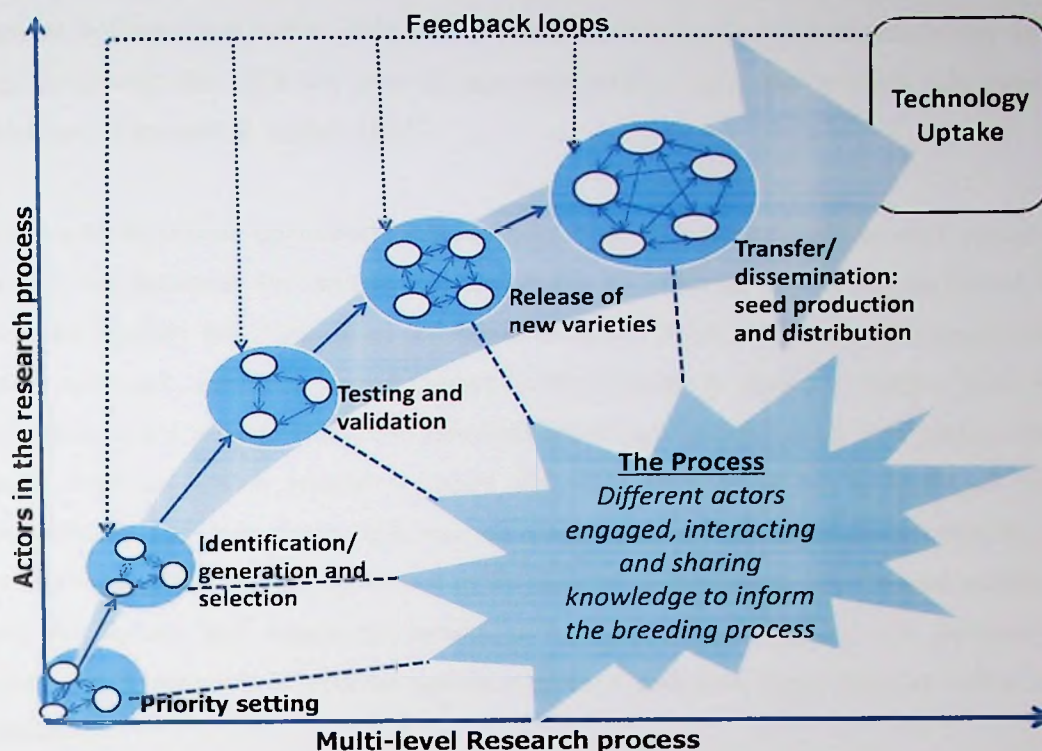


Figure 1.3 Multi-level Technology Development Process

Other studies have shown that engaging a variety of actors in an innovation process promotes interaction, knowledge exchange and learning that enhance innovation capacity and output (Hall, Janssen, Pehu & Rajalahti, 2006; Spielman, Ekboir & Davis, 2009; Kibwika, 2006). Douthwaite (2001) found that successful and sustainable innovations (typified by new HBVs in this study) are invariably those developed in a system that can be characterized as a ‘bazaar approach’ in which all actors interact and are involved as equal partners. It is therefore expected that a breeding process that engages diverse actors and takes into account their ideas and contributions would generate relevant and appropriate technologies that address the needs of the end users while benefiting all actors. While the importance of linkages between actors, coalitions, alliances and flow of information for successful innovation is stressed, these aspects are often not addressed systematically and explicitly in technology development. Most innovation processes are still characterized by weak linkages and interaction between actors. This may result in development of technologies that do not meet end-users’ needs thus affecting uptake (Biggs & Matsuert, 2004; Tenywa *et al.*, 2011; Odame, Kimenyi, Kabutha, Alemu & Oduori, 2013). Further, less attention has been given to

gender differentiated trait preferences in development of new varieties which may limit uptake among the different user groups particularly, men and women (Christinck, Weltzien, Rattunde & Ashby, 2017).

Uptake of improved agricultural technologies, innovations and management practices remain fundamental for transformation of the agricultural sector as reinforced in Science Agenda for Agriculture in Africa (FARA, 2014). Beyond the influence of socio-economic, institutional and market factors, this study aimed to analyze how the dynamics in the process shape the development of new varieties and their uptake. The study explored issues related to actor diversity, their level of involvement and interactions, and how these influence development and uptake of new varieties. It further explored the gender dynamics in the process of developing new banana varieties and the factors that determine uptake at household level. Figure 1.4 presents a schematic framework of various variables studied and how they relate to influence uptake.

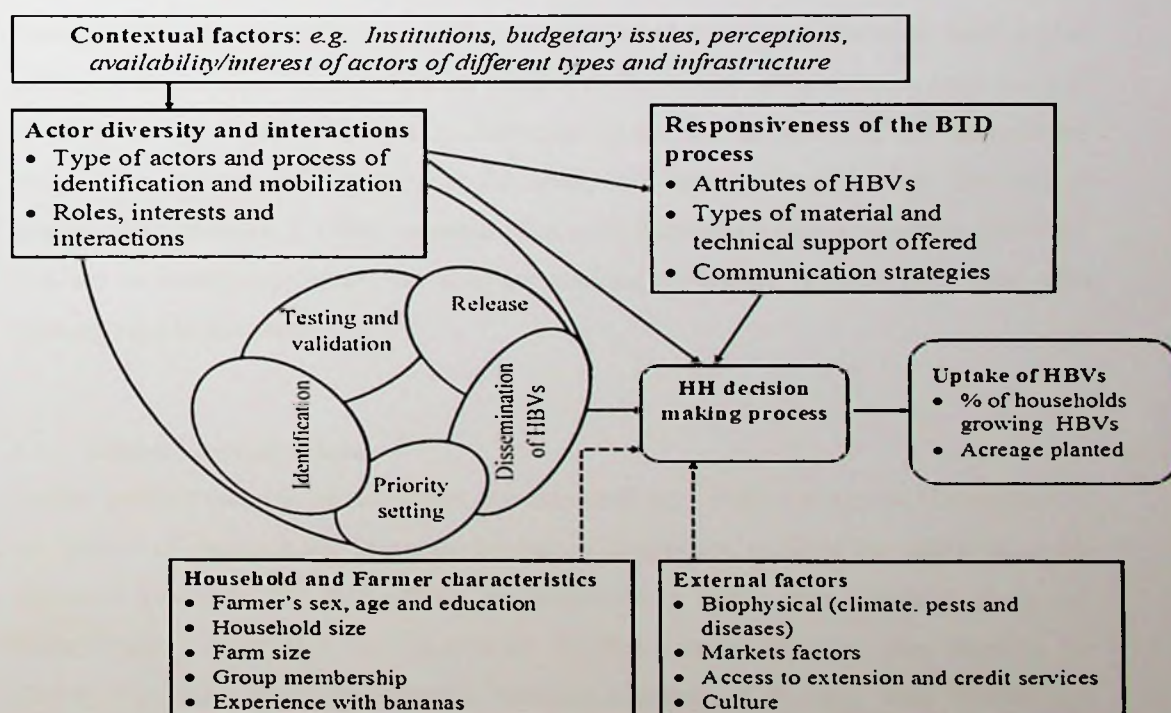


Figure 1.4 Conceptualization of the relationship between the social dynamics in BTD process and uptake of new hybrid banana varieties

Figure 1.4 shows that technology development is multi-staged and continuous process that starts with priority setting through breeding until release and dissemination of HBVs (Objective 1). At each of the stages of the BTB process, there are different actors whose diversity and interactions are dependent on a myriad of contextual factors (Objective 2). Perceptions of actors towards the lead agency could affect their level of involvement and roles in research process as well as availability and interest in the different activities. The process of identification and mobilization of actors may also influence how they engage in the process. Actor interactions that take place could potentially influence responsiveness of the BTB process to gender and market factors that are crucial to uptake of the output (HBVs). The gender and market responsiveness of the BTB is assessed by looking at the characteristics of the HBVs and to what extent they meet the end-user's expectations, needs and preferences. Therefore, the extent to which the BTB process is responsive to the dynamics related to actors' needs, preferences and interests influences decision-making about uptake of HBVs. Beyond the responsiveness of the BTB process and the HBVs, there are socio-economic, demographic characteristics as well as institutional and organizational factors that influence decisions at household level (objective 3). Actors in the process form the unit of analysis for objective 1 and 2. However, since use of most of the agricultural technologies occurs at farm household level, the banana farmers form the unit of analysis for objective 3. Other variables like actor perception and technology pathways that act as mediating factors for decision-making to uptake of new HBVs are also incorporated in the study.

1.9 Ethical consideration

Before commencement of the study, the Research and Higher Degrees Committee of the School of Agricultural Sciences, Makerere University, granted the approval to the proposed research. To this effect, an introductory letter was obtained from the Department of Extension and Innovation Studies (Appendix 5). I then applied for ethical clearance from the Uganda National Council of Science and Technology (UNCST). UNCST granted the ethical approval (A 504), clearance and permission to collect data from the four districts; Nakaseke, Luwero, Wakiso and Mukono (Appendix 6).

During data collection, permission was sought from the relevant District and sub-county local council leaders prior to conducting the focus group discussions and interviews in communities. In addition, voluntary informed consent was obtained from all respondents who participated in the study. Consent to capture field notes, photographs and audio recording (where applicable) was sought from the participants. A consent form (Appendix 7) detailing purpose, procedures, benefits, sharing and use of data, duration of the interview and or FGD and confidentiality was read out to each participant and their consent sought before signing the informed consent form. FGDs participants voluntarily consented to participate orally and in writing. All key informants, FGD participants and individual farmers interviewed gave a written consent to participate. Finally, during reporting and publication, the interviews were anonymized to ensure privacy and confidentiality of the interviewees.

1.10 Organization of the dissertation

Figure 1.5 provides an overview of the organization of the chapters. Chapter 1 gives a general introduction to the study highlighting the background of the study, statement of the problem, objectives, general research design and strategy, theoretical and conceptual framework as well as the significance of the study. Chapters 2-4 present the empirical findings for the study objectives and these are structured using the manuscript format.

Chapter 2 provides an analysis of the process that led to the development of the new HBVs while highlighting the level of gender integration in the process. The level of actor involvement at the different stages of the process and how this offers an explanation for the observed level of uptake of new HBVs in central Uganda is examined. The chapter uses the innovation systems functional framework to analyze the process. Chapter 3 empirically analyses the nature of actor networks through which the new HBVs were developed, particularly focusing on the diversity of actors, their roles and interactions, and how these informed the development of new HBVs. It further investigates the flow of information and tangible resources among actors in the BTD process. It highlights the issues of power and influence in the decision-making process, articulating the categories of actors who have influence over the process and those who do not have influence to enact their interests. Contextual factors which guide

decisions are also analyzed. The Actor Network Theory (ANT) and Social Network Theory (SNT) are applied to aid understanding of the nature of actor networks in which the new HBVs were developed and the existing relationships and how these influence the uptake. Chapter 4 investigates the determinants of uptake of new HBVs among smallholder banana farmers in Uganda. It further analyses the intra-household decision making processes for uptake of new HBVs using the Double-hurdle model. Finally, Chapter 5 summarizes the key empirical findings, conclusions and implications. It also presents recommendations for practice and policy as well as areas for further research.

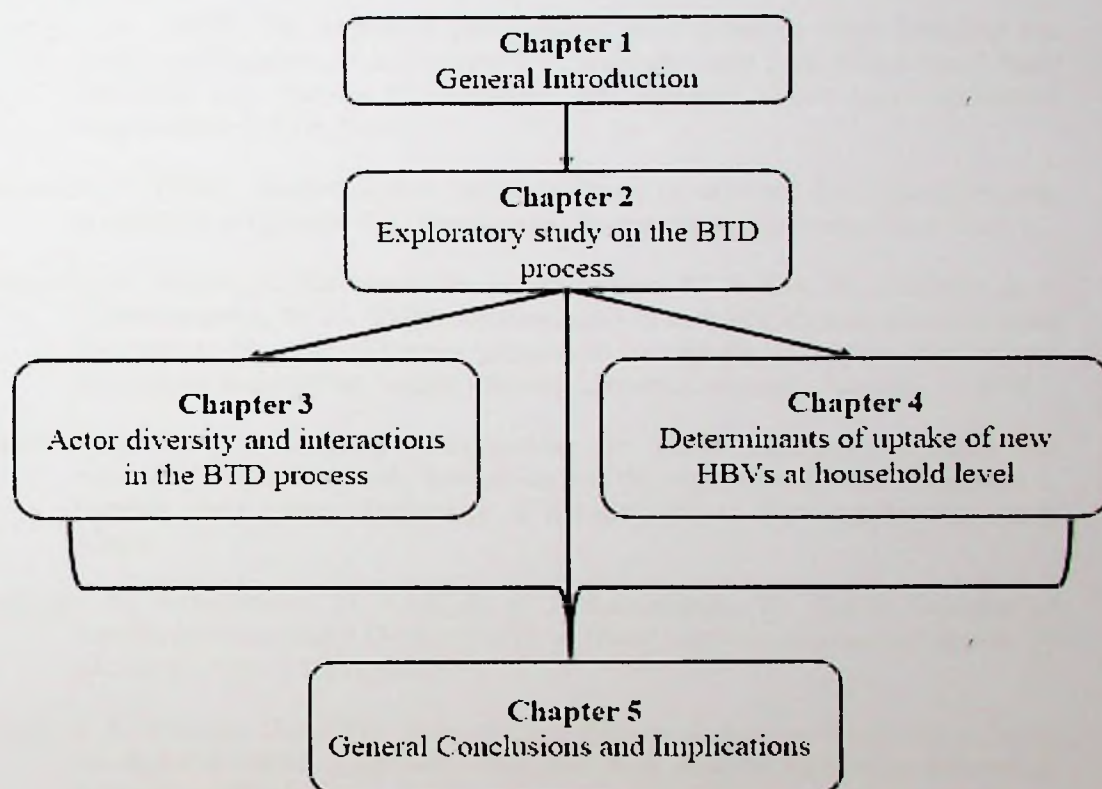


Figure 1.5 Overview of the Organization of the Dissertation

References

- Akankwasa, K., Ortmann, G., Wale, E. & Tushemereirwe, W. (2013). Farmers' choice among recently developed hybrid banana varieties in Uganda: A multinomial logit analysis. *Agrekon*, 52(2), 25-51.
- Akankwasa, K. (2014). Evaluating farmers' and consumers' acceptance of new cooking banana hybrids in Uganda: Micro-economic analysis and policy implications. PhD Dissertation, University of KwaZulu-Natal, Pietermaritzburg, South Africa.
- Amin, M. E. (2005). *Social Science Research: Conception, Methodology and Analysis*: Makerere University, Kampala Uganda.
- Ashby, J. A. (2009). The impact of participatory plant breeding: Plant breeding and farmer participation, in S. Ceccarelli, E. Guimares, and E. Weltzien (eds.) *Plant Breeding and Farmer Participation*, pp. 649-671. Food and Agriculture Organization (FAO), Rome.
- Bagamba, F. (2007). Market access and agricultural production: The case of banana production in Uganda. PhD Dissertation, Wageningen University, Netherlands.
- Bagamba, F., Ruben, R., Kuyvenhoven, A., Kalyebara, R., Rufino, M., Kikulwe, E. & Tushemereirwe, W. K. (2004). Determinants of resource allocation in low input agriculture: the case of banana production in Uganda. American Agricultural Economics Association Annual Meeting, Denver, Colorado, August 1-4, 2004
- Barekye, A. (2009). Breeding investigations for black Sigatoka resistance and associated traits in diploids, tetraploids and the triploid progenies of bananas in Uganda. PhD Thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa.
- Barekye, A., Ruberintwari, H., Ssali, R. & Tushemereirwe, W. (2012). Selection of Banana Hybrids Based On Resistance to Black Sigatoka Disease in Uganda. *E. Afr. agric. For. J.*, 78(1), 84-88.
- Biggs, S. & Matsuert, H. (2004). Strengthening Poverty Reduction Programmes Using An Actor Oriented Approach: Examples from Natural Resources Innovation Systems. *AgREN Network Paper* No. 134. London: Overseas Development Institute.
- Ceccarelli, S. (2009). Main stages of a plant breeding programme. In S. Ceccarelli, E. Guimares, and E. Weltzien (eds.) *Plant Breeding and Farmer Participation*, pp. 63-74. Food and Agriculture Organization (FAO), Rome.
- Ceccarelli, S., & Grando, S. (2007). Decentralized-participatory plant breeding: an example of demand driven research. *Euphytica* 155 (3): 349-360.

- Christinck, A.; Weltzien, E.; Rattunde, F.; Ashby, J. (2017). Gender Differentiation of Farmer Preferences for Varietal Traits in Crop Improvement: Evidence and Issues. Working Paper No. 2. CGIAR Gender and Agriculture Research Network; CGIAR System Management Office and International Center for Tropical Agriculture (CIAT). Cali, Colombia. 38 p.
- Creswell, J. W. & Clark, V. L. P. (2011). *Designing and Conducting Mixed Methods Research*. Thousand Oaks, CA: Sage Publications, Inc.
- Doss, C. R. (2006). Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. *Agricultural Economics*, 34, 207-219. <http://dx.doi.org/10.1111/j.1574-0864.2006.00119.x>
- Douthwaite, B., Keatinge, J. D. H. & Park, J. R. (2001). Why promising technologies fail: The neglected role of user innovation during adoption. *Research Policy*, 30, 819-836.
- Edmeades, S. Smale, M., Kikulwe, E.M., Nkuba, J.M. & Byabachwezi, M.S.R. (2007). Characteristics of banana-growing households and banana cultivars in Uganda and Tanzania. In: Smale M. and Tushemereirwe, W. K. (eds). An economic assessment of banana genetic improvement and innovation in the Lake Victoria Region of Uganda and Tanzania. Research Report No. 155, 49-74. IFPRI, Washington, D.C.
- Eledu, C. A., Karamura, E. B. & Tushemereirwe, W. (2004). Agroecological distribution of banana systems in the Great Lakes region. *African Crop Science Journal* 12: 33-42.
- FARA. (2014). Science Agenda for Agriculture in Africa, "Connecting Science" to transform agriculture in Africa. Forum for Agricultural Research in Africa (FARA), Accra, Ghana
- Franzel, S., Hitimana, L. & Akyeampong, E. (1995). Farmer participation in on-station tree species selection for agroforestry: a case study from Burundi. *Experimental Agriculture* 31, 27-38.
- Gold, C. S., Karamura, E. B., Kiggundu, K., Bagamba, F. & Abera, A. M. (1999). Geographic shifts in the highland cooking banana (*Musa* spp., group AAA-EA) production in Uganda. *International Journal of Sustainable Development and World Ecology*, 6(1), 45-59.
- Gold, C.S., Speijer, P. R., Karamura, E. B., Tushemereirwe, W. K. & Kashaija, I.N. (1994). Survey of the banana weevil and nematode damage assessment in Uganda. *African Crop Science Journal*, 2:309-321.
- Hall, A., Janssen, W., Pehu, E. & Rajalahti, R. (2006). *Enhancing agricultural innovation: How to go beyond the strengthening of research systems*. World Bank, Washington.

- IFAD. (2013). Enabling poor rural people to overcome poverty in Uganda. <http://www.ifad.org/operations/projects/regions/Pf/factsheets/uganda.pdf> [Online]. [Accessed 1/10/2014].
- IITA. (2009). Banana & Plantain. <http://www.iita.org/bananaand-plantain>.
- Kabahenda, M. & Kapiro, M. (2010). Analysing the agricultural science and technology innovation systems: a case study of the banana sub-sector in Uganda. In *Second RUFORUM Biennial Regional Conference on "Building capacity for food security in Africa"*, Entebbe, Uganda, 20-24 September 2010. (pp. 1691-1697). RUFORUM.
- Kagezi, G., Mpiira, S., Jogo, W., Karamura, E., Gotor, E., Garming, H. & Johnson, V. (2012). Adoption of New Banana Cultivars in Uganda. A Report for the DIVA Project (Unpublished report).
- Karamura, E., Frison, E., Karamura, D. & Sharrock, S. (1998). Banana production systems in Eastern and Southern Africa. In International Symposium on Bananas and Food Security. Picq, C., Foure, E. and Frison, E. A. (eds.), Cameroon, pp. 401-412.
- Katungi, E. M. (2007). Social Capital and Technology Adoption on Small Farms: The Case of Banana Production Technology in Uganda, PhD Dissertation, University of Pretoria, South Africa.
- Kibwika, P. (2006). Learning to Make Change: Developing Innovation Competence for Recreating the African University of the 21st Century. In: Richards P (ed), 1st ed. Wageningen: University of Wageningen.
- Kikulwe, E. M., Wesseler J. & Falck-Zepeda, J. (2011). Attitudes, perceptions, and trust. Insights from a consumer survey regarding genetically modified banana in Uganda. *Appetite*, 57(2), 401-413.
- Knickel, K., Brunori, G. Rand, S. & Proost, J. (2009). Towards a better conceptual framework for innovation processes in agriculture and rural development: from linear models to systemic approaches. *Journal of Agricultural Education and Extension*, 15(2): 131-146. doi:10.1080/13892240902909064.
- Krueger, R. A. (1994). Focus groups: A practical guide for applied research. Thousand Oaks, CA: Sage.
- Krueger, R.A. (2002). Designing and conducting focus group interviews. Retrieved 21 August 2014 from <http://www.eiu.edu/~ihed/Krueger-FocusGroupInterviews.pdf>
- Kubiriba, J., Tushemereirwe, W. K., Kenyon, L. & Chancellor, T. C. B. (2013). Field spread of banana streak virus (BSV). *African Journal of Agricultural Research*, 8(18), 1881-1890.
- Lorenzen, J., Tenkouano, A., Bandyopadhyay, R., Vroh, B., Coyne, D. & Tripathi, L. (2010). Overview of banana and plantain (*Musa* spp.) improvement in Africa: Past and future. *Acta Horticulturae*, 879: 595-603.

- MAAIF (Ministry of Agriculture, Animal Industry and Fisheries). (2010). *Agriculture for Food and Income Security. Agricultural Sector Development Strategy & Investment Plan: 2010/11 - 2014/15*. MAAIF, Kampala Uganda.
- Mayanja, S., Mudege, N. N. & Naziri, D. (2016). Gender Situational Analysis of the Banana Value Chain in Western Uganda and Strategies for Gender Equity in Postharvest Innovations. RTB-ENDURE Technical report <http://www.rtb.cgiar.org/endure/>
- Krejcie, R. V. & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement*, 30 (3), 607-610.
- Cochran, W. G. (1977). *Sampling techniques* (3rd Edition). New York: John Wiley & Sons.
- Mugisha, J. & Ngambeki, D. S. (1994). Marketing system of the Uganda banana industry. *African Crop Science Conference Proceedings* 1, 384-387.
- NaCRRRI (National Crop Resources Research Institute). (2007). Multiplication and promotion of black Sigatoka resistant banana genotypes in Uganda. Report submitted to ProGRA, 1 July 2007. NARO, Entebbe, Uganda.
- NARO (National Agricultural Research Organisation). (2011). Technology Compendium, September 2011. NARO, Entebbe Uganda.
- NARO (National Agricultural Research Organization). (2008). Ten-Year Strategic Plan 2008-2018 *Towards improved Agricultural Research Services Delivery NARO Medium Term Plan 2008/9 – 2014/15*. NARO, Entebbe, Uganda.
- NARO (National Agricultural Research Organization). (2012). The Impact of Agricultural Research in Uganda, 50years of Independence. in press: National Agricultural Research Organization.
- Nowakunda, K., Barekye, A., Ssali, R. T., Namaganda, J., Tushemereirwe, W. K., Nabulya, G., Erima, R. G., Akankwasa, K., Hilman, E., Batte, M. & Karamura, D. (2015). 'Kiwangaazi'(syn 'KABANA 6H') Black Sigatoka Nematode and Banana Weevil Tolerant 'Matooke'Hybrid Banana Released in Uganda. *HortScience*, 50(4), 621-623.
- Odame, H., Kimenye, L., Kabutha, C., Alemu, D. & Oduori, L. H. (2013) *Why the low adoption of agricultural technologies in Eastern and Central Africa?*. ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa). Entebbe, Uganda.
- Okyere, K. & Jemanah, S. (2012). Increasing Agricultural Productivity & Enhancing Food Security in Africa: New Challenges & Opportunities. Synopsis Of An International Conference. International Food Policy Research Institute, Washington, DC.
- Oso, W.Y. & Onen, D. (2009). *A general guide to writing research proposal and report*. Nairobi: The Jomo Kenyatta Foundation.

- Shively, G. & Hao, J. (2012). A Review of Agriculture, Food Security and Human Nutrition Issues in Uganda. Purdue University, West Lafayette, IN.
- Smale, M. (2007). Assessing the impact of technical innovations in African agriculture. In a. W. K. T. M. Smale (Ed.), *An economic assessment of banana genetic improvement and innovation in the Lake Victoria region of Uganda and Tanzania* (pp. 3-11). Washington, DC: International Food Policy Research Institute.
- Smale, M. & Tushemereirwe, W. (Eds.). (2007). *An economic assessment of banana genetic improvement and innovation in the Lake Victoria region of Uganda and Tanzania*. Research Report No. 155. International Food Policy Research Institute, Washington, D.C.
- Sperling, L., Loevinsohn, M. E. & Ntabomvura, B. (1993). Rethinking the farmer's role in plant breeding: Local bean experts and on-station selection in Rwanda. *Experimental Agriculture*, 29 (04), 509-519.
- Spielman, D. J., Ekboir, J. & Davis, K. (2009). The art and science of innovation systems inquiry: applications to Sub-Saharan African agriculture. *Technology in society*, 31(4), 399-405.
- Ssali, R., Nowankunda, K., Barekye, A. Erima, R., Batte, M. & Tushemereirwe, W. (2010). On farm participatory evaluation of East African highland bananas 'EAHB' hybrids (Musaspp). *Acta Hort.*, 879: 585-591.
- Tenywa, M.M., Rao, K., Tukahirwa, J. B., Buruchara, R. Adekunle, A., Mugabe, J., Wanjiku, C., Mutabazi, S., Fungo, B., Kashaija, N. I., Pali, P., Mapatano, S., Ngaboyisonga, C., Farrow, A., Njuki, J. & Abenakyo A. (2011). Agricultural Innovation platform as a Tool for Development Oriented Research: Lessons and Challenges in the Formation and Operationalization. *Learning Publics Journal of Agriculture and Environmental Studies*, 2(1), 117-146.
- Tushemereirwe, W., Kashaija, I., Tinzaara, W., Nankinga, C. & New, S. (2003). Banana production manual. 2nd edition. National Agricultural Research Organization. Fountain Publishers, Kampala, Uganda.
- Tushemereirwe, W., Tumuhimbise, R., Kubiriba, J., Batte, M., Barekye, A., Lorenzen, J., Nyine, M., Ssali, T.R. & Swennen, R. (2014). Performance of NARITA Banana Hybrids in the Preliminary Yield Trial, Project Report. Kampala, Uganda.
- Tushemereirwe, W., Gold, W., Speijer, P., & Holderness, M. (1993). Foliar diseases of banana in Uganda: results from a diagnostic survey. *African Crop Science Journal*, 1(2).
- UBOS (Uganda Bureau of Statistics). (2013). Statistical Abstract, 2013. *Kampala: UBOS*.

- UCA. (2010). Summary Report on Uganda Census of Agriculture 2008/2009. Accessed 01/8/2015 at <http://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/UCASummary.pdf>
- Uganda Bureau of Statistics, U. (2010). Abridged Report. Government report, UBOS, Statistics House, Kampala Uganda.
- UNDP (United Nations Development Programme). (2012). Africa Human Development Report 2012. *Towards a Food Secure Future*. United Nations Publications.
- van Asten, P.J.A., Gold, C.S., Wendt, J., De Waele, D., Okech, S.H.O., Ssali, H. & Tushemereirwe, W.K. (2005). The contribution of soil quality to yield and its relation with other banana yield loss factors in Uganda. In: Blomme, G., Gold, C.S. and Karamura, E. (Eds.). *Proceedings of a Workshop Held on Farmer Participatory Testing of IPM Options for Sustainable Banana Production in Eastern Africa*, Seeta, Uganda, December 8–9, 2003, International Plant Genetic Resources Institute, Montpellier. pp 100–115.
- van Asten, P. J. A., Wairegi, L. W. I., Mukasa, D. & Uringi, N. O. (2011). Agronomic and economic benefits of coffee–banana intercropping in Uganda’s smallholder farming systems. *Agricultural Systems*, 104 (4), 326-334.
- World Bank. (2008). World Development Report 2008: *Agriculture for Development*. World Bank, Washington, DC.
- World Bank. (2011). Development Indicators. Working paper, The World Bank.
- World Bank. (2013). *Agriculture for Development. World development report 2013*, The World Bank, Washington DC.

CHAPTER 2: COMPLEXITY OF AGRICULTURAL TECHNOLOGY DEVELOPMENT: IMPLICATIONS OF PROCESSES AND ACTOR ROLES FOR UPTAKE OF NEW HYBRID BANANA VARIETIES IN CENTRAL UGANDA¹

Abstract

Low uptake of improved technologies remains a challenge to enhancing agricultural productivity and food security in developing countries. The study reported on in this chapter uses the agricultural innovations systems approach to analyse how the recently released hybrid banana varieties (HBVs) were developed, and how the interplay between processes and actors affect their uptake in central Uganda. The study used a qualitative case study approach. Data were collected through 20 key informant interviews and 5 focus group discussions with purposively selected actors, and analysed using thematic-content analysis in NVivo. Results indicate that the process of developing HBVs is dominated by agricultural research institutions with limited involvement of other actors such as farmers, private sector and extension staff. Further, there is limited integration of social aspects including gender in the banana technology development process. From the results, it is recommended that inclusive participatory approaches in breeding of HBVs are used, as well as paying attention to intrinsic, socio-cultural and gender-specific attributes such as food colour, texture, flavour and taste since these are critical for uptake of the new varieties.

Key words Technology development; Innovation system; new hybrid banana varieties; Technology uptake; Uganda

¹ Manuscript accepted for publication by *Cogent Food & Agriculture*.

2.1 Introduction

The rapidly increasing population in Africa, amidst declining agricultural productivity, poses complex global challenges associated with poverty and food security (Food and Agriculture Organisation of the United Nations [FAO], 2015; AGRA, 2017). The projected rapid population growth in Africa will be the leading cause of food insecurity due to increased food demand (Hall, Dawson, Macdiarmid, Matthews, & Smith, 2017). Thus, agricultural research systems, as one of the key actors in enhancing food security, need to reorganise in an efficient and sustainable manner to address the food-related challenges. Many actors expect agricultural technologies to address the constraints associated with low productivity as well as contribute to narrowing of the food gap and overall agricultural development (USAID, 2011; Beintema & Stads, 2014). Therefore, acceleration of the rate of technological change is expected to propel the sustainable intensification of production systems (Godfray et al., 2010; World Bank, 2007). To this end, several national agricultural research systems in Sub-Saharan Africa have generated technologies with a potential to enhance agricultural productivity. However, the uptake of these technologies, particularly improved crop technologies, is disappointingly low (AGRA, 2013; World Bank, 2008). To achieve increases in productivity, agricultural research systems need to embrace innovative strategies and approaches in technology development. Systemic approaches and, specifically, the use of the Innovation Systems Approach (ISA), have been recently embraced in technological innovation processes (Hall et al., 2001; Klerkx & Leeuwis, 2009; Van Mierlo et al., 2010).

Adoption of the ISA resulted from failure of the linear approaches that viewed knowledge development and application as separate activities carried out by researchers and farmers respectively. Researchers were considered as specialists or “knowers” of what was good and who developed technologies that were “perceived” to address the needs of the end-users. Described as a one-way pipeline, from researcher to extension to farmer (Biggs, 1990; Douthwaite et al., 2017), researchers were expected to develop new technologies and transfer them to extension workers, who in turn transferred them to farmers for adoption. Unlike the linear approach, ISA is holistic and designed to enhance development and uptake of technologies via iterative involvement of diverse actors who contribute to the innovation processes. The social context of the approach

involves engaging multiple actors in the application of new ways of doing things and delivering new benefits to users (Almekinders, 2011; Hawkins et al., 2009). The approach focuses on integrating different actors, their resources and knowledge; and institutions that condition behaviours and practices in the process of innovation. Spielman, Ekboir & Davis (2009) argue that the future of technological development and delivery systems depends on the efficiency and effectiveness of actors in innovation systems. Owing to the importance of systemic approaches, the National Agricultural Research Organization (NARO) in Uganda has emphasized the need to engage different actors within and beyond the National Agricultural Research Systems (NARS) in its Research and Development (R&D) activities (NARO, 2008). The aim is to enhance the relevance of research, particularly the technological outputs, such as new varieties for national priority crops (MAAIF, 2010).

Banana (*Musa* spp.) is one of the most important priority crops with potential to contribute to food security and income in Uganda (Smale & Tushemereirwe, 2007). Although banana occupies the largest cultivated area among staple food crops, with more than 75% of the farmers growing the crop, its production has over time declined due to a complex of production constraints, mainly pests and diseases (Gold et al., 1999; Tushemereirwe et al., 2003; Kubiriba et al., 2013;). To reduce the impact of these constraints, NARO, through the National Banana Research Programme (NBRP), has taken technology generation as an efficient pathway for increasing banana productivity (MAAIF, 2010). The NBRP focuses on restoring production of bananas, especially of the East African Highland cooking bananas, locally known as *matooke*, through development and promotion of new technologies. A diagnostic study conducted in the 1990s revealed that the Black Sigatoka disease (*Mycosphaerella fijiensis*) and pests, mainly nematodes (*Radopholus similis*) and weevils (*Cosmopolites sordidus*), were the most important threats to banana production, especially in central Uganda (Tushemereirwe et al., 1993). Given that at the time there were no available resistant or tolerant cultivars, various banana plantations were devastated and almost wiped out in the region. The NBRP therefore embarked on a long-term strategy of developing new banana genotypes with resistance and/or tolerance to the identified pests and diseases. The breeding efforts that started in 1994 resulted in development, release and promotion of various technologies, including the new Hybrid Banana Varieties (HBVs) – also referred to as the *matooke* hybrids.

While efforts by the NBRP have led to development of these new varieties, their uptake remains low, especially in central Uganda (Kagezi et al., 2012). Past studies on hybrid bananas in Uganda have focused on socio-economic factors that influence adoption (Akankwasa et al., 2013; Edmeades et al., 2007; Kagezi et al., 2012). Results of these studies partially indicate failure of HBVs to meet end-user expectations. This raises questions as to *how* the new HBVs were developed from the Agricultural Innovation Systems (AIS) perspective, particularly, the processes and extent to which actors were involved in the process. While studies on Agricultural Technology Development (ATD) have tended to focus on farmers' participation in breeding programmes (Ashby 2009; Smale & Tushemereirwe 2007; Sperling et al., 1993), little is known about key processes that are crucial to enhance uptake. From a systems perspective, there was a need to explore how various actors are involved in Banana Technology Development (BTD) and the extent of their involvement in the process. Akankwasa et al. (2013) argue that farmers' involvement in banana varietal improvement and development is vital for meeting their preferences and could result into decisions for variety uptake. However, little is known about how this should happen, at what stages and in which critical processes to facilitate the choice decision of new banana cultivars. Therefore, this study analyses how the BTD process that led to new HBVs was organized and with which implications for uptake. In this study, the BTD process typifies an innovation process and provides a basis for analysing how banana research was designed and implemented to facilitate technology uptake. The main research question was: *how do the processes and actors in banana varietal development contribute to the output, and with which implications for uptake?* Exploration of the BTD process provides insights on how it was organised to shape and influence uptake of new technological innovations, which is critical to achieving the post-2015 SDGs.

2.2 The theoretical framework

To understand the dynamics and complexities embedded in BTD and to establish the relationship between the process and uptake of new HBVs, this study uses the AIS framework and the Innovation System Functions Approach in particular (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007; Klerkx & Leeuwis, 2009). The approach is key to understanding processes that are important for the success of any Technological

Innovation System (TIS) (Wieczorek & Hekkert, 2012). The processes are categorized as functions of the innovation system. Since the functions do not operate in isolation of structures, the analysis further integrated the structural dimensions of TIS (actors and institutions) that shape and influence action in the BTD process. Knickel, Brunori, Rand, and Proost (2009) note that innovation is systemic in nature and is an outcome of collective actions that depend on the social structure within which innovators operate. The extent and level of involvement of diverse actors promotes exchange of new knowledge and learning that is essential for innovation capacity (Spielman, Ekboir, & Davis, 2009) and consequently determines the output.

2.3 Methodology

2.3.1 Study design and area

A qualitative research design employing a case study approach (Sarantakos 2012; Yin 2013) was used. The qualitative design was the most feasible to understand the constructed realities of technology development and how these realities vary within a given context. The case studied was the new HBVs (*matooke* hybrids) to provide a deep analysis of the process of their development. The study focused on understanding *how* the new HBVs were developed based on the value chains approach to analyse the key processes, activities and actors at each node of the BTD process.

The study was conducted in central Uganda where a decline in banana production has been experienced over the years. The districts of Nakaseke, Luwero, Wakiso and Mukono were purposively selected for this study on the basis of their prior participation in banana R&D activities. The choice of these districts was also based on the efforts by the NBRP to improve banana production in the region.

2.3.2 Sample selection and data collection

The study population included different actors (individuals and organizations) along the nodes of the BTD and dissemination chain. These included researchers, extensionists, banana farmers, private tissue culture laboratory operators/entrepreneurs, and policy makers. Project and program documents were also reviewed and exploratory meetings held with researchers from the NBRP to guide the selection of the study population. Actors were identified and listed in each category to form a sampling frame.

Representatives of each actor category were purposively selected by virtue of their experiences, involvement and knowledge of the process that resulted into the new HBVs.

Data were collected using qualitative methods, including key informant and in-depth interviews, and focus group discussions (FGDs). Twenty purposively selected actors, including agricultural researchers, extensionists, producers/farmers, training institutions, private tissue culture laboratory operators/entrepreneurs and policy makers that were involved in the process of developing new HBVs were interviewed. Five FGDs consisting of 7-9 farmers each were conducted with banana farmer research groups. Semi-structured instruments consisting of open-ended questions were used as interview guide (Appendix 2) and FGD guide (Appendix 3) during the key informant interviews and FGDs, respectively. The semi-structured format of instruments allowed for extensive probes, breadth of responses and emergence of a wide variety of viewpoints (Sseguya et al., 2014). The interviews were conducted face-to-face with actors. In-depth interviews aimed to provide a description of actors' lived experiences during the process. The research team moderated the FGDs to ensure that each participant was given a chance to express their views while a rapporteur recorded notes to make sure that all participants' views are captured. A digital voice recorder was used to back up the recorded notes during the interactions with respondents.

To ensure content validity, the instruments were developed after extensive review of documents and related literature. In addition, the instruments were subjected to technical review by peers and University supervisors for their opinion on the representativeness and suitability of the questions. Reliability was achieved by triangulation of data sources and collection methods.

2.3.3 Analysis

The data collected using a digital recorder were transcribed verbatim using express scribe transcription software (Ver 5.78). Where the local dialect (*Luganda*) was used during the interview, it was translated into English and transcribed for analysis. The transcripts were imported into NVivo software (Ver 10) for thematic coding and analysis. The analysis followed a thematic content analysis approach which results in a descriptive presentation of data. Both deductive and inductive approaches to coding

were used. The deductive approach was based on the themes that were developed ex-ante guided by information that was required to support the study objectives while the inductive approach aimed at creating new and emerging themes. After the coding, further searches through the data and analysis were done to identify emerging patterns from the categories. Sections of each transcript were coded under an appropriate theme and direct verbatim quotes from the interviews extracted for use when discussing the results.

2.4 Results and discussion

The analysis revealed four themes that underlie the BTD process: stages, activities, actors and their roles. These themes are discussed simultaneously based on the different stages of the BTD process while identifying the underlying gaps at each stage and how these gaps affect the uptake of new HBVs.

Information from key informant interviews indicates that the process that led to development of the new HBVs can be described as a five-stage process involving; i) *setting the research agenda*; ii) *breeding*; iii) *trait evaluation and selection*; iv) *variety naming, release and registration*; and v) *promotion and commercialization*. Figure 2.1 presents a summary of the key processes, particularly the key activities and actors at each of the stages in the development of new HBVs.

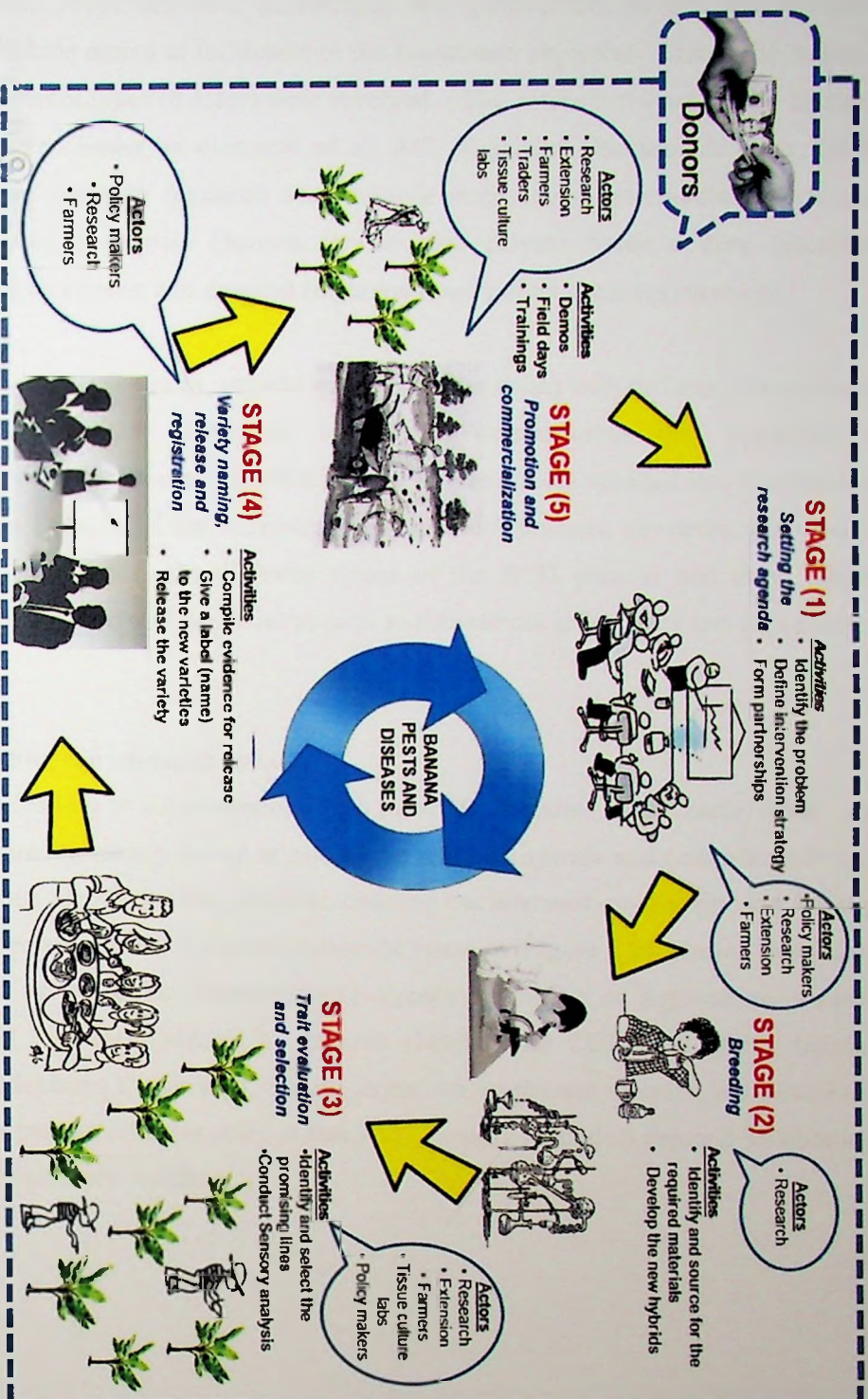


Figure 2.1 The process of developing the new HBVs: stages, activities and actors
Source: Study data, 2015

At each stage, different activities were conducted guided by various aspects as in any ATD process. These activities necessitated the involvement of different actors to perform functions aimed at fulfilment of the innovation objective. Across the stages of the BTD, different types of actors were involved. . The actors involved can be clustered in four domains based on elements of an AIS (Rajalahti, Janssen, & Pehu, 2008): education and research (research and training institutions; intermediary (extension agents, donors); enterprise (banana farmers and private tissue culture laboratory operators/entrepreneurs; and demand (regulatory and policy agencies) domains.

In most innovation processes, various actors come on board with differing interests and expectations either as individuals or for the organizations they represent. A combination of the processes, activities, actors and their roles resulted into complexities at the different stages of the technology development process. However, the level of complexities differed at the different stages of the BTD process and these mainly resulted from the nature of activities as well as differences in interests and capacities of actors.

Stage 1: Setting the research agenda

The process leading to development of the new HBVs started in the early 1990s with planning. Planning mainly aimed at setting the research agenda and comprised of three main activities: identifying the problem, defining the intervention strategy and forming the required partnerships for implementing the strategy (Figure 2.2). During this phase, actors, such as the policy implementing agency (Ministry of Agriculture, Animal Industry and Fisheries [MAAIF]), research (NARO and CGIAR Centers), training institution (Makerere University), donors, extension agents and farmers, were involved. These actors played different roles at this stage, mainly related to demand articulation, visioning and network building.

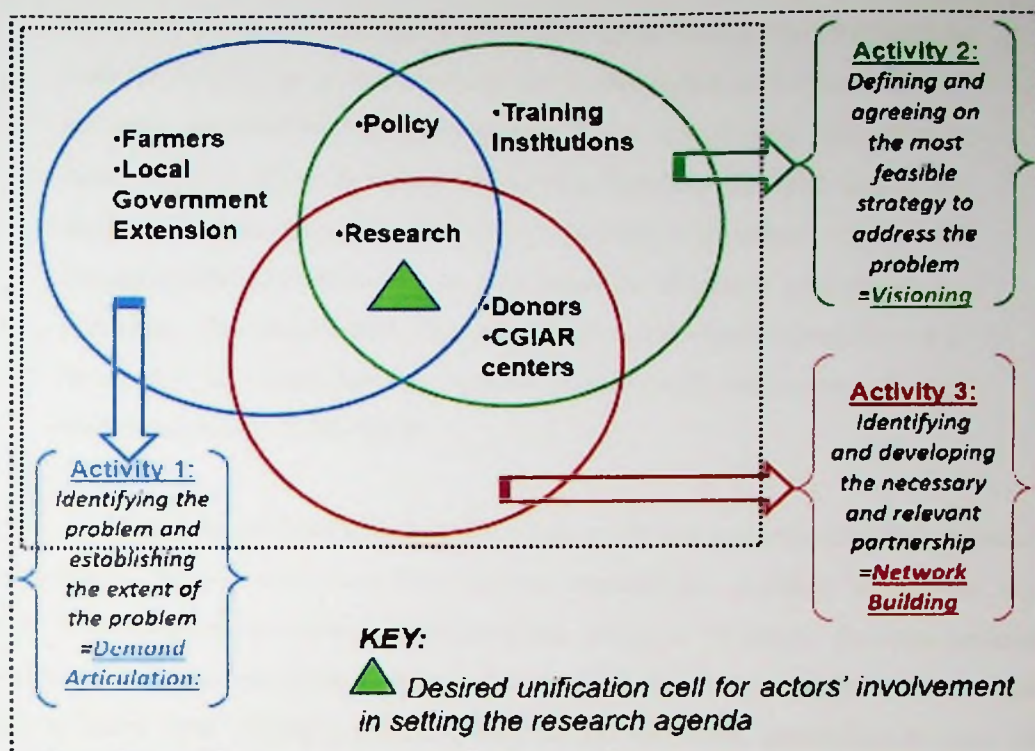


Figure 2.2 Venn Diagram showing the level of actor involvement in key activities of setting the research agenda

Source: Study data, 2015

Setting the research agenda started with identifying problems in banana production. Interviews with researchers indicates that this followed reports on the outbreak of banana pests and diseases in central Uganda. These reports led researchers from NARO to engage with various actors, including MAAIF and Makerere University supported by donors such as the Rockefeller Foundation, to conduct a field diagnostic study that established the extent of damage to the crop. Farmers and extension staff were involved in guiding the assessment as respondents and informants, respectively. Conducting a diagnostic study at farm level and the approach used characterises a change whereby more stakeholders, especially farmers, were involved to inform the planning of a scientific process. Corroboratively, key informant interviews revealed that, overtime, there has been a change and effort to involve different actors in the identification of research needs, as explained by one of the actors;

Research needs are currently jointly identified during our interaction with farmers. In the past, we used to get technologies from research and we were required to implement them without questioning. But, things have changed. There is more participation whereby farmers, extension staff and researchers meet to jointly identify constraints which are disaggregated into those to be addressed by research and those by extension. The constraints that require research-based solutions are forwarded to researchers to handle (Agricultural extension officer, Mukono District, 12/02/2015).

Having identified the problems, it was necessary to define and prioritize the potential interventions. Actors, such as policy makers, researchers, training institutions and donors were involved in defining the intervention strategy. However, findings indicate that the need to breed resistant banana varieties was opted for by mainly breeders from research since new varieties were viewed to be the most cost-effective way of addressing the predominant constraints;

Given the high cost of fungicides, their unavailability to smallholder farmers, and the recurring problem with fungicide resistance, it was clear that genetic resistance to black Sigatoka would be most feasible option. If resistant and acceptable cultivars are available, they would provide the best solution to this problem (Breeder, 16/04/2015).

Though invisible, donors had interest in the selected strategy of breeding new varieties since this presented a tangible output as a measure of success. Actors such as farmers and extension agents were not visible during the process of defining the intervention.

To effectively breed new cultivars, breeders at NARO needed to identify partners with whom they could collaborate for the success of the process. It was found out from the interviews that when the breeding strategy was agreed upon, researchers from NARO, as lead actors in the BTD process, selectively identified and engaged other actors that were perceived to play an important role in the technology generation process. CGIAR centres (International Institute of Tropical Agriculture [IITA] and Bioversity International) were identified as actors to collaborate with at this stage.

Although results show that different actors were involved in setting the research agenda, there were variations in the extent of their involvement (Figure 1). Actors, such as the national research entity, were present in all the activities while farmers and extension agents were only involved in identifying the problem at this stage. Other actors, such as policy makers, training institutions and CGIAR centres were involved in at least two activities of this stage. Involvement of actors was largely determined by the nature of activity and how each actor was perceived to contribute to that activity. Farmers and extension agents mentioned that usually, the focus of the needs assessment and intervention strategy are essentially pre-determined by researchers. As actors in the process, they are merely consulted for opinions rather than being rigorously involved in priority setting for a jointly shared research agenda. Also, it was evident during the interviews that only researchers were in a relatively better position to describe the planning phase of the BTD process, compared to other actors. Exclusion of such actors who are central to knowledge diffusion in decision making at the prioritising and strategizing phase has critical implications on successful technology development, acceptability and uptake. It was necessary to collectively harmonize interests and needs of all actors at the priority setting stage since this allows for demand articulation and a shared vision for all the actors. This deliberate effort would mean that all actors are involved in and are informed of the actions taken in the entire process of setting the research agenda, which would position them in the *unification cell* for actors' involvement (Figure 2.2). Farmers, as key actors, need to play a more inclusive role in the collective identification of interventions on which researchers can build for the effectiveness of the research process and relevance of the output.

Stage 2: Breeding new HBVs

The material making of the *matooke* hybrids followed a scientific approach that involved germplasm collection and characterization of breeding materials, cross pollination of the female varieties and laboratory screening. Therefore, most of the activities carried out at this stage were based on the technical aspects of plant breeding. Since this is largely a scientific process, the analysis aimed to identify *how* these technical activities were implemented, particularly the methods used, the actors involved and how they contributed to the decisions in the process.

Findings from interviews with researchers indicate that most of the actors at this stage were technical actors, mainly from the education and research domain. National breeders from NARO, in collaboration with breeders from IITA, identified the breeding approach and materials. The conventional cross-breeding approach was considered to be the most appropriate given the nature of the crop. Breeders also identified sources of resistance, and Calcutta4 – a wild resistant banana cultivar – was obtained by Bioversity International from the International Transit Centre (ITC), Belgium for crossing with the farmers' preferred local cultivars. Researchers from Makerere University were involved in the process of characterising the *matooke* landraces since they had the necessary expertise.

Discussion with banana breeders indicate that although conventional cross-breeding was considered the most appropriate approach at that time, it is slow, costly and less participatory. This corresponds with the technical view of Ortiz (2011) on conventional banana and plantain breeding. Conventional cross breeding of banana involves the transfer of pollen from resistant fertile diploid male plants to the female flowers of triploid clones with female fertility, to obtain resistant tetraploid hybrids. This approach is complicated by the long duration of 18 months for the crop to establish from seed to seed. The complex banana genetics, low genetic variability, polyploidy and the low levels of female and/or male fertility in most widely-grown triploid clones once made banana cross-breeding an almost impossible venture (Pillay et al., 2002; Rowe 1984). These challenges made the probability of obtaining an acceptable product uncertain at the initial stages of BTD. This approach also restricted the involvement of actors, such as farmers, extension agents, the seed sector, and the integration of their views in the early stages of the breeding process as compared to other approaches, like participatory plant breeding, which have proved to be effective in engaging different actors in the breeding process (Witcombe et al., 2005; Assefa et al., 2014; Ceccarelli 2015). Additionally, the use of a wild banana rather than a *matooke* parent was appropriate for breeding purposes but could explain why the hybrids failed to meet the attributes of the *matooke* consumers. This relates to the findings of Ceccarelli et al. (2000) that use of germplasm that can best meet the needs of target clients is important in breeding programmes and it enhances acceptance. Breeders' own recommendations indicated the need to continuously identify and

embrace participatory approaches and techniques at the breeding stage for bananas as also suggested by Ortiz (2011). Approaches that allow for quick selection and involvement of relevant actors at early stages of breeding ultimately enhance the quality of research outputs thereby contributing to higher levels of uptake of selected lines.

Stage 3: Trait evaluation and selection of new HBVs

The promising lines were tested, evaluated and selected in Early Evaluation Trials (EET), Preliminary Yield Trials (PYT) and Advanced Yield Trials (AYT). The aim of the different stages of evaluation was to identify promising hybrids that could be advanced for cultivar release. From a total of 1,000 lines at the crossing stage, 28 were selected and tested at PYT and 18 at AYT. The 18 conventionally bred hybrid lines selected at AYT were advanced to multi-locational on-farm trials for further evaluation and selection in comparison to a local check - *Mbwazirume*. The multi-locational trials were established at selected ZARDIs while on-farm trials were established on 18 farmers' fields in Nakaseke District. Sensory evaluations were also done at PYT, AYT and on-farm to assess consumer acceptance and preferences. At PYT, the sensory evaluations were done at a NARO institute (Kawanda) by a panel comprised of mainly staff and consumers from the surrounding areas, while at AYT the evaluations were done with farmer research groups in Nakaseke and Wakiso Districts.

The evaluation and selection of lines at EET and PYT was mainly done by breeders at NARO and IITA, basing on criteria that largely focused on plant growth, yield (measured by bunch size and weight) and resistance as it is for most plant breeding programmes (Figure 2.3). At this stage, private tissue culture laboratory operators/entrepreneurs were contracted to multiply the planting materials that were distributed to host farmers for the trials. Selections of lines was done by farmers in collaboration with researchers. Four lines (M2, M9, M14 and M17) were selected as the most promising hybrids among which M9 and M2 emerged as the best performing and were advanced for release.

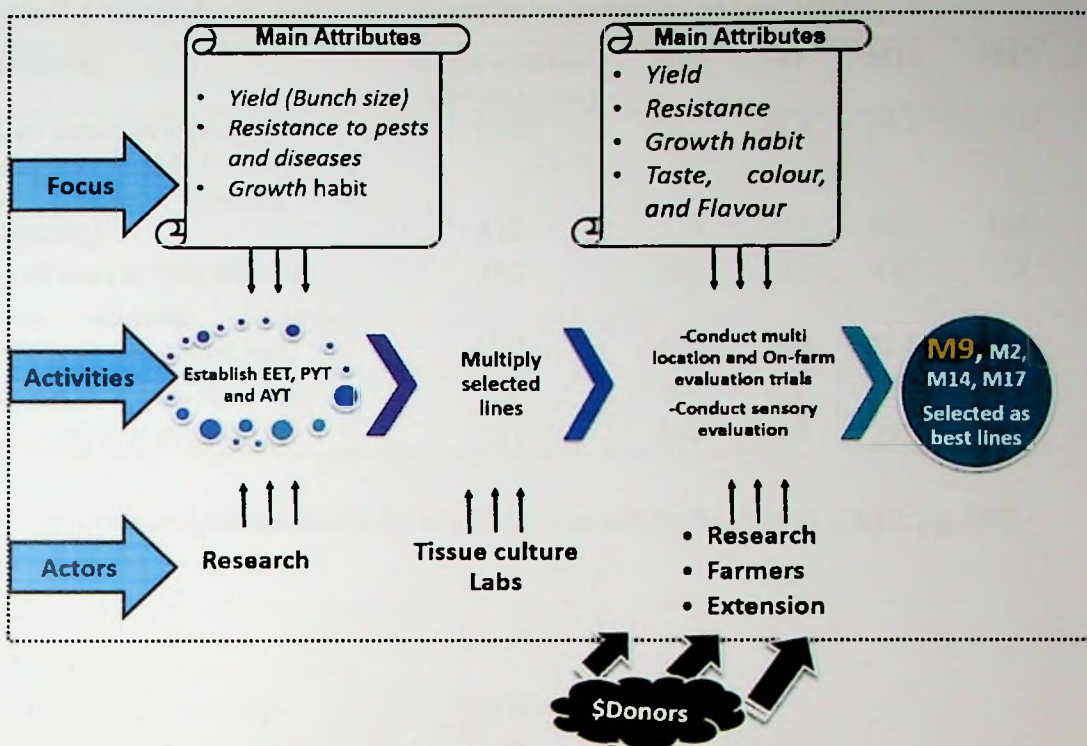


Figure 2.3 Evaluation and selection of new HBVs: Actors involved and criteria followed

Results indicate that the selected *matooke* hybrids performed better than the local check in terms of yield, plant growth related attributes and resistance to diseases (Table 2.1). However, when overall acceptability and preference for culinary attributes of food appearance, taste, flavour and texture were scored using a structured six point hedonic scale that ranged from one for extreme disapproval to six for extreme approval (Ssali et al., 2010), the local check was scored highest in all these quality attributes (Figure 2.4).

Table 2.1 Scores for technical attributes in the selection of new HBVs

Attributes	Local cultivar (Mbwarzirume)	M2	M9	M14	M17
Mean bunch Weight (Kgs)	15.5	23.2	21.3	20.1	22.4
Maturity period (Number of days from planting to flowering)	452	374	447	408	392
No. of days to fruit maturity	112	142	133	132	132
Black sigatoka resistance (index of non-spotted leaf)	51.2	84.1	74.9	82.6	86.8
Number of leaves at harvest	1.2	5.6	4.3	4.5	4.4
Plant height at flowering	321	309	340	292	315

Source: Own compilation based on data from an article by Ssali et al. (2010, pg. 590)

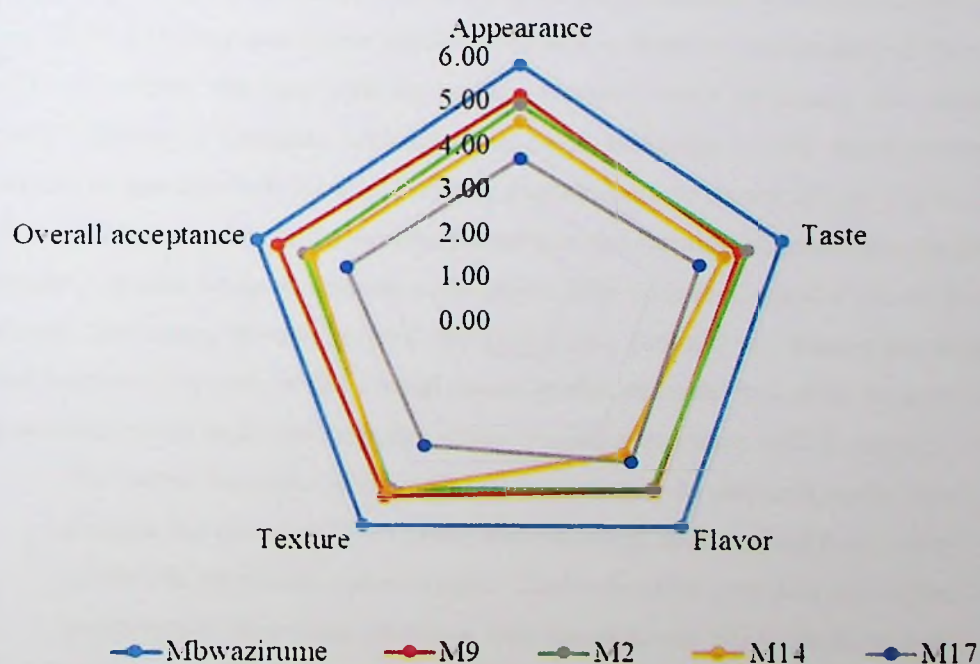


Figure 2.4 Mean preference scores for the quality attributes of cooked matooke during sensory analysis

Source: Own compilation based on data from an article by Ssali et al. (2010, pg. 591)

Involving farming communities in the evaluation and selection process is a better way of selecting new crop varieties and this is meant to guide choice of the most acceptable hybrids. However, findings at this stage allude to the fact that the breeders prioritized mainly technical attributes of the varieties during the evaluation and selection of new varieties. The hybrids were evaluated for disease and pest resistance, yield-related traits and plant growth related traits since these were perceived by breeders to be the most important criteria used by farmers to select cultivars for growing. The intrinsic socio-cultural and gender-specific attributes were given limited consideration during the selection of hybrids for advancement and release. This corroborates with other studies (Ceccarelli, 2015; Mgumia et al., 2015) which report that most researchers are largely accustomed to indicators associated with productivity potential, ignoring a wide body of literature showing that yield is not often the main driver of uptake. Such quantitative indicators undermine the value and use of qualitative indicators in assessing new technologies. Indicators related to the *intrinsic* socio-cultural attributes, such as food taste, texture, flavour and colour which are valued by farmers, particularly in the central region for whom the new hybrids mainly targeted, were necessary for enhancing uptake. Failure to integrate and prioritize such attributes in the development and selection of *matooke* hybrids may probably explain the low uptake of new HBVs. There was a need to consider the social attachment that the farming communities have about *matooke* varieties because *matooke* is the staple food crop in Central Uganda. To these farmers, food taste, flavour, texture and appearance (colour) are among the most key considerations. Farmers in the central region prefer *matooke* that takes long to harden when served (with high heat retention capacity) and with a deep yellow colour;

The hybrid varieties yield well and are tolerant to diseases, pests and drought but the taste is not good. The colour of cooked food is not deep yellow like our local matooke types. It also hardens very fast even after steaming for more than six hours. One needs to eat this matooke hybrid while on the cooking stove or immediately after taking it off (Female farmer, Nakaseke District, 2/05/2015).

Results of the discussions with breeders indicate that the process of breeding bananas was much longer than it is for most of the other crops. Researchers were therefore under pressure from donors to release and deliver *matooke* hybrids to farmers. This complicated the selection process as the researcher's interest was in fulfilling its

mandate of developing new varieties and that of the donors' need for a tangible output from the process while addressing the farmers need for a new variety with desired attributes. Ultimately, this caused a mismatch in the criteria for varietal attribute selection between researchers and end-users (farmers and consumers). To the farmers, it was not just about disease and pest resistance but also to what extent the new varieties met the consumption attributes inherently present in their local cultivars. Glenna, Jussaume, and Dawson (2011) while assessing how farmers matter in shaping agricultural technologies observed similar findings that end-users may have an interest in a technology for reasons other than what the technology developers (plant breeders) intended.

The differing interests and influence of actors, such as donors and researchers on the actions and decisions at this stage compromised the selection criteria. This made it difficult for the researchers to fully integrate farmers' preferences and feedback on the social attributes in a bid to release new varieties. The failure to integrate farmers' feedback on desired attributes could offer an explanation for the observed low level of uptake of *matooke* hybrids. Other related studies (Feder et al., 1985; Smale, 2007) post similar findings that adoption of a new technology by smallholder farmers largely depends on the extent to which the new technology meets the underlying social conditions and intrinsic attributes. Farmers' dissatisfaction with attributes of a new technology is an important disincentive to the adoption of most agricultural technologies. Research needs to be aware of end-users' preferences and their potential constraints to use of new technologies since this ultimately determines acceptability of new technologies. As Douthwaite et al. (2017) note, it is imperative that technology developers shift from being outside 'knowers' to 'enablers'. That way, researchers will be able to facilitate rather than control the selection process. This will enable end-users to play a key role in the evaluation and selection of new varieties so that only those varieties that meet their needs and preferences are considered for release.

Stage 4: Variety naming, release and registration of *Matooke* hybrids

At this stage, studies were conducted in support of the requirement for Distinctiveness, Uniformity and Stability (DUS) by MAAIF for any new variety. Breeders at the NBRP compiled the required data and applied for release and inclusion of *matooke* hybrids on the national cultivar list. During breeding, the hybrid lines were represented by

different cultivar numbers and later, the 'M' initial was coined as a label for *Matooke* so that farmers would easily relate with the new cultivars. In 2010, variety M9 which emerged as the best candidate at the evaluation stage was advanced for release. The variety was observed to be disease resistant and tolerant to pests and drought. It was released later in 2010 as 'KABANA 6H' by the national variety release committee of MAAIF.

Complexity at this stage mainly resulted from the criteria used to file the varieties for release, the label (name) given to the emerging *matooke* hybrids and extent of actor involvement. The criteria for release mainly focused on technical attributes of the new cultivars, while the rigor for farmers' preferred attributes diminished. Although a name can be regarded as just a label, information from the FGDs with farmers indicate that a name of a new variety has an effect on its use. Farmers' naming criteria were associated with variety attributes and this differed from the NARO nomenclature. However, the varieties were named, released and registered according to the NARO criteria. The use of a different label from what farmers think is appropriate implies that farmers, as actors in the development process, are passive participants with limited influence on how decisions are made in the process. It was observed during the FGDs that farmers do not seem to understand the naming process of new varieties, making them associate even the most suitable varieties with genetically modified (GM) technologies. This could also be attributed to their past experiences with banana varieties from research.

Naming the varieties according to researchers' criteria delinks with farmers' known attributes which also de-orient their attitude towards new crop attributes and their perceived benefits. The official variety names tend to be complex for end-users to comprehend. This, coupled with limited awareness about the meaning of the names, impacts negatively on farmers' perceptions and attitudes about new crop varieties from research, thereby limiting their 'ownership' and use despite having participated in the selection process. Also, extension agents, as key actors in the intermediary domain, were not involved in the release process; yet they are critical to the promotion of new technologies. Research needs to recognize the role of farmers and extension agents in the research process, and farmers should be given opportunity to participate in the naming and release processes of new varieties.

Stage 5: Promotion and commercialisation of new HBVs

Key activities at this stage included on-farm demonstrations, field days, training and distribution of plantlets. These were largely implemented by researchers, extension and farmers with donor support. During the interviews and FGDs, actors in different categories were asked to rank the weakest node in the BTD process. The majority (about 95%) of the responses across actors indicated that promotion and commercialisation was the weakest link. This was mainly attributed to limited in-built strategies for creating awareness and interest among users, as well as minimal involvement of other actors in the planning and implementation of promotional activities.

The results indicate inadequacies in the level of actor involvement in promotion and dissemination of *matooke* hybrids. While actors, such as local leaders, NGOs and media, play an important role in popularising new technologies, they were rarely involved. Research continued to take a leading role in the promotion of new HBVs through distribution of planting materials on a free-of-charge basis. Despite the emergence of private companies dealing in tissue culture materials for bananas, research was reported to still be at the forefront of multiplication of *matooke* hybrids for dissemination. The NBRP continued to contract tissue culture laboratories to multiply planting materials on a commercial basis for distribution to end-users. Literature shows that activities that aim at facilitating diffusion of new technological knowledge are an essential function of any innovation system (Hekkert et al., 2007; Johnson 2001). Although other studies have indicated greater success and impact where the R&D team continued to champion the technology (for example, Douthwaite & Gummert 2010), the findings herein are an indication of what Mgumia et al. (2015) characterise as partially successful innovations. Such innovations are mainly multiplied and disseminated in informal and unsustainable project-based interventions that target a limited number of users over a short time-span.

The leadership of research in promoting new HBVs could be attributed to limited interest among entrepreneurs, mainly private tissue culture laboratory entrepreneurs, to invest in the multiplication and commercialisation of *matooke* hybrids. The low interest of private tissue culture laboratory entrepreneurs could be explained by the low demand for hybrid bananas and their [private tissue culture laboratory entrepreneurs]

diminished involvement in the development process. Future TISs should involve actors that perform entrepreneurial activities from the outset of the innovation process. This will trigger their interest in the new technology and probably contribute to their ability to invest in multiplication and commercialisation of new varieties. From their perspective, key informants (mainly research, extension and farmers) suggested that research needs to proactively engage and collaborate with other agencies that brand and promote research outputs in a way that attracts end-users. Promotion needs to be a well-planned process with clear progression activities if it is to achieve the intended results. Therefore, promotion should not be looked at as an end activity; instead there should be in-built activities that engage the necessary actors from the onset of a breeding process.

2.5 Reflections on the process

In this chapter, the process of developing agricultural technologies was analysed to gain an understating of how this process affects technology uptake. Results of this study have shown that the new HBVs resulted from a five-stage process that followed the conventional scientific breeding approach. Performance of the new HBVs was largely measured by yield and resistance to pests and diseases as key criteria in the selection process, which could also explain why sensory analysis studies were introduced later in the process and its outcome not fully integrated. The focus on mainly technical aspects coupled with the long breeding time affected integration of farmers' preferred quality attributes related to socio-cultural and gender-differentiated preferences that emerged during evaluation of new HBVs. Two possible explanations could be advanced for this result. First, there was limited gender integration in the process of developing new HBVs across the stages. This could have resulted from the failure to identify and define the gender dimensions of the problem that was to be addressed by the BTD process. Quality attributes are critical to *matooke* growers, and are important factors for inducing market demand and use particularly in central Uganda. Secondly, the national breeders supposedly knew the suitable cultivars and the necessary traits while the international level breeders had networks beyond technical knowledge that complemented the research efforts. Other categories of researchers, such as social scientists and zonal level scientists who are critical for assessing the end-users and zonal specific preferences respectively, were not fully involved at most of the stages. Although the research system in Uganda has emphasised multi and interdisciplinary research teams overtime, this does not happen in reality or it happens later in the

research process. Key informants argued that different disciplines are important in the entire process and need to be involved from the outset to assess how the technologies being developed meet the existing specific demands. The findings of this study provide empirical insights into the need to integrate both technical and social aspects in developing and selecting new varieties. Such an arrangement would stretch the breeding process but guarantee high levels of acceptability of the output. This calls for more participatory approaches and techniques in crop variety improvement and development programmes. Breeders' recommendations indicated the need to develop methods that can enable them [breeders] to select for various traits at once, instead of multiple evaluations of lines for various attributes which slows the process.

From the AIS perspective, identification and involvement of multiple actors is central to the performance of any innovation process typified by the BTD process in this study. The actors support the innovation process by performing innovation activities (functions), which contribute to the goal of the innovation system. This study has demonstrated that although various actors were involved in the BTD process, variations in the level of their involvement and roles performed exist. The findings further indicate absence of critical actors at certain stages and across the BTD process. Within the stages, there was minimum involvement of the seed sector, extension and certain categories of scientists, while across the BTD process, local leaders, agro-processors, financial institutions and media were missing actors yet these play a critical role in stimulating demand. The absence or diminished involvement of necessary actors at different stages of the process shows shortfalls in the BTD process and could be a possible loophole in enhancing uptake of new HBVs. Klein-Woolthuis et al., 2005 (cited by Wieczorek and Hekkert, 2012) indicate that absence of certain actors can lead to systemic problems which may hinder the development and functioning of an innovation system. The findings of this study emphasize the need to reorient technology development processes such that actors are brought on board earlier in the process with clearly defined roles. Adequate involvement of diverse actors in technology development is critical for adequate incubation of new technologies and serves as a key motivator for uptake.

As discussed, involvement of actors varied from stage to stage, depending on their perceived roles and usefulness. However, it emerges from the results that researchers at

the national level, mainly breeders, took the lead for most of the important activities and decisions throughout the entire process with evolving roles. Although the leading role of research could be attributed to their mandate and technical expertise to guide the process, it barricaded other actors' involvement, performance of their functions and integration of their ideas in the innovation process. This limits optimal support to enhance development and uptake of new technologies. It also indicates that latent use of a linear, top-down approach is still inherent in research systems which negatively impacts uptake of outputs from ATD process.

2.6 Conclusions and Recommendations

R&D organisations generally approve that yield-enhancing technologies, particularly new crop varieties, are vital to increasing agricultural productivity. The aim of this chapter was to offer an analysis of the underlying structure of the BTD process from the AIS perspective. This chapter provides insights in the processes, activities, and actors, their roles and extent of involvement in the development of new HBVs and how these account for their uptake. These insights demonstrate the complexities and gaps in the BTD process that ultimately impact the development, acceptance and use of new technologies. The results contribute to the existing literature on innovation systems and technology adoption by providing an integrated view of agricultural technology uptake and its inducing factors in the ATD context.

Overall, it is concluded that leadership in variety development in the banana sub-sector is being coordinated by NARO and other research-orient actors. Such as, the process of developing new varieties is largely controlled by agricultural research institutions with limited involvement of other actors such as farmers, private sector actors and extension staff across the stages. Additionally, technical attributes remain the key drivers in selection of HBVs in the early stages while consideration for social attributes happens in the later stages. This affects integration of social related/quality preferred attributes which ultimately impacts on acceptability of new HBVs. The study thus proposes an integrated approach that provides a holistic framework with a social perspective for ATD and optimizing uptake. Based on the AIS, new technologies should be a result of an iterative process that fosters feedback while allowing for actor involvement in prioritization at different stages of the process. Such a process needs to take into

account both technical and social aspects as well as the needs and traits preferences of both men and women end-users.

From the practitioner's perspective, research needs to reorient TD processes to be a rigorous but flexible process that identifies and actively engages with the necessary actors while integrating their knowledge, skills and capabilities and recognising their interdependence for a better functioning of the system. Further, researchers should reorient their role in the process to be more responsive to the needs of the innovation system, particularly end-users if uptake is to be improved. In particular, breeders need to appreciate the complementary role of social science in the scientific research process. This will require breeders to re-define their role as 'champion actors' in the technology generation process. From how they have been described and classified overtime, breeders need to change and play more of a catalyst role in the process, allowing for other actors to play different roles that can stimulate and sustain use of the new technologies. Additionally, research needs to redefine the indicators for measuring research outputs and successful technologies. Rather than focusing on the number of varieties released, this study recommends that uptake, should be prioritised as a measure of research success.

Farmers' efforts and participation in technology development interventions should also be rewarded by involving them in naming the varieties in a way that is familiar to them as target end-users, to foster their 'ownership' of the new varieties. This will require a blend between farmers' preferred quality attributes and the technical attributes, implying redefining trait evaluation and selection criteria. Since the varieties which farmers may choose to grow may be different from the breeders' choice, there is need to integrate farmers' preferences differentiated by gender if breeding programmes are to be more relevant to the needs of men and women end-users. Additionally, practitioners need to be aware that a 'blanket' approach is not as effective as a 'tailor' approach to the naming and release of new varieties. A tailored approach takes into account the differences between communities, implying that release of tailor-made varieties targeting specific regions would require decentralised release processes that take place in the actual locations with the active involvement of key actors and stakeholders, such as extension, local and political leaders, among others. This will

accelerate diffusion and also serve as a promotion strategy for enhancing technology acceptance and use.

From a policy perspective, the study highlights the need for effective partnerships and collaborations in ATD and dissemination. This could be achieved by establishing multi-actor platforms and strengthening the existing private-public partnerships in technology development and promotion. NARS needs to streamline the engagement of actors in the TD process while empowering them to support and sustain the new technologies. It is also important that the National Agricultural Research Institutes (NARIs) streamline their engagement with Zonal Agricultural Research and Development Institutes (ZARDIs) in research processes, since these were established to adapt and disseminate research and technology outputs across the different agro-ecological zones. Stronger collaboration between the NARIs and ZARDIs will not only tap into the potential of ZARDIs to contribute to wider impact but will also serve as a mentoring process for zonal level scientists. Such collective and collaborative arrangements that support efficient and effective exchange of information will go a long way to accelerate the proliferation and uptake of new varieties.

References

- AGRA. (2013). Africa Agriculture Status Report: Focus on Staple Crops. Alliance for a Green Revolution in Africa (AGRA). Nairobi, Kenya.
- AGRA. (2017). *Africa Agriculture Status Report: The Business of Smallholder Agriculture in Sub-Saharan Africa* (Issue 5). Nairobi, Kenya: Alliance for a Green Revolution in Africa (AGRA). Issue No. 5
- Akankwasa, K., Ortmann, G., Wale, E., & Tushemereirwe, W. (2013). Farmers' choice among recently developed hybrid banana varieties in Uganda: A multinomial logit analysis. *Agrekon*, 52(2), 25-51.
- Almekinders, C. (2011). The joint development of JM-12.7: A technographic description of the making of a bean variety. *NJAS-Wageningen Journal of Life Sciences*, 57(3), 207-216.
- Ashby, J. A. (2009) The impact of participatory plant breeding: *Plant breeding and farmer participation*, in S. Ceccarelli, E. Guimares, and E. Weltzien (eds.) *Plant Breeding and Farmer Participation*, pp. 649-671. Food and Agriculture Organization (FAO), Rome.
- Assefa, T., Sperling, L., Dagne, B., Argaw, W., Tessema, D., & Beebe, B. (2014). Participatory plant breeding with traders and farmers for white pea bean in Ethiopia. *The Journal of Agricultural Education and Extension*, 20(5), 497-512.
- Beintema, N., & Stads, G. J. (2014). Taking stock of national agricultural R&D capacity in Africa South of the Sahara. *ASTI Synthesis Report. Agricultural Science and Technology Indicators report. online at <http://www.ifpri.org/sites/default/files/publications/astiafricasynthesis.pdf>*.
- Biggs, S. D. (1990). A multiple source of innovation model of agricultural research and technology promotion. *World Development*, 18(11), 1481-1499.
- Ceccarelli, S. (2015). Efficiency of plant breeding. *Crop Science* 55: 87-97 doi: 10.2135/cropsci2014.02.0158.
- Ceccarelli, S., Grando, S., Tutwiler, R., Baha, J., Martini, A.M., Salahieh, H., Goodchild, A., & Michael, M. (2000). A Methodological Study on Participatory Barley Breeding. I. Selection Phase. *Euphytica* 111: 91-104.
- Douthwaite, B. Marina Apgar, J., Schwarz, A.M., Attwood, S., Sellamuttu, S. S. & Clayton, T. (2017). A new professionalism for agricultural research for development, *International Journal of Agricultural Sustainability*, 15:3, 238-252, DOI:10.1080/14735903.2017.1314754
- Douthwaite, B., & Gummert, M. (2010). Learning selection revisited: How can agricultural researchers make a difference? *Agricultural Systems*, 103(5), 245-255.

- Edmeades, S., Smale, M., Kikulwe, E. M., Nkuba, J., & Byabachwezi, M. S. R. (2007). Characteristics of banana-growing households and banana cultivars in Uganda and Tanzania. *An economic assessment of banana genetic improvement and innovation in the Lake Victoria Region of Uganda and Tanzania. IFPRI Research Report, 155*, 49-74.
- Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic development and cultural change*, 33(2), 255-298.
- Food and Agriculture Organisation of the United Nations [FAO]. (2015). The state of food insecurity in the world 2015. Meeting the 2015 international hunger targets: Taking stock of uneven progress. Rome: Food and Agriculture Organisation of the United Nations.
- Glenna, L. L., Jussaume Jr, R. A., & Dawson, J. C. (2011). How farmers matter in shaping agricultural technologies: Social and structural characteristics of wheat growers and wheat varieties. *Agriculture and Human Values*, 28(2), 213-224.
- Godfray, C., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., Robinson, S., Thomas, S. M., & Toulmin, C., (2010). 'Food security: the challenge of feeding 9 billion people', *Science* 327, 812-818.
- Gold, C. S., Karamura, E. B., Kiggundu, A., Bagamba, F., & Abera, A. M. (1999). Geographic shifts in the highland cooking banana (*Musa* spp., group AAA-EA) production in Uganda. *International Journal of Sustainable Development and World Ecology*, 6(1), 45-59.
- Hall, A., Bockett, G., Taylor, S., Sivamohan, M., & Clark, N. (2001). Why research partnerships really matter: innovation theory, institutional arrangements and implications for developing new technology for the poor. *World development*, 29(5), 783-797.
- Hall, C., Dawson, T. P., Macdiarmid, J. I., Matthews, R.B. & Smith, P. (2017). The impact of population growth and climate change on food security in Africa: looking ahead to 2050. *International Journal of Agricultural Sustainability*, 15 (2), 124-135, DOI:10.1080/14735903.2017.1293929
- Hawkins, R., Heemskerk, W., Booth, R., Daane, J., Maatman, A., & Adekunle, A. (2009). *Integrated Agricultural Research for Development (IAR4D)*. Paper presented at the A Concept Paper for the Forum for Agricultural Research in Africa (FARA) Sub-Saharan Africa Challenge Programme (SSA CP). FARA, Accra, Ghana.
- Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological forecasting and social change*, 74(4), 413-432.
- Johnson, A. (2001). *Functions in innovation system approaches*. Paper presented at the Electronic Paper presented at DRUID's Nelson and Winter Conference, Aalborg, Denmark.

- Kagezi, G., Mpiira, S., Jogo, W., Karamura, E., Gotor, E., Garming, H., & Johnson, V. (2012). Adoption of New Banana Cultivars in Uganda. A Report for the DIVA Project (Unpublished report).
- Karamura, E. B., Tinzaara, W., Kikulwe, E., Ochola, D., Ocimati, W., & Karamura, D. (2016). Introduced banana hybrids in Africa: seed systems, farmers' experiences and consumers' perspectives. XXIX IHC- Proc. Int. Symp. Banana: ISH-ProMusa Symposium on Unravelling the Banana's Genomic Potential. Eds.: I. Van den Bergh et al, *Acta Hortic.*, 1114 (ISHS 2016), 239-244.
- Klerkx, L., & Leeuwis, C. (2009). Establishment and embedding of innovation brokers at different innovation system levels: Insights from the Dutch agricultural sector. *Technological forecasting and social change*, 76(6), 849-860.
- Knickel, K., Brunori, G., Rand, S., & Proost, J. (2009). Towards a better conceptual framework for innovation processes in agriculture and rural development: from linear models to systemic approaches. *Journal of Agricultural Education and Extension*, 15(2): 131-146. doi:10.1080/13892240902909064.
- Kubiriba, J., Tushemereirwe, W. K., Kenyon, L., & Chancellor, T. C. B. (2013). Field spread of banana streak virus (BSV). *African Journal of Agricultural Research*, 8(18), 1881-1890.
- MAAIF (Ministry of Agriculture, Animal Industry and Fisheries). (2010). *Agriculture for Food and Income Security. Agricultural Sector Development Strategy & Investment Plan: 2010/11 - 2014/15*. MAAIF, Kampala Uganda
- Mgumia, A. H., Mattee, A. Z., & Kundi, B. A. (2015). The application of the agricultural innovation system approach in technology development in Tanzania: researchers' perceptions and practices. *African Journal of Science, Technology, Innovation and Development*, 7(3), 211-219.
- NARO (National Agricultural Research Organization). (2008). Ten-Year Strategic Plan 2008-2018 *Towards improved Agricultural Research Services Delivery NARO Medium Term Plan 2008/9 – 2014/15*. NARO, Entebbe, Uganda.
- NARO (National Agricultural Research Organization). (2012). The Impact of Agricultural Research in Uganda, 50years of Independence. in press: National Agricultural Research Organization.
- Ortiz, R. (2011). *Conventional banana and plantain breeding*. Paper presented at the VII International Symposium on Banana: ISHS-ProMusa Symposium on Bananas and Plantains: Towards Sustainable Global Production 986.
- Pillay, M., Hartman, J., & Tenkouano, A. (2002). Bananas and plantains: future challenges in *Musa* breeding. Pages 223-252 in: Crop Improvement, Challenges in the Twenty-First Century (M.S.Kang, ed.), Food Products Press, New York.
- Rajalahti, R., Janssen, W., & Pehu, E. (2008). Agricultural innovation systems: From diagnostics toward operational practices: Agriculture and Rural Development Department, World Bank.

- Rowe, P. (1984). Breeding bananas and plantains. *Plant Breeding Reviews* 2: 135-155.
- Sarantakos, S. (2012). *Social research*: Palgrave Macmillan.
- Smale, M. (2007). Assessing the impact of technical innovations in African agriculture. In a. W. K. T. M. Smale (Ed.), *An economic assessment of banana genetic improvement and innovation in the Lake Victoria region of Uganda and Tanzania* (pp. 3-11). Washington, DC: International Food Policy Research Institute.
- Smale, M., & Tushemereirwe, W. (Eds.). (2007). *An economic assessment of banana genetic improvement and innovation in the Lake Victoria region of Uganda and Tanzania*. Research Report No. 155. International Food Policy Research Institute, Washington, D.C.
- Sperling, L., Loevinsohn, M. E., & Ntabomvura, B. (1993). Rethinking the farmer's role in plant breeding: Local bean experts and on-station selection in Rwanda. *Experimental Agriculture*, 29(04), 509-519.
- Spielman, D. Ekboir, J. J., & Davis, K. (2009). The art and science of innovation systems inquiry: applications to Sub-Saharan African agriculture. *Technology in society*, 31(4), 399-405.
- Ssali, R., Nowankunda, K., Barekye, A., Erima, R., Batte, M., & Tushemereirwe, W. (2010). On farm participatory evaluation of East African highland bananas 'EAHB' hybrids (Musaspp). *Acta Hort.*, 879: 585-591.
- Sseguya, H., Mazur, R. E., Wells, B., & Matsiko, F. (2014). Quality of participation in community groups in Kamuli District, Uganda: implications for policy and practice. *Community Development*, 46(1), 14-25.
- Tushemereirwe, W., Gold, W., Speijer, P., & Holderness, M. (1993). Foliar diseases of banana in Uganda: results from a diagnostic survey. *African Crop Science Journal*, 1(2).
- Tushemereirwe, W., Kashaija, I., Tinzaara, W., Nankinga, C., & New, S. (2003). *Banana Production Manual*. 2nd edition. National Agricultural Research Organization. Fountain Publishers, Kampala-Uganda.
- USAID. (2011). Feed the future: Global food security research strategy. Washington DC: US Agency for International Development.
- Van Mierlo, B., Leeuwis, C., Smits, R., & Woolthuis, R. K. (2010). Learning towards system innovation: Evaluating a systemic instrument. *Technological forecasting and social change*, 77(2), 318-334.
- Weltzien, R., Smith, M. E., Meitzner, L. S., & Sperling, L. (2003). Technical and institutional issues in participatory plant breeding-from the perspective of formal plant breeding: A global analysis of issues, results, and current experience. CGIAR Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation Working Document 3. Cali: CGIAR, PRGA.

- Wieczorek, A. J., & Hekkert, M. P. (2012). Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. *Science and Public Policy*, 39(1), 74-87.
- Witcombe, J., Joshi, K., Gyawali, S., Musa, A., Johansen, C., Virk, D., & Sthapit, B. (2005). Participatory plant breeding is better described as highly client-oriented plant breeding. I. Four indicators of client-orientation in plant breeding. *Experimental Agriculture*, 41(3), 299-320.
- World Bank. (2008). *World Development Report 2008: Agriculture for development*. Washington, DC: World Bank.
- Yin, R. K. (2013). *Case study research: Design and methods*: Sage publications.

CHAPTER 3: ACTOR DIVERSITY AND INTERACTIONS IN THE DEVELOPMENT OF BANANA HYBRID VARIETIES IN UGANDA: IMPLICATIONS FOR TECHNOLOGY UPTAKE²

Abstract

This chapter examined the nature of networks through which new hybrid banana varieties in Uganda (HBVs) are developed, and how different actors engage in the technology development process. Data were collected through 20 key informant interviews with purposively selected actors that were involved in the BTD process and 5 focus group discussions with banana farmers. Data was analysed using NVivo and Social Network Analysis software. Results indicate that the process of developing HBVs involves many actors with a diversity of roles and interests. The network density was 29.4, implying existence of only 29.4 % of the possible direct linkages. Strong ties mainly existed among research-oriented actors, with other actors in the periphery. The current position of smallholder farmers and other non-research actors inhibits their influence on decisions in the technology development process. Based on these findings, the study recommends that smallholder farmers should be empowered through better organization so that they can influence the process of developing HBVs. Researchers, supported with appropriate policies and programmes, should engage more with actors in the intermediary, enterprise and support service domains for a more vibrant agricultural research system.

Key words: Agricultural research, technology development, technology uptake, actor networks, hybrid banana varieties, Uganda

² Published as: Nasirumbi-Sanya, L., Sseguya, H., Kyazze, F. B., Baguma, Y. & Kibwika, P. (2017). Actor diversity and interactions in the development of banana hybrid varieties in Uganda: Implications for technology uptake. *Journal of Agricultural Education and Extension*, DOI: [10.1080/1389224X.2017.1401549](https://doi.org/10.1080/1389224X.2017.1401549).

3.1 Introduction

Agricultural research is increasingly characterized by new actors and relationships that influence how research institutions engage in technology generation and dissemination (Rajalahti, Janssen, and Pehu 2008). Greater emphasis is being placed on active involvement of diverse actors in agricultural research to generate relevant technologies and enhance uptake. This has led to innovative and interdisciplinary approaches to agricultural research and technological development such as the Innovation Systems Approach (Knickel et al. 2009; World Bank 2006), particularly, the Agricultural Innovation Systems (AIS) framework. The AIS framework sheds light on the roles and responsibilities; actions and interactions and institutions that condition behaviours and practices (Wood et al. 2014). It is argued that the framework has the potential to enhance adoption of agricultural technologies by end-users in Sub-Saharan Africa (SSA) where adoption levels are still low. For instance, in Uganda, agricultural production continues to be characterised by low use of agricultural technologies – adoption levels are at 30% for most technologies – hence exacerbating the livelihood insecurity situation of the country (MAAIF 2010).

The persistent low uptake of agricultural technologies in SSA calls for researchers to analyse the critical contextual factors and how processes related to agricultural technology development and change evolve (Eidt, Hickey, and Curtis 2012). Heeks and Stanforth (2015) note that most research on technological change in developing countries provides little detail on what the process entails, particularly the role played by actors in shaping the use of new technologies. Although factors such as relevance, cost, markets, farmer and farm characteristics are usually put forth to explain the low adoption of agricultural technologies, little focus has so far been placed on studying the processes that lead to development of these technologies. It therefore remains unclear how innovation success and/or failure relates to different characteristics pertaining to the nature, structure and agency of actors in networks in which new technologies emerge and how this influences farmer technology uptake. This chapter analyses actor engagement in the research processes for development of new hybrid banana varieties (HBVs) in Uganda. The aim is to gauge how the involvement of various actors in Agricultural Technology Development (ATD) shape technology uptake and sustained use of the technology. This objective of the study specifically focussed on: (i)

characterizing the nature of actors in the Banana Technology Development (BTD) network and (ii) interaction and influence of actors with respect to flow of information and tangible resources.

3.2 Theoretical framework

Breeding new crop varieties is a multi-stage and cyclic process in which one step feeds into the next, and each cycle feeds into the next (Ceccarelli 2009). Different actors engage in the various stages and their linkages, interactions and positions in the technology development process are influenced by the roles and interests of the various actors at a given stage. In this study, the Actor Network Theory (ANT) and the Social Network Theory (SNT) were used to aid analysis of actor relationships and their influence on the BTD process. These relationships in turn influence the uptake of new technologies, operationally defined as acceptance and use of new HBVs. From the AIS perspective, technology is seen as embodied knowledge developed by learning and supported by networks of organizations and institutions (Johnson and Andersen 2012). Since innovations result primarily from the exchange and use of knowledge, the nature of interactions between and among actors is an important aspect for consideration in technology development. Donovan (2014) states that action is never accomplished alone, but instead requires networks of collaboration and technological mediation. Ideally, an actor operates independently but has connections with other actors and it is these actors and connections that link to form networks. As implied by Latour (2005), the ANT contextualizes the interactions and agency of social and technical *actants* in the BTD network.

The ANT emphasizes 'translation' as a key tenet in understanding actor-networks (Latour 2005). It presupposes the existence of one set of actors 'translating' by reinterpreting and displacing their interests or identities of other actors so as to align other actors' interests with their own. The focus on translation is important for expounding on the mechanism by which networks in the BTD process progressively evolve. ANT offers insights on how the networks associated with the process are formed, particularly how the interests and identities of various actors are translated (Heeks and Stanforth 2015). The study also incorporates elements of the SNT to examine actor interactions, defined as relationships that are determined by flow of information and tangible resources that shape the innovation output and decision

making behaviour. SNT is critical to understanding relationships and linkages between actors in the BTD process, in which the new HBVs function as the boundary object around which actors coalesce. The 'boundary' concept (Almekinders 2011; Tisenkopfs et al. 2015) is necessary to facilitate understanding of the operations of actors with different roles, interests and knowledge, and how this becomes apparent in the process of generating new HBVs.

3.3 Methodology

3.3.1 Study area and design

The study was conducted in central Uganda, which was once a main banana growing area until the 1990s when pests and diseases became a major constraint to production. The Uganda National Agricultural Research Organization (NARO) developed new HBVs to revamp banana production in the region. Four districts, namely Nakaseke, Luwero, Wakiso and Mukono, were purposively selected for this study based on their prior participation in the HBVs research and dissemination activities from 2008 to present.

The research design was largely qualitative, employing a case study approach (Yin 2013). The case study methodology which utilizes different research methods was appropriate to provide a detailed description and analysis of the BTD process particularly the actors, their interactions and perceptions. Stake (1995) characterizes three types of case studies: intrinsic, instrumental and collective. An *intrinsic* case study is typically undertaken to learn about a unique phenomenon whereas an *instrumental* case study uses a particular case (some of which may be better than others) to gain a broader appreciation of an issue or phenomenon. A *collective* case study involves studying multiple cases simultaneously or sequentially to generate a broad appreciation of a particular issue (Stake, 1995; Baxter and Jack, 2008). This case study can be categorized as an *instrumental* one since it uses the case of developing new HBVs to gain a broader understanding of *how* actor diversity, interactions and linkages informed the process and their implications for uptake. Further, the BTD process was studied as an exemplar of the more general phenomenon of agricultural technology development.

3.3.2 Study population and data collection

The study targeted different actors – individuals and organizations – along the nodes of the BTB and dissemination chain. Specifically, actors in research, extension, production (banana farmers), tissue culture and policy implementing agencies were identified and representatives of each actor category included in the study. The selection was purposive, basing on the actors' knowledge of what happened in the BTB process.

Data were collected using Focus Group Discussions (FGDs), Key Informant Interviews (KIIs) and document reviews. In total, 5 FGDs that involved 39 banana farmers were conducted and 20 actors interviewed as part of the KIIs. Broadly, the FGDs and KIIs focused on collecting data pertaining to the roles of different actors at different stages of BTB, nature of linkages among the actors, type of information and 'tangible resources shared and their flow mechanisms. The FGDs focused on exploring farmers' involvement and roles in the BTB process including: (i) stages in which they were involved; (ii) extent of their involvement; (iii) their level of interaction with other actors in the BTB process and (iv) feedback and information sharing. Data on barriers, constraints and motivating factors to uptake of HBVs and perceptions about HBVs were also collected from them. Each FGD was attended by eight farmers on average, with each session lasting about 2 hours. The FGDs were moderated by the researchers to ensure that each participant was given a chance to express their views. Data were digitally recorded after obtaining respondents' consent, and later transcribed. The data from FGDs and KIIs was supplemented with review of project reports and publications.

3.3.3 Data Analysis

Transcription of responses was conducted verbatim using express scribe transcription software. Where the local dialect (*Luganda*) was used during the interview, responses were first translated into English. The transcriptions were then imported into NVivo 10 software for thematic coding and analysis. An inductive approach was used to assign open codes to the individual narratives. The open codes were grouped into categories and these later constituted two broad themes (actor diversity and linkages) in the BTB process.

The Social Network Analysis (SNA) software (UCINET6, v6.584) was used to analyse linkages and interactions between actors in the BTD process. In the SNA, actors are represented as nodes while the joining lines represent relationships between the nodes/actors. The Network visualization tool (NetDraw 2.153) of Ucinet6 (Borgatti, Everett, and Freeman 2002; 2014) was used to illustrate and visualize the network maps. Network mapping helps to identify the different actors involved, their roles, linkages, and influence on the flow of information and resources. Structural positions of actors in the network were also generated to show direct alter ties to the ego. This was necessary to visualize the positions and relationships of actors in the BTD process and how they co-influence each other. Centrality measures were analysed to determine the strength of existing ties and the degree of centrality in the BTD network. In network analysis, the relation between actors is operationalized as a tie which can be represented as a binary measure. If an actor has a relationship with another actor related to information and/or resources, then the tie has a value of 1; otherwise it has a value of 0 (Borgatti and Foster 2003). A description of the key elements of the SNA is presented in Table 3.1.

Table 3.1. Elements of Social Network Analysis used in the study

Element	Definition
Node	Any individual, organization or other entity of interest
Tie	Links between nodes which denote interaction between nodes (actors)
Ego	Actor of interest within a network
Alter	In a tie linking an ego to another node, the other node is referred to as an 'alter'.
Network	Graphical representation of relationships that displays points to represent nodes and lines to represent ties
Network size	Total number of nodes in a network
Ego network	Network that only shows direct ties to the ego and not between alters
Network centralization	Degree to which a network revolves around a single node
Geodesic distance	The length of the shortest path between two nodes
Network density	Nodes that are actually tied as a proportion of all possible ties in a network. The density measures the "proportion of ties that are present" in a dichotomous relation.
Centrality	Measure of the number of ties that a node has relative to the total number of ties existing in the network as a whole; centrality measures include degree, closeness, and betweenness

Source: Borgatti, Everett, and Johnson (2013); Hanneman and Riddle (2005).

3.4 Results and discussion

3.4.1 Actor diversity in the BTD process

As discussed in Chapter 2 of this dissertation, the BTD process used to develop the HBVs comprised of five key stages with different types of actors participating at each stage. As shown in Figure 3.1, the stages included: (i) setting the research agenda; (ii) breeding; (iii) trait evaluation and selection; (iv) variety naming, release and registration; and (v) promotion and commercialization.

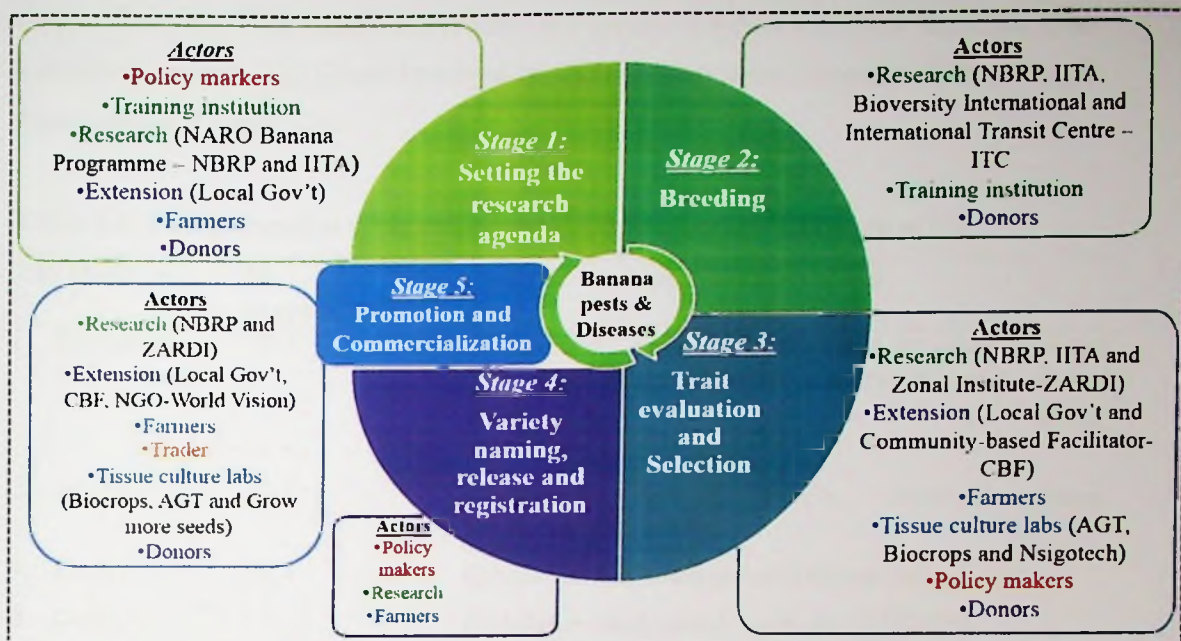


Figure 3.1 Actors involved at the different stages of the BTB process for new HBVs

Source: Study data, 2015

Key: Education and research, Intermediary, Enterprise, Demand, Support services actors

Seventeen actors were part of the BTB process, although not all of them were involved in all the stages (Figure 3.1). There were variations in number and category of actors involved at the different stages. Most actors were deliberately sourced by NARO at each stage, based on their perceived relevance and contribution to the research process. However, some actors such as the Non-government Organizations (NGOs) and traders who were already working with the banana growing communities deliberately sought to be involved. These represented an empowered actor with the capability to demand for involvement where they thought they could make a contribution. The NGOs were keen to participate in the research process because they perceived it to be an opportunity to improve the livelihoods of communities that were affected, while to the traders, this provided an opportunity to improve their business prospects.

Based on the elements of an AIS, Rajalahti, Janssen, and Pehu (2008) identify five actor domains namely; education and research; intermediary; enterprise; demand and

support domains. The domains represent the nature of actors and their functions in an innovation process. The actors involved in BTD process were categorized according to these domains (Table 3.2).

Table 3.2. Categorization of actors in the BTD process for HBVs (n = 17)

AIS Domain	% representation	Specific type of actors involved
1. Education and research	35.3	Agricultural research institutions at zonal, national and international levels, genetic research center (International Transit Centre - ITC) and training institution
2. Intermediary	23.5	Extension agents, NGOs, community-based facilitator and donors
3. Enterprise	29.4	Banana farmers and private tissue culture labs
4. Demand	5.9	Regulatory and policy agencies (MAAIF)
5. Support	5.9	Traders

Source: Study data, 2015 based on elements of an AIS (Rajalahti, Janssen, and Pehu, 2008).

Generally, most of the actors across the BTD continuum were agricultural researchers from research agencies (zonal, national and international) and universities, collaborating with NARO. Given that it is researchers from NARO who determined whom to involve, it is not surprising that the majority of actors were from research-related institutions, creating a “club” of people with similar ‘ideologies’ and ‘language’. This phenomenon, according to Rijswijk and Brazendale (2017), arises because actors from the same domain tend to trust each other more and to have a common focus. Across the BTD network, actors who offer support services such as media, financial institutions and agro-processing were non-existent. These actors would have been key in disseminating information about HBVs and providing credit and market services for those interested in investing in HBVs. This situation has critical implications for the functionality of the BTD network as well as uptake of the HBVs.

3.4.2 Actor linkages in the BTD network

SNA results revealed 80 connections/ties that existed among the 17 actors in the network. The ties represent linkages and interactions in relation to flow of information and tangible resources such as funds, inputs and materials (Figure 3.2).

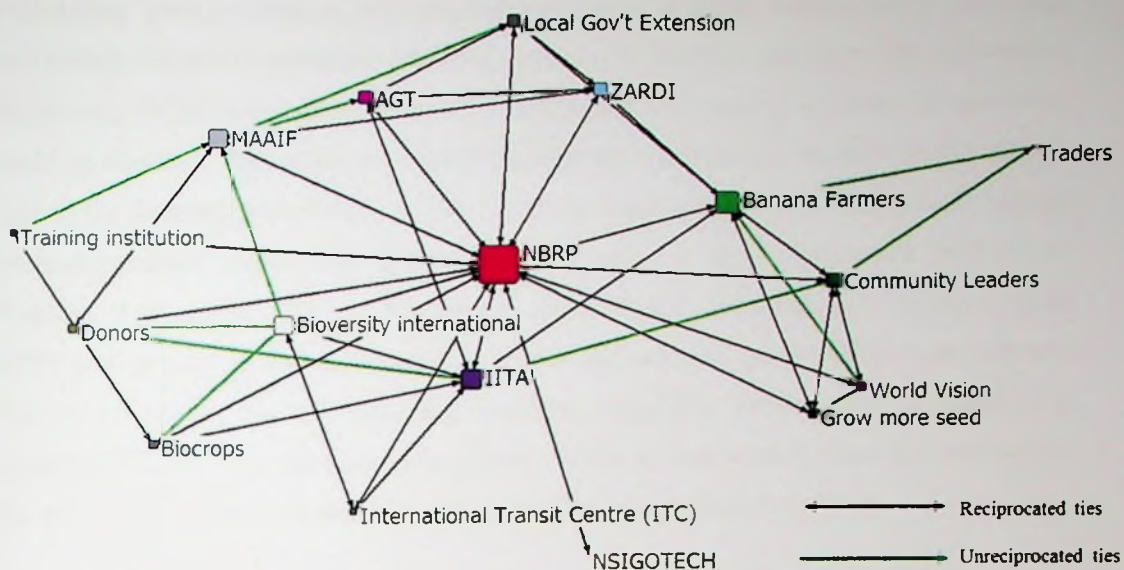


Figure 3.2 Network map for information and tangible resources between actors in the BTD process.

Key: AGT: Agro-genetic Laboratories; ZARDI: Zonal Agricultural Research and Development Institutes; NARO/NBRP: National Banana Research Program; NSIGOTECH: Tissue Culture Lab. *Source:* Study data, 2015

From the analysis, 68 of the 80 ties (85%) were reciprocated suggesting existence of both outward (*out-directed ties*) and inward (*in-directed ties*) linkages between the actors. Although actors were interlinked for various reasons and to varying degrees, knowledge seems to be the key commodity linking them. In this regard, Ramirez (2013) argues that knowledge exchange is embedded within the interactions that occur among actors and this is the dominant means by which networks influence and shape new technologies. Because the type of information exchanged varied with actor categories and the stage of technology development, the nature of actor networks that existed at the different stages of the BTD process were further explored.

Results of this additional analysis indicate that actor networks varied with progression of the BTD process. The information and resource requirements also differed according to stage, and this also applies to factors associated with actor interaction. At the planning stage, information seeking and sharing was the main reason for actor interactions and the linkages were mainly among actors who had interest in demand

articulation, such as farmers, extensionists and policy makers. Information at this stage was mainly related to problems affecting banana production. Actors mainly focused on diagnosing the different dimensions of the problem and sharing information on how it could be handled. This offers an explanation for the existence of actors who are mainly critical for demand articulation. At the breeding stage, interactions were mainly among research-oriented actors, with a few nodes in place – the International Institute of Tropical Agriculture (IITA), Bioversity International, International Transit Centre (ITC) and donors. These exchanged technical information on breeding protocols and flow of resources, mainly funds and breeding materials. These actors operated as a closed-out network for generating the HBVs. While the network at this stage was small, the nodes were densely connected with greater proximity between them.

At the evaluation stage, information was mainly shared on attributes of the new varieties to guide varietal selection. At this stage, most of the linkages were between farmers, community mobilisers and researchers with fewer ties between research and extension. In situations where extension agents were absent, community mobilisers substituted for their role. The farmers provided feedback on performance of the varieties, leading to double-looped information flow. At variety release stage, the interactions were guided by the supply of information to guide policy actors at this stage. Ties existed between research, farmers and policy actors. Policy actors needed evidence on performance of the new varieties, which created the need to link up with NARO for such information. In turn, the farmers provided scientists with their assessment since this is mandatory for release of new crop varieties. The nodes at this stage were densely connected, with researchers playing a key role of information seeking and sharing among actors. The promotion and commercialisation stage had the highest number of actors, but with weak connections. There were no arrangements in place for coordination of efforts.

Throughout the entire process (from planning to promotion), donors mainly supplied tangible resources in form of funds and as such had an influence on the decisions taken by actors, thereby shaping the innovation output. Although resource access is vital for realization of results, provision of these by certain categories of actors in an innovation network can lead to an imbalance decision-making of the different actors (Rijswijk and Brazendale 2017).

3.4.3 Structural positions of actors in the BTD network

Analysis of the BTD network structure indicated existence of one major group that mainly revolves around provision of technical information and tangible resources. Results show that NARO was central to the network performance and that it had close links with other research-oriented actors. These actors were highly interconnected, sharing a number of connections to form the main clique of the BTD network (Figure 3.3). Although smallholder farmers tended to form a sub-group mainly with extension-related actors in the BTD network, there were limited nodes with all possible ties. This scenario points to farmers' weak linkages with other actors in the BTD network resulting in low access to information and resources for uptake of new HBVs as well as limited feedback to inform decisions during technology development.

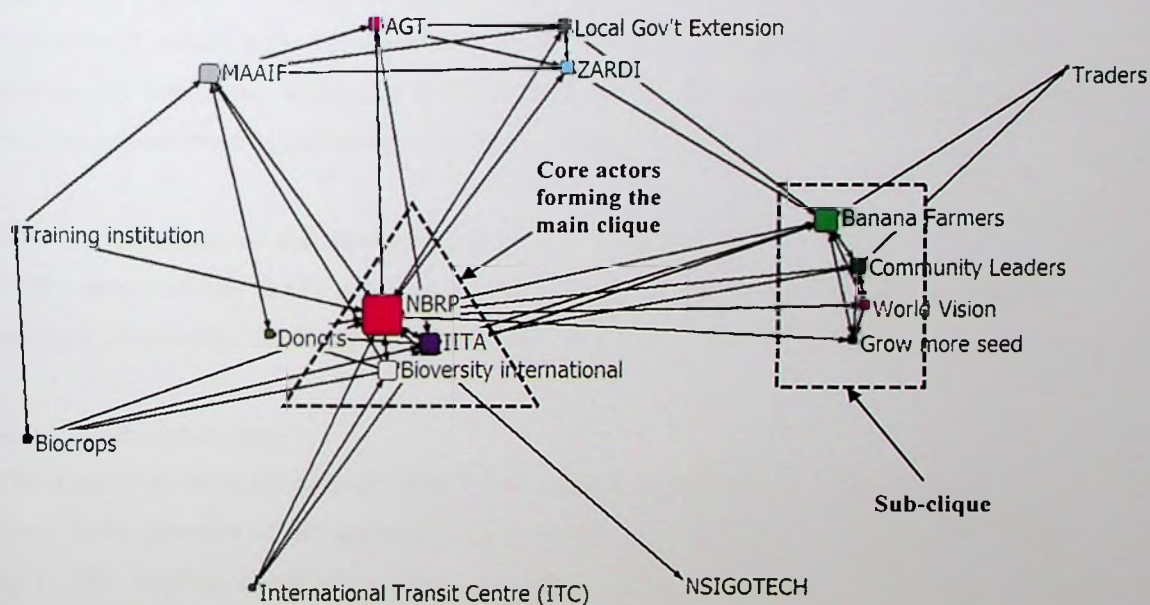


Figure 3.3 Nature of the BTD Network structure

Source: Study data, 2015

Cliques in networks indicate the maximum number of nodes that have all possible ties present among themselves (Spielman et al. 2010). Critical differences in the levels of

tie-strength in a network arise because individuals that share strong and multiple ties tend to form close-knit groups that interact frequently and create shared norms (Dowd et al. 2014). Hanneman (2001) suggests that cliques in a given network can offer opportunities and/or constraints due to power relations. Core actors tend to be closely connected to many actors and are thus in position to receive information or other resources from the network. Such actors tend to advance their individual interests with limited consideration of other actor interests in the network. This may affect integration of knowledge from the various actors, especially that of end-users, as a critical element for technology development and use (Eidt, Hickey, and Curtis 2012). Innovation as a systemic activity requires a network approach that allows different actors to engage in the process while integrating their diverse knowledge (Leeuwis and Aarts 2011). Therefore, the position of farmers in a network can offer opportunities on one hand and on the hand impose constraints for uptake of new HBVs. The current position of farmers in the BTD network implies that they have low access to information and resources, plus limited feedback and fewer connections to other actors, yet these are necessary to enhance the uptake of new HBVs. Other actors such as intermediaries are also poorly connected within the BTD network. Implicitly, the BTD process is driven by research-oriented actors rather than the end-users.

3.4.4 Performance of the BTD network

Performance of the BTD network was analysed on the basis of network density, strength of network “ties” and network centrality.

3.4.4.1 Network density

The density of the BTD network was 0.294, indicating that only 29.4% of the potential direct links between actors that could exist in this network are actually present (Table 3.3). This implies existence of weak linkages across actor categories in the BTD process, which indicates disparities in access to information and resources among actors, with a possible negative effect on the BTD process. Information and knowledge is transmitted more accurately and timely in networks where many actors are intensely and directly connected to each other. Such a scenario also indicates under-utilization of the potential relationships that would otherwise foster development and uptake of new HBVs. The average degree was 4.7, which represents the average number of links for each actor with other actors in the network. The geodesic distance results show that the

longest path was 3, while the average path length was 1.8. This represents the direct and indirect distances between actors in the network and the ease with which actors can connect with each other. The research-oriented actors seemed to exhibit strong ties and cohesiveness with each other in the network. NARO also had the shortest path and this could be attributed to the central linking and bridging roles it plays in the network. As reflected by the number of ties, research actors serve as a reliable source of information for the diverse actors in the network.

Table 3.3 Measures of network density for the BTD network

Measure	Value
Network density (number of ties)	0.294
Average degree (average number of ties a node has to other nodes)	4.706
Diameter (longest geodesic distance)	3
Average path length (no. of links)	1.776

Further, the analysis reveal that networks vary within the stages of the BTD process. Analysis of elements such as ties, degree distribution, network density and the average path length indicate differences in the existing actor network at the different stages (Table 3.4).

Table 3.4 Comparison of cohesion measures for networks at different stages of BTD process

Stage	Total no. of ties	Average degree	Network density	Average path length
1. Setting the research agenda	24	3.429	0.571	1.429
2. Breeding	20	3.333	0.667	1.333
3. Trait evaluation and selection	38	3.800	0.422	1.578
4. Variety naming, release and registration	8	2	0.667	1.333
5. Promotion and commercialization	33	3.667	0.458	1.542

Source: Study data, 2015

The actor network at the naming, registration and release stages was relatively smaller but closely connected as compared to other stages (Table 3.4). The high network

density of 0.667 indicates close connections among the actors at this stage. The breeding stage had few nodes of mainly research-oriented actors, with close ties and alter connections occurring. The number of actors at the trait evaluation and promotion stages were more compared to other stages although with the lowest densities. Implicitly, this indicates that actors at the trait evaluation and promotion stages are less densely connected. Based on the observed network densities and average path length, the results imply that actors at the breeding and variety release stages are better and more integrated than at any other stage of the BTD process. The integration of actors at the breeding stage could be attributed to the complexity and technicality involved at this stage of the process that necessitates actors to frequently interact and share information. However, the interactions were largely among research-oriented actors with far reaching implications for variety uptake.

The disparities between numbers of ties across the different stages is an important finding, which may imply that actors are not collectively aware of what happens at the different stages of the process. Although certain actor categories may not have roles to perform at certain stages of the BTD process, it is important that they are aware of what happens throughout the process. The implication of this finding for BTD is that research, and specifically breeders, need to identify strategies for integrating more actors in the entire technology development process, especially end-users whose knowledge integration is critical at all stages of the process to foster uptake of new varieties.

3.4.4.2 Strength of the ties

Results indicate that linkages exist at the higher tier level down to the lower level. Connections at both higher and lower levels are associated with flow of information and/or tangible resources that are required to facilitate development and uptake of new HBVs. At the higher level, close ties exist mainly between actors in the education and research domains. Analysis of the “strength” of ties is based on the extent to which these are reciprocated rather than the intensity of interaction (Hanneman and Riddle 2005). In networks, individuals with stronger, more informed and more effective ties are regarded as more resilient to generic change events than those with weaker ties (Dowd et al. 2014).

Strong ties were mainly exhibited between the national and international research groups as indicated by the reciprocated ties and geodesic distances. The strong ties could be attributed to technical support (mainly knowledge) that is provided by the international level scientists to national level scientists. Other studies have also found strong ties to be more beneficial and associated with exchange of complex knowledge and information (Fritsch and Kauffeld-Monz 2010). Existence of strong linkages between international and national level research organizations is useful in promoting information and knowledge flow as a necessary pre-requisite for successful development of new technologies. However, the findings suggest that the BTD network may be insufficiently configured to provide actors, particularly the smallholder farmers and intermediary actors, with ties that facilitate uptake of new technologies such as the new HBVs. Suvedi, Ghimire, and Kaplowitz (2017) argue that development of new technologies alone even though appropriate may not lead to its automatic uptake. Adoption of innovation is an interactive process and as such, farmers learn about the new technologies through interactions and linkages with other actors. Therefore, support to strengthening smallholder farmers' and intermediaries' abilities to build stronger networks with other actors is necessary to foster uptake of technologies.

3.4.4.3 Network centrality

Centrality of the BTD network was determined based on the results of the three most important measures, namely, network degree, closeness and betweenness (Borgatti, Everett, and Johnson 2013). Centrality measures the importance of an actor in a network by capturing the level of connectedness and status. It also measures the number of ties each node possesses which helps to explain actors' positions in a network based on their *in degree* (prominence) and *out degree* (influence). Closeness centrality measures the average of the shortest path link from one node to every other node in a network, while the betweenness centrality indicates the number of times an actor is located at the shortest path of all pairs of actors who are not linked to each other directly. The lower the average shortest path link, the closer a node is to other nodes in a network and a higher betweenness measure indicates an actor in the most favoured position of a network. Therefore, centrality measures were used to identify the most important actor(s) with the highest number of direct connections, and those that played the most dominant and influential role in the BTD network.

Results of the degree measure of centrality identify only four main actors with high degree measures of centrality; NARO, farmers and IITA (Table 3.5). However, NARO (NBRP) had the highest degree centrality relative to other nodes, with 93.8% of the existing direct linkages present in the network being with this actor.

Table 3.5. Descriptive measures of centrality in the BTD process

Actor	Degree	Out degree	In degree	Closeness	Betweenness
NARO	0.938	0.938	0.938	1.063	55.350
IITA	0.438	0.438	0.438	1.500	7.783
Bioversity International	0.250	0.438	0.344	1.563	4.133
International Transit Centre (ITC)	0.188	0.188	0.188	1.875	0.000
Training institution	0.125	0.188	0.157	1.875	0.333
ZARDI	0.313	0.313	0.313	1.688	0.867
Banana Farmers	0.563	0.438	0.501	1.438	15.600
Extension services	0.313	0.250	0.282	1.688	0.867
World Vision	0.125	0.250	0.188	1.750	0.000
Community Leaders	0.250	0.375	0.313	1.625	5.400
Grow more seed	0.250	0.188	0.219	1.750	0.000
AGT	0.313	0.250	0.282	1.750	0.917
Biocrops	0.250	0.188	0.219	1.813	0.833
NSIGOTECH	0.063	0.063	0.063	2.000	0.000
Traders	0.063	0.063	0.063	2.313	0.000
MAAIF	0.313	0.313	0.313	1.625	4.667
Donors	0.250	0.125	0.188	1.813	0.250

Source: Study data, 2015

The NBRP also had the highest out degree (influence) and in degree (prominence) and betweenness centrality (favoured position). NARO still had the lowest average shortest path links of 1.063, indicating that this actor was the most closely connected to other nodes in the network. The highest betweenness value of 56.6 for NARO reflects this actor as a key player in the network and with a high potential to connect and control the relations between other actors. The smallholder farmers had the second highest degree

centrality and average shortest path links which could be attributed to their links with mainly extension-related actors.

Positions of individuals within networks can constrain or enhance their ability to exercise influence (Mulema 2012). Actors with more opportunities such as NARO can exert more influence in decision-making in a network relative to other actors. Additionally, actors with a higher degree of centrality in a network are more likely to be major channels of information and knowledge (Ramirez 2013). In the BTB network, NARO does not only serve as a conduit for information among actors but also plays a prominent and influential role in the process of developing new HBVs. Although the prominence of the research-oriented actors could be attributed to the technical nature of the process, the diminished level of other actors such as farmers depicts their passive role. Ganpat et al (2009) note that in most agricultural technology development initiatives, the active role of smallholder farmers is largely underestimated. In most cases, technology development remains an exclusive domain of researchers although farmers tend to have considerable interest in the process. This potentially results in a mismatch between breeding and end-users priorities (Assefa et al. 2014).

3.5 Conclusions and implications

Increasing interest in engaging diverse actors in technology development processes reflects the desire to increase uptake of new technologies. This chapter analysed the notion of actor diversity and interaction in the BTB process and how this shapes the uptake of new HBVs by end-users. The study highlights the positions and roles of the different actors in the BTB network and how these impact the performance of the BTB process.

Overall, the study findings confirm the value of actor networks in a technology development process and the central role played by the different actors. Existence of diverse actors represents the different roles performed and the diversity of interests in the process, which reflects power relations in the BTB network. The main actor in the network was the NBRP of NARO, which largely determined who was to be involved in the BTB process, based on entrants perceived capacities and interests. As such, performance of the BTB network was dominated by research-oriented actors placing

research in a central position of the process. Consequently, research-oriented actors tended to exert a strong influence on the BTD process, potentially crowding out smallholder farmers, who are the pivotal end-user actors of new technologies as well as other actors who play non-research roles. The position of smallholder farmers was more-or-less peripheral in the network. They were loosely connected to other actors, yet their involvement in the co-development of a new technology is a critical component for understanding the value of the technology to their needs and eventual uptake. The centrality of NARO in the BTD network depicts a main focus on technology development rather than promotion of technology uptake. This hence questions the neutrality of research organisations in technology development particularly to what extent they (research) aim to meet their own interests in the process.

This chapter therefore conclude that although the aim of the BTD process was to deliver new technological innovations – the HBVs – to end-users including smallholder farmers, their influence on the process was minimal given their position in the BTD network. In addition, intermediary actors particularly extension agents and commodity traders were also largely in the periphery of the BTD network, with minimal influence on the process. From a practitioner's perspective, actors in the enterprise, intermediary and support service domains need to be actively involved in the technology development process to enhance commercialisation and uptake of new HBVs. Such involvement can contribute to strategic optimization of knowledge integration through the participation of different actors. Although this strategy could be context-specific, it can be achieved through the use of already proven participatory approaches that aim to engage a wide range of actors.

From a policy perspective, the results point to a need to strengthen linkages between the diverse actors in the technology development process. This will require strengthening application of the systems approach in agricultural research such that the process seeks to engage more actors, especially those in the intermediary, enterprise and support service domains, as essential components for a more vibrant and relevant agricultural research system. Furthermore, policies, approaches and strategies such as multi-actors platforms that enhance actor interactions in a technology development process, but which also create more space for smallholder farmers to participate

effectively in technology development networks as a strategy to improve uptake, should be explored.

Whereas the BTD process reflects a wide range of actors involved, actors in the support domain were lacking while those in the enterprise and intermediary domains had minimum influence. Future research should focus on analysing the perspectives of different actors in agricultural technology development networks and how this affects their level of commitment to commercialization and uptake of the resultant new technologies. Such studies could also assess drivers of interaction among the different actor categories in agricultural technology development processes.

References

- Almekinders, C. 2011. 'The joint development of JM-12.7: A technographic description of the making of a bean variety', *NJAS-Wageningen Journal of Life Sciences* 57(3): 207-216.
- Assefa, T., L. Sperling, B. Dagne, W. Argaw, D. Tessema, and S. Beebe. 2014. 'Participatory Plant Breeding with traders and farmers for White Pea Bean in Ethiopia', *The Journal of Agricultural Education and Extension* 20(5): 497-512.
- Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The qualitative report*, 13(4), 544-559.
- Borgatti, S. P., M. G. Everett, and L. C. Freeman. 2014. 'Ucinet *Encyclopedia of Social Network Analysis and Mining*', New York: Springer.
- Borgatti, S. P., M. G. Everett, and J. C. Johnson. 2013. '*Analyzing social networks*'. London: Sage.
- Borgatti, S. P., and P. C. Foster. 2003. "The network paradigm in organizational research: A review and typology", *Journal of Management* 29(6): 991-1013.
- Ceccarelli, S. 2009. Main stages of a plant breeding programme. In S. Ceccarelli, E. Guimares, and E. Weltzien (eds.) *Plant Breeding and Farmer Participation*, pp. 63-74. Food and Agriculture Organization (FAO), Rome.
- Donovan, K. P. 2014. "'Development' as if We Have Never Been Modern: Fragments of a Latourian Development Studies", *Development and Change* 45(5): 869-894.
- Dowd, A. M., N. Marshall, A. Fleming, E. Jakku, E. Gaillard, and M. Howden. 2014. 'The role of networks in transforming Australian agriculture', *Nature Clim. Change* 4(7): 558-563. doi: 10.1038/nclimate2275
- Eidt, C. M., G. M. Hickey, and M. A. Curtis. 2012. "Knowledge integration and the adoption of new agricultural technologies: Kenyan perspectives", *Food Security* 4(3): 355-367. doi: 10.1007/s12571-012-0175-2
- Fritsch, M., and M. Kauffeld-Monz. 2010. 'The impact of network structure on knowledge transfer: an application of social network analysis in the context of regional innovation networks', *The Annals of Regional Science* 44(1): 21-38.
- Ganpat, W. G., W.-A. P. Isaac, R. A. I. Brathwaite, and I. Bekele. 2009. "Farmers' attitude towards a participatory research method used to evaluate weed management strategies in Bananas", *Journal of Agricultural Education and Extension*, 15(3), 235-244
- Hanneman, R. A. 2001. "Introduction to social network methods". CA: University of California, Riverside.
- Hanneman, R. A., and M. Riddle. 2005. "Introduction to social network methods". CA: University of California, Riverside.

- Heeks, R., and C. Stanforth. 2015. "Technological change in developing countries: opening the black box of process using actor-network theory", *Development Studies Research* 2(1): 33-50.
- Johnson, B., and A. D. Andersen. 2012. *"Learning, Innovation and Inclusive Development: New perspectives on economic development strategy and development aid"*. Aalborg, Denmark: Aalborg University Press.
- Knickel, K., G. Brunori, S. Rand, and J. Proost. 2009. "Towards a better conceptual framework for innovation processes in agriculture and rural development: from linear models to systemic approaches", *Journal of Agricultural Education and Extension* 15(2): 131-146. doi:10.1080/13892240902909064.
- Latour, B. 2005. *Reassembling the Social: An Introduction to Actor-Network Theory*. Oxford: Oxford University Press.
- Leeuwis, C., and N. Aarts. 2011. "Rethinking Communication in Innovation Processes: Creating Space for Change in Complex Systems", *The Journal of Agricultural Education and Extension* 17(1): 21-36. doi: 10.1080/1389224X.2011.536344
- MAAIF (Ministry of Agriculture, Animal Industry and Fisheries). 2010. *Agriculture for Food and Income Security. Agricultural Sector Development Strategy & Investment Plan: 2010/11 - 2014/15*. MAAIF. Kampala, Uganda
- Mulema, A. A. 2012. *"Organization of innovation platforms for Agricultural Research and Development in the Great Lakes Region of Africa"*. PhD dissertation, Iowa State University.
- Rajalahti, R., W. Janssen, and E. Pehu. 2008. *Agricultural innovation systems: From diagnostics toward operational practices: Agriculture and Rural Development Discussion Paper 38*. Washington, DC: World Bank.
- Ramirez, A. 2013. "The Influence of Social Networks on Agricultural Technology Adoption", *Procedia - Social and Behavioral Sciences*. 79 (2013): 101-116. doi: <http://dx.doi.org/10.1016/j.sbspro.2013.05.059>
- Rijswijk, K., and R. Brazendale. 2017. "Innovation networks to stimulate public and private sector collaboration for advisory services innovation and coordination: the case of pasture performance issues in the New Zealand dairy industry", *Journal of Agricultural Education and Extension* 23(3): 245-263.
- Spielman, D. J., K. Davis, M. Negash, and G. Ayele. 2010. "Rural innovation systems and networks: findings from a study of Ethiopian smallholders". *Agriculture and Human Values*, 28(2), 195-212. doi: 10.1007/s10460-010-9273-y
- Stake, R. E. 1995. *The art of case study research*. Thousand Oaks, CA: Sage Publications Ltd.
- Suvedi, M., R. Ghimire, and M. Kaplowitz. 2017. "Farmers' participation in extension programs and technology adoption in rural Nepal: a logistic regression analysis". *The Journal of Agricultural Education and Extension* DOI:10.1080/1389224X.2017.1323653

- Tisenkopfs, T., I. Kunda, S. šūmane, G. Brunori, L. Klerkx and H. Moschitz. 2015. "Learning and Innovation in Agriculture and Rural Development: The Use of the Concepts of Boundary Work and Boundary Objects", *The Journal of Agricultural Education and Extension* 21(1): 13-33.
- Wood, B. A., H. T. Blair, D. I. Gray, P. D. Kemp, P. R. Kenyon, S. T. Morris, and A. M. Sewell. 2014. "Agricultural Science in the Wild: A Social Network Analysis of Farmer Knowledge Exchange", *PloS one* 9 (8): e105203. doi: 10.1371/journal.pone.0105203.
- World Bank. 2006. *Enhancing agricultural innovation: How to go beyond the strengthening of research systems*, World Bank, Washington DC, p. 135.
- Yin, R. K. 2013 *Case study research: Design and methods*. Fifth Edition. Sage, Thousand Oaks.

CHAPTER 4: DETERMINANTS OF UPTAKE OF NEW HYBRID BANANA VARIETIES BY SMALLHOLDER FARMERS IN CENTRAL UGANDA³

Abstract

While advances in plant breeding have led to generation of improved new Hybrid Banana Varieties (HBVs) with enhanced yield potential, these have been received with mixed feelings and perceptions among the farming communities in Uganda. However, limited empirical evidence exists on the relative importance of variety attributes along with the farm and farmer characteristics and institutional factors in the uptake of new HBVs. This chapter utilizes data from a cross-sectional survey of 242 smallholder farmers in Nakaseke and Luwero districts in Central Uganda, to analyze the empirical determinants of adoption and intensity of adoption of new HBVs using the Double-Hurdle model. Descriptive and inference statistics were also used to characterize and describe the sample. The findings reveal that only 36% of the households grew HBVs. Land allocated to banana production, access to relevant information and neighborhood effects significantly affected adoption of new HBVs. Once the adoption decision had been made, household size and a farm household's interactions with other actors significantly influenced the intensity of adoption. Production and consumption related attributes are associated with adoption and intensity of adoption of HBVs. The study provides insights on the need for integration of both production and consumption related attributes in breeding efforts for new cooking banana varieties. Breeders need to target development of varieties with multi-traits that meet end-users' preferences and diverse needs through involvement of these users. Facilitating establishment of multi-actor platforms that bring together the different actors to share information and learn might be useful in increasing the intensity of adoption. This will require research to prioritize end-users trait preferences and trade-offs associated with local and hybrid bananas as key to guide future banana breeding programs.

Key words: New Hybrid Banana Varieties, uptake, banana farmers, Central Uganda

³ Manuscript accepted for publication by the *Journal of Sustainable Development*

4.1 Introduction

Progress towards attainment of food security remains a challenge in many Sub-Saharan African (SSA) countries partly due to low agricultural productivity (FAO, IFAD & WFP 2015). Technological improvements, particularly yield enhancing technologies offer opportunities for improving agricultural productivity and ensuring global food security (Edgerton, 2009). Therefore, efforts geared at agricultural research and development continue to receive considerable attention with investments directed towards development of new crop varieties for priority crops.

Banana is one of the crops critical to global food security in SSA, and in Uganda it is a priority crop since it is a source of food and income for many households (Eledu, Karamura & Tushemereirwe, 2014; Ministry of Agriculture, Animal Industry and Fisheries [MAAIF], 2010). The East African highland cooking banana type, locally known as '*Matooke*', is the most important group of cultivars grown and consumed in Uganda (Karamura, Frison, Karamura & Sharrock, 1998). Production of cooking banana in the country is mainly by smallholder farmers who depend on the crop as a source of food and income.

Despite the value and benefits, banana production levels in the country have not met the demand. Deficit in supply is attributed to low productivity which is estimated at less than 30% of the attainable yield, and is a result of pests (mainly banana weevil and nematodes), diseases (*Fusarium* wilt, bacterial wilt and black Sigatoka) and drought stress (Viljoen, 2010; Tushemereirwe et al., 2014). Since 1994, the Uganda National Agricultural Research Organization (NARO) through the National Banana Research Program (NBRP) has been conducting research to produce varieties that are either resistant and or tolerant to pests and diseases. A combination of approaches including introduction and evaluation of accessions, conventional breeding, transgenic breeding and biotechnology have been exploited in efforts to meet the end-user needs. In the 1990s, the NBRP introduced FHIA hybrids with resistance to weevils, black sigatoka and *Fusarium* wilt from the Honduras Foundation for Agricultural Research (Karamura et al., 2016). Studies indicate that the introduced hybrids did not meet the needs of end-users especially banana farmers in the lowland areas around the Lake Victoria crescent zone (Edmeades et al., 2007). As a result, less than 50% of the introduced hybrids met

the needs and preferences of end-users (Barekye, 2009) which prompted the NBRP to intensify breeding efforts towards development of cooking banana (*matooke*) varieties with desirable attributes. In collaboration with CGIAR centers such as the International Institute of Tropical Agriculture (IITA), the NBRP embarked on a banana breeding programme that has led to new cooking banana type hybrids herein referred to as the new Hybrid Banana Varieties (HBVs). To-date, two HBVs (KABANA 6H and KABANA 7H) have been released and these have been further promoted through uptake pathways as a means of restoring production levels especially in central Uganda that was devastated by pests and diseases (Nowakunda et al., 2015).

While the advances in plant breeding have made it possible to develop varieties with resistance to a range of biotic and abiotic constraints, reports indicate that the new HBVs have been received with mixed feelings and perceptions among the farming communities in Uganda (Kagezi et al., 2012, Karamura et al., 2016). Most of the HBVs have been detested especially in central Uganda although this was the main targeted region for the varieties. Use of the varieties is generally low, ranging between 5 - 15% nationally, and estimated at about 11.3% in central Uganda (Kagezi et al., 2012).

From the innovation adoption literature, several studies have assessed the factors influencing agricultural technology adoption in Sub-Saharan Africa. These factors range from technology specific attributes; farmer, household and farm characteristics; and institutional factors (Figure 1). Technology specific attributes such as production related (pest and disease resistance, tolerance to drought, tolerance to poor soils) and consumption related attributes (taste, colour and texture among other) have been found to be important determinants of adoption (Edmeades, Smale & Karamura, 2005; Edmeades, Phaneuf, Smale & Renkow, 2008; Katungi, Sperling, Karanja, Farrow & Beebe, 2011; Lunduka, Fisher & Snapp, 2012). Thus, adoption is influenced by subjective assessments of technology specific attributes. Among the farmer, household and farm characteristics that influence technology adoption include farmer's age, sex, education, household size, income and farm size while the institutional factors include membership to farmers' groups, access to credit, markets, agricultural information and extension services (Feder et al., 1985; Nkonya, Schroeder & Norman, 1997; Doss, 2006). Past studies have reported mixed findings on the influence of these factors on

agricultural technology adoption. For instance, farmers' education level has been reported to have a positive and negative influence on adoption under different circumstances. Although studies such as Kiyingi, Edriss, Phiri, Buyinza and Agaba (2016); Bezu, Kassie, Shiferaw and Ricker-Gilbert (2014); and Katungi et al. (2011) report a positively significant relationship between education level and adoption of agricultural technologies, others such as Kikulwe et al. (2011) and Akankwasa et al. (2013) found a negatively significant relationship between education level and adoption of crop varieties. Further, Katungi et al. (2011) reported that while education had a positive effect on area share allocated to common bean varieties with relatively preferred attributes, it reduced land allocation to the risk increasing variety when other factors including farm size are controlled. Similarly, while some studies (Doss, 2006; Cavatassi, Lipper & Narloch, 2011; Lunduka, Fisher & Snapp, 2012; Barungi et al., 2013) found that adoption of agricultural technologies was positively influenced by farm size, other studies (Yaron, Dinar & Voet, 1992) found a negatively significant relationship between farm size and technology adoption. The negative influence of farm size is mainly explained in terms of farmers' risk aversion since a new technology may entail unknown risks.

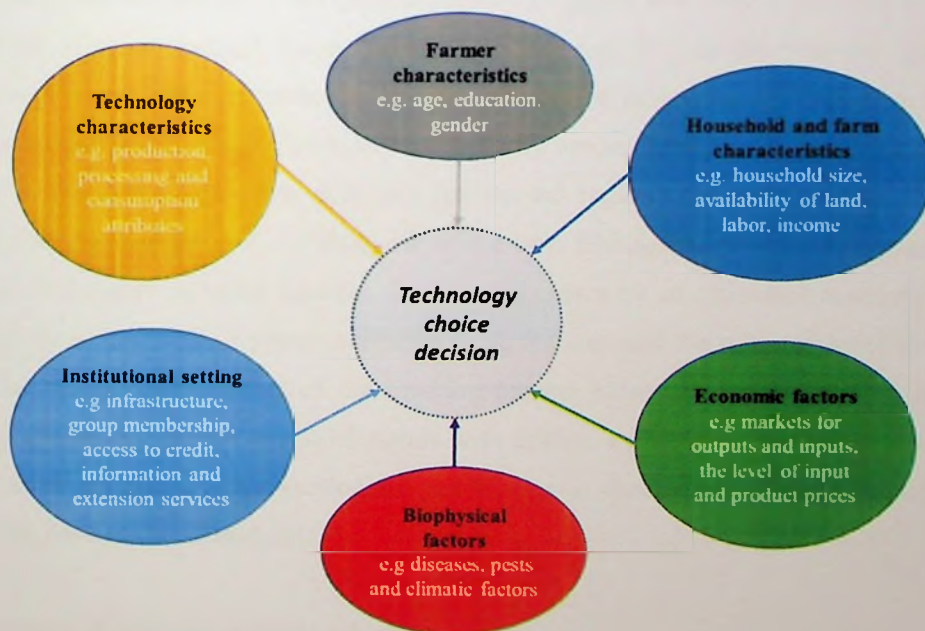


Figure 4.1 Conceptual model for factors influencing agricultural technology adoption and intensity of adoption.

Source: Adapted from Sodjinou (2011, pg 34).

Although several empirical studies exist on adoption, few studies have specifically analyzed factors influencing adoption of cooking banana hybrid varieties in Uganda. Limited empirical evidence exists on the relative importance of variety attributes along with the farmer, household and farm characteristics and institutional factors in the uptake of new hybrid banana varieties. Existing studies have mainly focused on early-stage (ex-ante) adoption of these varieties to explain the likelihood of farmers' adoption and consumers' willingness to purchase the matooke hybrids (Akankwasa, Ortmann, Wale & Tushemereirwe, 2013, 2015). None of the existing studies on cooking banana hybrids has jointly analyzed the factors influencing adoption and intensity of adoption decisions thus justifying further investigation. This study explores the empirical determinants of uptake (adoption and intensity) of new HBVs among smallholder farmers in central Uganda.

4.2 Methodology

4.2.1 Study area

The study was carried out in the Central region of Uganda that covers the Lake Victoria Crescent Agro-ecological Zone (LVCAZ). The region was purposively selected because it is one of the major banana-producing regions in the country. The crop is also highly valued for its contribution to food security among households and high market value in the urban areas that dominate the central region. According to the Uganda Census of Agriculture (UCA) 2010, out of the 807, 000 agricultural households in the region, 58 % grow cooking bananas. The crop is grown on an estimated mean plot size of 0.30 ha which is the highest compared to all regions and the national level mean of 0.28 ha (UCA, 2010). Most of the cooking banana plantations (64%) in the central region are largely grown in mixed stands with coffee, a practice that farmers consider to be more resilient to agro-ecological and economic shocks and stresses (van Asten, Wairegi, Mukasa & Uringi, 2011).

4.2.2 Study design and sample selection

The study reported in this chapter employed a quantitative research design and data were obtained through a cross-sectional survey conducted in February 2016. The study aimed at identifying factors that influence uptake and intensity and hence this design

was most suitable since it collects data that can be used to compare different groups of farmers i.e. users and non-users of new HBVs at a single point in time. A questionnaire was administered to every respondent to generate data on different variables of interest.

A multi-stage sampling procedure employing both non-probability and probability sampling techniques was used. Non-probability sampling was employed to select study sites and generate the sampling frame. In terms of study sites, two districts of Nakaseke and Luwero were purposively selected due to their prior participation in banana research and development activities, and efforts by the NBRP to sustain banana production using the new HBVs in the two districts. In each district, one major banana growing sub-county that participated in research activities - Kasangombe and Makulubita sub-counties in Nakaseke and Luwero districts respectively was purposively selected. This was then followed by selection of only the participating parishes. Based on that procedure, Bukuuku, Bulyaake, Nakaseeta and Sakabusolo parishes were selected from Nakaseke district while Mawale parish was selected from Luwero district.

The non-probability sampling further involved purposive selection of banana farmers in each of the selected parishes. Banana farmers were purposively targeted because the study focused on HBVs and these were the farmers that were presumed to possess the information needed for the study. Therefore, with the help of community-based facilitators (CBF), names of all banana farmers in the selected parishes were compiled to generate the sampling frame with a total of 1,689 banana farmers. The total size of the sampling frame was then used to compute the sample size using Cochran (1977) and Krejcie & Morgan (1970) formula indicated below;

$$n = \left(\frac{pqZ_{1-\alpha/2}^2}{d^2} \right) \times DF$$

Where: p = is the prevalence, q=1-p, d = precision (5%), $Z_{1-\alpha/2}$ = desired level of confidence, $\alpha = 0.05$ (1.96) and DF = Design effect

Since $n/N > 0.05$, the correction factor is applied;

$$n_f = \frac{n}{1 + (n/N)}$$

Based on the formula, the computed sample size was 257 farmers. The proportionate to size method was used to compute the number of farmers to be drawn from each of the selected parishes (Table 4.1).

Table 4.1 Number of farmers targeted for the study

Parish	Total number of farmers listed	Proportion	Number of farmers selected
Bukuuku	347	0.21	53
Bulyaake	355	0.21	54
Nakaseeta	443	0.26	67
Sakabusolo	161	0.10	25
Mawale	383	0.23	58
Total	1,689	1	257

During the actual data collection, 242 banana farmers were successfully interviewed representing a response rate of 94.2% of the targeted 257.

4.2.3 Data collection

Primary data were collected from the 242 randomly selected banana farmers using a semi-structured questionnaire. To test for suitability and reliability, the survey tool was pre-tested and then modified for clarity and sequencing of questions based on the pre-test experiences and results. Data were collected through face-to-face interviews with the selected banana farmers. Data were collected on individual and household characteristics, farm characteristics, and institutional and access-related factors, banana varieties grown and their attribute preferences. Farmer preferences for the varietal attributes (production and consumption) were measured using a five-point ranking scale where, 1=least important and 5=most important.

4.2.4 Data processing and analysis

Data were entered using the Census and Survey Processing application (CSPPro 6.2) and analyzed using STATA, version 14. General exploratory analysis was done using the gladder command in STATA to determine the distribution of the data for the continuous variables such as age, education, household size, income, farm size and proportion of land allocated to bananas and new HBvs. Variables that did not fit a normal distribution were transformed before being subjected to further analysis

(difference of means and regression analysis) Further diagnostic tests were run to establish whether there was any significant correlation between any two independent variables to be included in the model estimation. Most of the explanatory variables were found to be independent except between membership to groups and number of groups that members of a given household belong to, and also sex of the farmer and household headship. As such, the variable household headship and membership to groups were dropped in estimating the models to avoid getting biased estimates emanating from Multicollinearity. Correlations between the 14 variety attribute preferences also indicated very high correlations and significant coefficients between several attributes. The attributes were therefore subjected to a factor analysis procedure using principal components method to extract a set of factors to be treated as uncorrelated variables to handle multicollinearity in the econometric analysis. The Principal Component extraction method is more appropriate if one is interested in practical application and real world situation (Field, 2013). Based on the criterion of an Eigenvalue greater than 1 (Kaiser, 1960), the 14 variety attributes were grouped into three independent attributes according to three unobserved factors loadings in absolute terms (Table 4.2). The three (3) factors explained 65.2% of total variance in the stated preferences for variety attributes subjected to factor analysis. Specifically, factors 1, 2 and 3 accounted for 43.7%, 11.7%, and 9.8% of the total variance respectively. The first factor seems to indicate production related attributes and loads most strongly on variables related to biotic and abiotic stress resistance or tolerance. The second factor loading seem to indicate consumption related attributes whereas the third factor reflects agronomic related characteristics based on the type of attributes that factor together. Thus, the factors (1-3) are interpreted as: production traits related index, consumption attribute related index and agronomic traits related index. These three underlying latent factors for preferences for variety attribute index were included in the econometric analysis as explanatory variables.

Table 4.2 Factor Loadings for varietal attribute preferences using a Factorial Analysis, (n=87)

Variety attribute	Factor Loadings*		
	Factor 1	Factor 2	Factor 3
Tolerance to drought	0.809		
Tolerance to poor soils	0.791		
Tolerance to pests and diseases	0.701		
Bunch size	0.685		
Early maturity period	0.614		
Sucker production	0.610		
Taste		0.830	
Texture when cooked		0.679	
Flavor		0.677	
Color of the food when cooked		0.652	
Plant height			0.892
Resistance to wind			0.788
Eigenvalues	5.241	1.401	1.177
% of variance explained	43.675	11.674	9.808

*Extraction Method: Principal Component Analysis and Rotation Method: Varimax with Kaiser Normalization. Only attributes with absolute factor loadings > 0.5 are included.

Notes: Farmer preferences scored on a scale of 1-5 and then recorded as a binary, where 1=important attribute, 0=not important.

Source: Survey data, 2016.

Descriptive methods (frequencies, percentages, means and tests of difference between variables) were used obtain a frequency of responses for the most popular banana varieties grown and to characterize households by new HBVs users and non-users. The t-test static (for continuous variables) and chi-square (for categorical variables) were used to determine the differences between households that grow and those that don't grow new HBVs. The t-test static was also used to determine the level of involvement in decision-making between women and men at household level regarding uptake of new HBVs. Average scores representing farmers preferences for production and consumption attributes across variety types (local vs. hybrids) grown were also generated. A higher mean aggregate score indicates a stronger rating for these particular attributes in a given variety type. Finally, the Double-Hurdle Model (Cragg, 1971) was used to analyze the factors influencing the adoption and intensity of adoption of new HBVs.

4.2.5 Analytical framework

A farmer's decision to adopt or not to adopt new HBVs is binary in nature and can be measured with two possibilities: adoption ($Y=1$) or no adoption ($Y=0$). Therefore, new HBVs adoption decision is a binary statistic. The study aimed to predict the probability of new HBVs adoption of a random farmer in the population represented by the sample. The adoption question can be presented in detail as equation 1 adapted from Wooldridge (2009).

$$P(y = 1|x) = G(\beta_k x_k) \quad 1$$

Where $P(y = 1|x)$ is the probability that one adopts the HBVs (*dependent variable*) given: farmer, household and demographic characteristics; farm characteristics, institutional factors and variety attributes (x_k). β_k is the vector for the coefficients to be estimated.

In adoption literature, many nonlinear functions have been suggested for the function G in 1. All suggestions are aimed at making sure that the probabilities are between zero and one. The most commonly used functions are the standard normal distribution function which results in the probit model and the standard logistic distribution function which leads to the logit model (Greene & Hensher, 2010; Wooldridge, 2009). In most applications, the choice between these two models does not seem to make much difference (Greene, 2008). Indeed, the two statistical distributions are very close to each other, except at the tails. Maddala (1983) argues that the results using the probit and the logit model are not likely to be very different, unless the samples are large to have enough observations at the tails. However, the probit specification has an edge over the Logit model in cases of small sample sizes - less than 1000 observations (Atemnkeng, Boboh, & Kenyi, 2010). Thus, with a sample size of 242 farmers, the present study employed a probit model to assess the determinants of farmers' decision to use or not to use the new HBVs.

Further to adoption, this study predicts how much of the new HBVs a farmer would grow (intensity) which is measured as the proportion of land a farmer allocates to the new HBVs out of the total land allocated to banana production. Intensity to non-

adopters becomes an automatic zero. It is assumed that a farmer chooses to adopt new HBVs and then decides on how much of the HBVs to grow. This implies that adoption precedes intensity leading to two equations (2&3) that is solved by Double-Hurdle model estimations following the arguments by Kiyangi et al. (2016) who compared Censored Tobit Model with Double-Hurdle model and found the later more superior than the former.

$$d_i^* = \alpha z_i + \mu_i \quad 2$$

$$y_i^* = \beta x_i + \varepsilon_i \quad 3$$

Where

$$d_i = \begin{cases} 1, & \text{if } d_i^* > 0 \\ 0, & \text{if } d_i^* \leq 0 \end{cases} \text{ and } y_i = \begin{cases} y_i^*, & \text{if } y_i^* > 0 \text{ and } d_i^* > 0 \\ 0, & \text{if otherwise} \end{cases} \quad 4$$

Where d_i^* is the latent variable describing a farmer's decision to adopt the HBVs that is similar to equation 1 taking on value of 1 if the farmer adopted or 0 if the farmers did not adopt. y_i^* is the latent variable describing a farmers decision on the proportion of land to allocate to the new HBVs. d_i and y_i are their respective observed counterparts respectively. z_i and x_i are vector variables that explain the adoption and intensity decisions while α and β are the respective slopes, μ_i and ε_i , the error terms respectively. If the adoption decision and intensity decisions are randomly and independently distributed, then error terms in 2 and 3 above are characterized as equation 5 (Wooldridge, 2009);

$$\varepsilon_i \sim N(0,1) \text{ and } \mu_i \sim N(0, \sigma_i^2) \quad 5$$

4.2.6 Hypothesis Testing

In the Double-Hurdle Model, individual significance is tested so as to ascertain the contribution of each explanatory variable in explaining the observed outcomes. The test is performed using a student's t-test, (Wooldridge, 2009). This is to test the null hypothesis (H_0) that the individual coefficient (β_i) of an explanatory variable (z_i) is not statistically different from zero. This is tested against the alternative hypothesis (H_1) being that the null is not true

$$H_0: \beta_i = 0$$

$$H_1: H_0 \text{ is not true}$$

The t-statistic (t_{β_i}) used is equal to the estimate (β_i) divided by its standard error ($\hat{\sigma}$) this ratio is compared to the critical value of t-distribution table at 5% level of significance. The null is accepted if the critical value is greater than t_{β_i} .

$$t_{\beta_i} = \frac{\beta_i}{\hat{\sigma}} \quad 6$$

Further Joint significance is tested that is whether all the explanatory variables together significantly explain the observed outcomes. The null hypothesis (H_0) is that all coefficients of the explanatory variables are jointly equal to zero. This is tested against the alternative hypothesis (H_1) that the null is not true. That is at least one of the coefficients is different from zero.

$$\begin{aligned} H_0: \beta_1 = 0 = \beta_2 = 0 = \beta_i = 0 \\ H_1: H_0 \text{ is not true} \end{aligned}$$

This test is performed using likelihood ratio test (LR). Following Kiyangi et al. (2016), the assumption is that adoption and intensity decisions are randomly and independently distributed (equation 5). The likelihood function is the sum of the Probit model, and truncated regression given as equation 7:

$$L = \Pi_{y_i=0} \left[1 - \Phi(z_i \alpha) \Phi\left(\frac{x_i \beta}{\sigma}\right) \right] + \Pi_{y_i>0} \left(\Phi(z_i \alpha) \frac{1}{\sigma} \phi\left(\frac{y_i - x_i \beta}{\sigma}\right) \right) \quad 7$$

Where Φ and ϕ are the standard normal cumulative distribution function and density function, respectively.

4.2.7 Model specification

As alluded to in the previous section, the factors influencing adoption and intensity of adoption were analysed using the Double-Hurdle model. This model was chosen because it assumes that households make two sequential decisions with regard to adopting new varieties. A decision is first made by a farmer to adopt a new HBVs and then the decision on the intensity of use follows. Therefore, a different latent variable is used to model each decision process. The dependent variable in the first hurdle is binary in nature, taking numeric value 1 for adopters, and 0 for non-adopters. A probit

model was used to determine the probability that a household will adopt a new hybrid banana variety (using all observations).

From equation 1, a probit model with a constant is specified as:

$$y_i = \alpha_0 + \alpha_1 W_1 + \alpha_2 W_2 + \dots + \alpha_{14} W_{14} + v_i \tag{8}$$

Where y_i = Dependent variable (Adoption =1 if farmer adopted HBVs, 0 otherwise)

α_0 = Intercept

$\alpha_1 \dots \alpha_{14}$ = parameters to be estimated

$W_1 \dots W_{14}$ = Vector of explanatory variables

v_i =Error term

Specifically, the explanatory variables in the model are;

W_1 =Sex of farmer (1= Male, 0 = Female)

W_2 = Age of farmer (years)

W_3 = Formal schooling of the farmer (number of years)

W_4 = Household size (Number of persons in a household)

W_5 = Total size of land allocated to other crops (Acres)

W_6 = Total size of land under banana crop (Acres)

W_7 = Household receives information about new HBVs (1=Yes, 0=No)

W_8 = Number of years since the household first heard about new HBVs

W_9 = Average number of times a household interacts with other actors in a year

W_{10} = Number of groups that a given household belongs to

W_{11} = Neighborhood effects (the proportion of adopters in the parish excluding the household of interest)

W_{12} = Production biotic and abiotic related attributes index

W_{13} = Agronomic related attributes index

W_{14} = Consumption related attributes index

In the second hurdle, the dependent variable is the proportion of land allocated to HBVs (out of the total land size allocated to banana production). Given the multiple varieties grown in one plot and the mixed stands usually practiced, area occupied by a

single variety was not straight forward. However, farmers were able to recall the number of mats for each variety and this was then used to compute the area under hybrids for the analysis. A truncated regression model was used to determine the intensity of adoption (only on the non-zero observations) (Cragg, 1971).

Based on equation 2 and 3, and the fact that adopting farmers have to decide on the proportion of their cultivable land they allocate to HBVs, a truncated regression model is used to analyse the intensity of adoption as specified below;

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots \dots \dots + \beta_{13} X_{13} + \mu_i \text{ -----} \quad (9)$$

Where y_i = Dependent variable (intensity of adoption of HBVs measured by proportion of land allocated to HBVs)

β_0 = Intercept

$\beta_1 \dots \dots \dots \beta_{13}$ = parameters to be estimated

$X_1 \dots \dots \dots X_{13}$ = Vector of explanatory variables

μ_i =Error term

Specifically, the explanatory variables in the model are;

X_1 =Sex of farmer (1= Male, 0 = Female)

X_2 = Age of farmer (years)

X_3 = Formal schooling of the farmer (number of years)

X_4 = Household size (Number of persons in a household)

X_5 = Total size of land allocated to other crops (Acres)

X_6 = Household receives information about new HBVs (1=Yes, 0=No)

X_7 = Number of years since the household first heard about new HBVs

X_8 = Average number of times a household interacts with other actors in a year

X_9 = Number of groups that a given household belongs to

X_{10} = Neighborhood effects (the proportion of adopters in the parish excluding the household of interest)

X_{11} = Production biotic and abiotic related attributes index

X_{12} =Agronomic related attributes index

X_{13} = Consumption related attributes index

4.2.8 Description of the variables used in the empirical model estimation

Each hurdle in the Double-Hurdle model is conditioned by the farmer and household socio-economic and demographic characteristics as well as institutional factors and technology specific attributes. Selection of the explanatory variables included in the empirical model was mainly drawn from literature on technology adoption in developing countries as presented in the introduction section for this chapter. These explanatory variables were hypothesized to influence farmers' decisions regarding adoption and intensity of adoption of new HBVs. A summary description of all the explanatory variables along with hypotheses on how each variable may influence adoption and intensity of adoption of new HBVs is presented in Appendix 8. Since the Double-Hurdle model allows for the possibility that the same factors may impact each decision differently, the same set of independent variables were used in estimation of the adoption and intensity models. However, to address endogeneity, land allocated to banana production was dropped in estimating the model of the intensity decision. To account for Heteroskedasticity, the regressions were estimated using robust standard errors. The variance inflation factor (VIF) for adoption and intensity models estimated were 1.34 and 1.30 respectively indicating the absence of problems of multicollinearity.

4.3 Results and discussion

4.3.1 Sample characteristics

Results show that about 50% of the sample respondents were females and the other one males (Table 4.3). About 74% of these respondents reported to be the household heads. Overall, most of the households surveyed (71%) were male-headed and the others (29%) female-headed. Over 67% of the respondents reported to be married while 17% were widowed. Only 3% of the sample reported that they were single and never been married while 12% reported to have divorced or separated. Majority of the household heads (90%) reported farming (both crop and livestock) as their primary occupation.

Table 4.3 Distribution of sample characteristics of banana farmers sampled

Characteristics	Response	Percent (n=242)
Sex of respondent	Female	50.41
	Male	49.59
If respondent is household head	Yes	74.38
	No	25.62
Sex of household head	Male	71.07
	Female	28.93
Marital status	Married	67.36
	Widowed	16.94
	Divorced/separated	12.40
	Single	3.31
Primary occupation of household	Farming (crop and livestock)	90.08
	Salaried employment	4.13
	Self-employed off-farm	2.48
	Casual laborer off-farm	3.31

Source: Survey data, 2016

4.3.2 Characterization of the banana growing households

The surveyed banana growing households were categorized into two groups of new HBV users and non-users (adopters and non-adopters respectively). The new HBV users consist of households that grow at least one of the varieties of interest in this study – the new HBVs while the non-users consist of farmers who do not grow any of the new HBVs. Table 4.4 presents the summary socio-economic and demographic statistics that characterize the new HBV users and non-users households.

The results show that the overall average age of the respondent was about 48 years and that of the household head was 50 years. The heads of the adopting households were relatively older (51 years on average) than the non-adopters (49 years). The average number of years of formal education of the respondent was about seven (7) years. On average, the household size was 7 persons and HBVs users report a relatively bigger household size of about 7 members as compared to their counterparts that report 6 members. The total land size owned by the sampled households was an average of 4.5 acres, with an average of about 3.8 acres (approximately 83%) allocated to crops and about 1.1 acres (approximately 29% of the crop area) to banana production. Adopters report significantly more total land owned (about 5.3 acres) and allocated to banana

production (1.2 acres) as compared to non-adopters that owned on average 4.1 acres and allocated 0.9 acres to bananas.

Table 4.4 Socio-economic and demographic characteristics of sampled banana-growing households by HBVs users and HBVs non-users

	Overall (n=242)	HBVs Users (n=87)	HBVs non- users (n=155)	
Variable	Mean			T-statistic
Age of farmer (years)	47.9	47.9	47.9	-0.006
Formal education of farmer (years)	7.3	7.3	7.2	-0.040
Age household head (years)	49.8	51.0	49.2	-0.967
Formal education of household head (years)	7.4	7.4	7.4	-0.025
Household size (Number of persons)	7	7	6	-1.711*
Total farm size (Ha)	1.8	2.2	1.7	-2.962***
Total crop area (Ha)	1.5	1.7	1.4	-1.593
Land allocated to banana (Ha)	0.4	0.5	0.4	-3.064***
Annual household income (UGX'000)	2,504	2,643	2,427	-1.189
Number of years known hybrids	5.4	5.3	5.4	1.103
Number of actors interact with	0.8	1.6	0.3	-10.167***
Number of times interact with actors	4.8	10.9	1.3	-8.513***
Number of years of membership to groups	5.5	5.2	5.7	0.511
Experience in banana research activities (years)	1.5	2.7	0.8	-4.575***
		Proportion		P-value
Membership to groups	67.4	75.9	62.6	0.034
Receipt of information on HBVs in the last 5 years	40.9	81.6	18.1	0.000
Households involvement in banana research activities	26.9	47.1	15.5	0.000

***, ** and * indicate statistical significance level at 1%, 5% and 10%, respectively.

On average, annual household income across all households was about UGX 2,504,455 (US\$ 737). Both HBV users and non-users report more less the same amount of annual household income which is mainly derived from farming activities (both crop and livestock). Only 27% of the households in the sample had participated in banana research activities, with HBV users having significantly more years of experience (3 years) in banana research activities compared to non-users (1 year). In addition, the

HBV users report more linkages and interaction with other actors in the banana chain especially research and extension, and had significantly more access to information about new HBVs. About 67% of the households had at least a family member belonging to a farmer group or association.

4.3.3 Banana varieties grown in the study area

Results indicate that different categories of cooking banana varieties (matooke) exist in the study area and these are grown to varying extents. All farmers involved in the study grew local banana cultivars and on average had about three main local cultivars that are normally planted in mixed stands. Nakitembe, Mpologoma, Muyovu and Nakabululu were the most popular local varieties while M9 (Kabana 6H or Kiwanganzi) was the most popular hybrid variety grown (Table 4.5).

Table 4.5 Main banana varieties grown

Variety type	Variety/cultivar Name	Frequency (n=242)	Percentage (%)
<i>Local cultivars</i>	Nakitembe	182	75.21
	Mpologoma	132	54.55
	Muyovu	108	44.63
	Nakabululu	102	42.15
	Musakala	91	37.60
	Kisansa	71	29.34
	Mbwazirume	65	26.86
	Kibuzi	45	18.60
	Nakyatengu	33	13.64
	Muvubo	32	13.22
	Muzira Nyama	29	11.98
	Namwezi	29	11.98
<i>HBVs</i>	M9 (Kabana 6H or Kiwanganzi)	85	35.12
	FHIA 17	34	14.05
	M2 (Kabana 6H)	23	9.50
	FHIA 25	20	8.26
	Kilometer5/Kabana	8	3.31
	M17	5	2.07
	M14	3	1.24
	M3	1	0.41

Source: Survey data, 2016

In order to analyze the level of uptake of new HBVs, the varieties were broadly classified into three categories: local cultivars, FHIA hybrids and new HBVs. Results (Figure 4.2) indicate that about 49% of the farmers in the sample grew at least one of the banana hybrids (the FHIA hybrids and new HBVs), in addition to their preferred local cultivars while 51% grew only local cultivars. In addition to their preferred local cultivars, 22% of the households grew FHIA hybrids while 36% grew the new HBVs. About 9% of the households grew all the varieties – the local cultivars, FHIA hybrids, and new HBVs. None of the households in the study grew only the improved banana hybrids (FHIA hybrids and new HBVs). This indicates that different banana varieties provide different attributes that guide farmers' decisions on choice of varieties. This implies that farmers tend to select and grow the types of varieties that meet their diverse needs and farming objectives (Nalunga, Kikulwe, Nowakunda, Ajambo & Naziri, 2015).

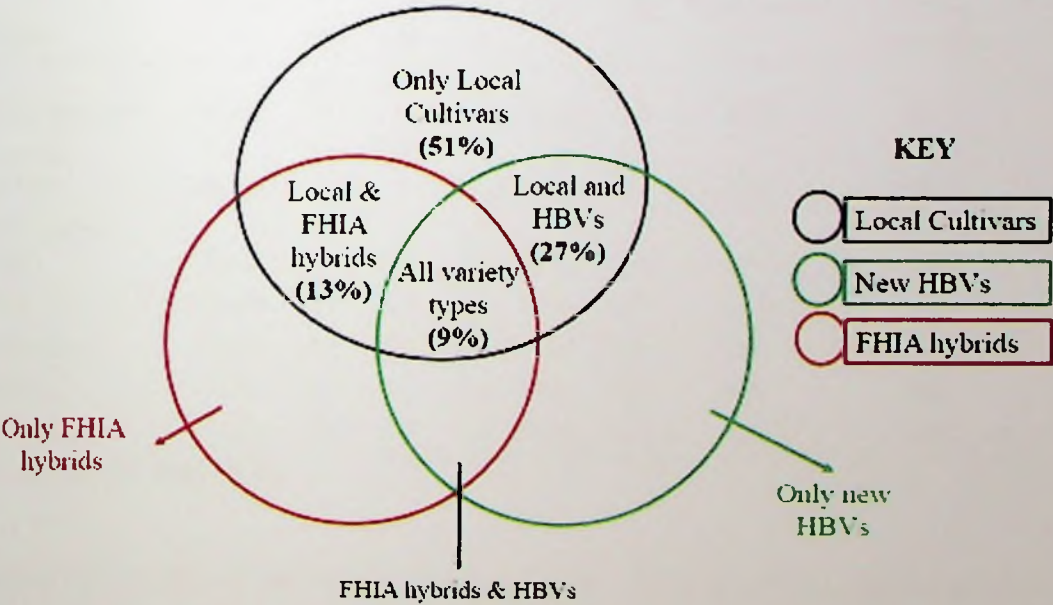


Figure 4.2 Venn diagram showing percentages of sampled households ($n=242$) using the different categories of cooking banana varieties.

Source: Survey data, 2016

4.3.4 Access to planting materials for new HBVs

For the HBVs users, results (Table 4.6) indicate that the most important source of planting materials for their initial planting was fellow farmers (62%), followed by research institute (41%) and community based leader (39%). The high percentage of farmers reporting fellow farmer as a source of planting materials could be attributed to the farmer-to-farmer planting material distribution and on-farm demonstrations initiatives that were implemented by the banana programme since 2008. The least source of planting materials was input supply companies (reported by only 1.2%). This could be explained by their limited involvement in the BTD process and or low interest in multiplication of hybrid banana varieties since these varieties tend to have low demand and subsequently, market.

Table 4.6 Source of planting materials for new HBVs

Source	Total, (N=87)	% response for each of the hybrid varieties						
		M9	M2	M1 4	M1 7	M 3	KABANA 5	Other hybrids
Fellow farmer	62.07	44.7	43.5	0.0	20.0	0.0	50.0	33.3
Research Institute	41.38	23.5	39.1	33.3	60.0	10.0	0.0	66.7
Community leader	39.08	20.0	4.3	0.0	20.0	0.0	12.5	0.0
NGO	12.64	7.1	8.7	33.3	0.0	0.0	25.0	0.0
Extension	4.60	3.5	0.0	33.3	0.0	0.0	0.0	0.0
NAADS	2.30	1.2	4.3	0.0	0.0	0.0	0.0	0.0
Input supply	1.15	0.0	0.0	0.0	0.0	0.0	12.5	0.0

Source: Survey data, 2016

Further, about 81% of the farmers who grow new HBVs reported to have shared suckers with other farmers. On average, each farmer had shared with about five (5) other farmers, out of which 60% were women and 40% men. The interest of women in matooke hybrids could be attributed to their distinct role in ensuring food security of their households. The role of women in food provision could explain the adaptive strategies taken by women to tailor new HBVs (mainly M9) to their conditions and continue to innovate on diverse utilization. Farmers reported changes in preparation and

cooking methods to enrich banana texture and flavor. The new HBVs are for instance mixed with the local preferred cultivars at a ratio of 1:2 when cooking. The HBVs fingers are split in the middle after peeling to reduce hardness and washed to reduce on the sap, a myth perceived to shorten the longevity of a banana plantation. Other farmers reported to store the bunch for about 3-4 days after harvest and before cooking to reduce on the sap.

However, access to planting materials does not always guarantee uptake. Adoption of new varieties involves farmer evaluation of the different attributes using their own perceived criteria. Therefore, further analysis was done to identify farmers' assessment and preferences for attributes of the banana variety types grown.

4.3.5 Production and consumption attribute preferences

The growing of a variety of banana varieties indicates that farmers desire to obtain the positive traits from them such as high yields from hybrids and favorable consumption attributes from local cultivars (Lunduka, Fisher & Snapp, 2012). In this study, respondents were asked to score the production and consumption attributes that influenced their decisions to grow particular banana varieties. The production attributes scored included; resistance to pests and diseases, tolerance to drought and low soil fertility, maturity period, size of bunch and fingers, skin colour, level of sucker production, plant height and resistance to wind while consumption attributes included color and texture (softness) of the cooked food, flavor and taste. Results indicate that although the new HBVs were scored highest in terms of production related attributes, they were rated inferior in terms of consumption related attributes (Figure 4.3 and 4.4). On the other hand, local cultivars were rated superior than hybrids on consumption related attributes but inferior in production attributes.

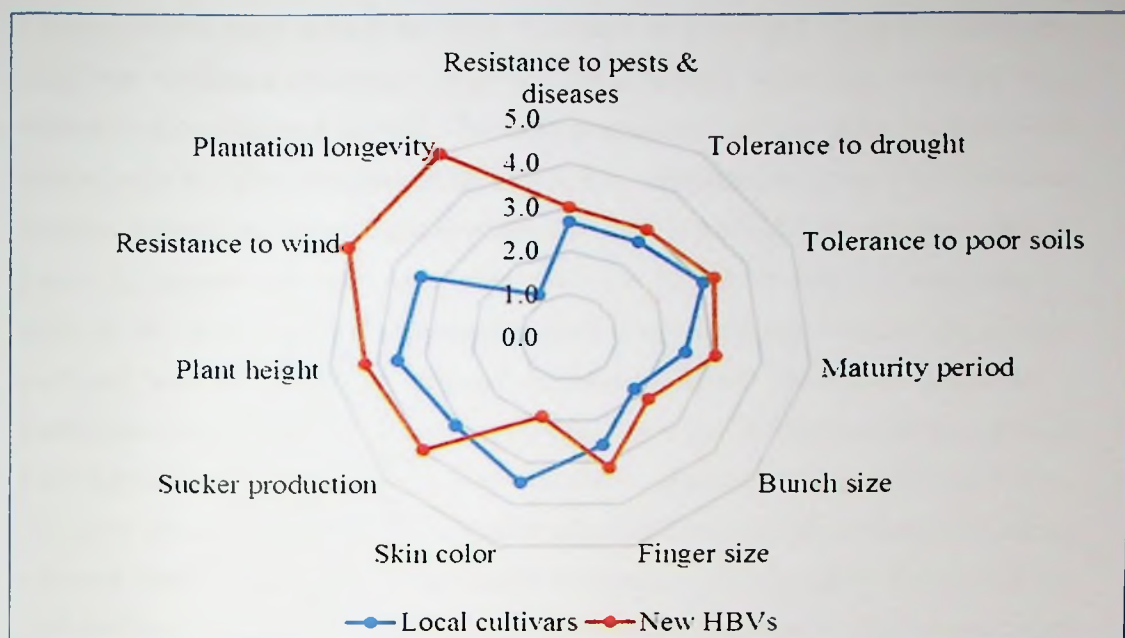


Figure 4.3 Aggregated average rating of production related attributes across local cultivars and new HBVs in central Uganda

Source: Survey data, 2016

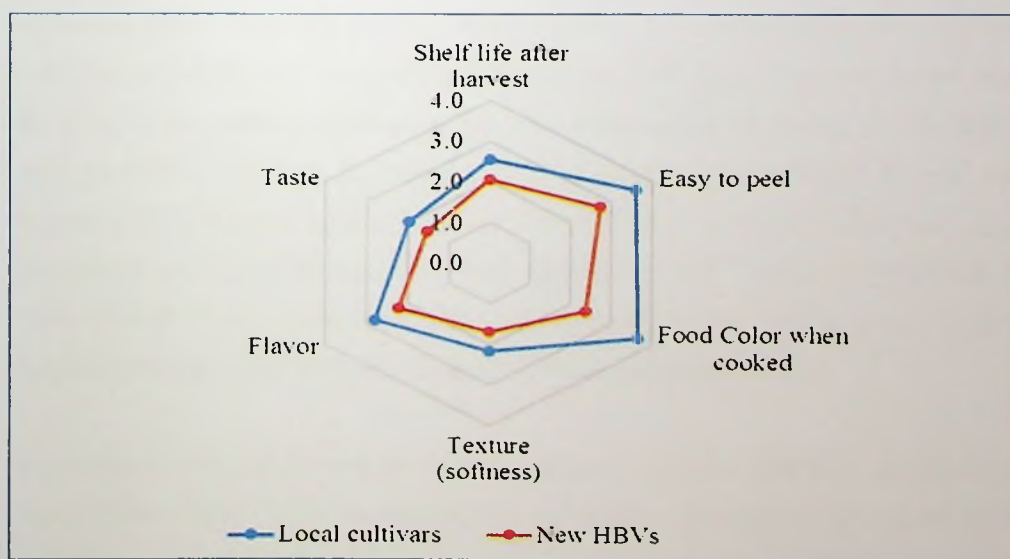


Figure 4.4 Aggregated average rating of processing and consumption related attributes across local cultivars and new HBVs in central Uganda

Source: Survey data, 2016

The new HBVs were valued for their resistance to pests and diseases which also contributes to banana plantation longevity. These hybrids were also observed to be tolerant to poor soils and drought. The only production attribute where local cultivars rated superior to HBVs was skin color, an attribute considered important for marketing bananas. Farmers in central Uganda prefer the deep green color for the outer skin of banana as opposed to the pale green skin color for HBVs. In terms of consumption attributes, the local cultivars were rated highest in all attributes. None of the hybrids performed better than the local cultivars in these attributes. The results imply that a combination of production and consumption attributes derived from different varieties guide farmers' decisions in selection of varieties to grow (Lunduka, Fisher & Snapp, 2012). For instance, the high yield potential of hybrids could assist farm households in achieving food security and having surplus harvest to sell from either the hybrids or local cultivars. Other studies (Kikulwe et al., 2011; Akankwasa et al., 2013) have found acceptability of banana hybrids by consumers as being dependent on a combination of production and sensory attributes.

However, further descriptive analysis indicates that 61% of the farmers who were aware of the new HBVs were not growing these varieties. In most cases, farmers tend to first experiment with the new varieties and/or observe their fellow farmers before making the decision on whether to adopt or not. The main reasons advanced for the failure to plant the HBVs included; limited access to planting materials (34%), limited market demand (20%), limited land availability (20%), poor palatability (19%) and negative perceptions i.e. that HBVs destroy local varieties (16%). The hybrid varieties were rarely planted in the same field with local cultivars as the case is always since the hybrids were perceived to reduce longevity of the banana plantation.

In terms of variety traits that discourage potential adoption (farmers' ability to grow new HBVs), these were mainly related to quality (processing and consumption) attributes (Table 4.7). Overall, texture (reported by 55%), taste (24%), finger splitting (26%), sappiness (17%) and food color (13%) were indicated by farmers as the key traits that require enhancement. The traits that need improvement were specific to particular varieties and Table 4.8 presents farmers' recommendation for improvement for specific banana hybrid varieties. Farmers' recommendations indicate that M9

(KABANA 6H) needs further improvement of the texture to reduce hardening of the food.

Table 4.7 Areas that need improvement for the most important new HBVs

Attribute/trait	% cases*			
	M9, n=73	M2, n=19	M17, n=3	K5, n=4
Texture (reduce hardness)	58.9	63.2	66.7	75.0
Reduce finger splitting	39.7	5.3	0.0	75.0
Improve the taste/palatability	15.1	21.1	66.7	0.0
Reduce the sap content	13.7	26.3	0.0	0.0
Improve the food color	15.1	10.5	0.0	25.0
Improve flavor	5.5	5.3	0.0	0.0
Sucker production	5.5	0.0	0.0	0.0
Reduce plant height	5.5	5.3	0.0	0.0
Increase finger size	4.1	10.5	0.0	0.0
Improve resistance to pests and diseases	2.7	0.0	33.3	0.0
Make skin color to be deep green	2.7	5.3	0.0	0.0
Make easy to peel	2.7	0.0	0.0	0.0
Increase bunch size	1.4	5.3	0.0	0.0
Shorten maturity period	1.4	5.3	0.0	0.0

**Total percentage greater than 100% due to multiple response*

Source: Survey data, 2016

4.3.6 Factors that influence adoption and intensity of adoption of the new HBVs

Results of the Double-Hurdle regression indicate that both the probit model and truncated regression model estimated to identify factors influencing adoption and intensity of adoption of new HBVs respectively were significant at 1%, implying that the models are a good fit for the data. On one hand, the results (Table 4.8a and 4.8b) show education of the farmer, land allocated to banana production, access to information, experience with HBVs and neighborhood effects to be significant determinants of the adoption decision. On the other hand, household size, proportion of land allocated to other crops and the average number of times a farm household interacts with other actors were found to have a statistically significant influence on the adoption intensity. In addition, varietal attributes (those that address biotic and abiotic constraints, and consumption attributes) were positive and significantly associated with both adoption and intensity decisions.

4.3.6.1 Factors associated with the adoption decision

Contrary to most similar studies (Zavale, Mabaya & Christy, 2005; Shiferaw, Kebede & Youc, 2008; Kiyangi et al., 2016), the model estimates show that the education of the farmer had a negative effect on the adoption decision. A unit increase in a farmer's education level by one year decreases the expected likelihood of adopting HBVs by 2.4%. This corroborates with findings of Akankwasa et al (2015) who found education of a farmer to be negatively associated with early adoption of M9 hybrid banana variety. A possible explanation for the less educated farmers planting HBVs could be attributed to the large household size associated with less educated households who may find the hybrids a better alternative to provide sufficient food for the household members. This could be attributed to the important production attributes associated with hybrid bananas such as high yields, big bunch size, resistance to diseases and pests, and tolerance to drought and poor soils. However, the negative effect could also imply that farmers with high education may be sensitive to try out new banana hybrids for food safety reasons, since some farmers perceive hybrids to be genetically modified crop varieties.

Further, the total land allocated to banana production had an influence on the likelihood of adopting new HBVs. Increasing the land size allocated to bananas by one acre, in turn, increases the likelihood that farmers would try out the new HBVs by 11.5%. This suggests that farmers with bigger land size allocated to banana production are more likely to try out the new HBVs. This is in line with most adoption studies (Feder & Slade, 1984; Nkonya, Schroeder & Norman, 1997; Doss, 2006; Cavatassi, Lipper & Narloch, 2011; Lunduka, Fisher & Snapp, 2012; Olson, Morris & Méndez, 2012; Barungi et al., 2013) that established that households with larger farm sizes were more likely to adopt a new technology than those with smaller farm sizes. Such farm households may be more willing to take risks and allocate a portion of their land to try out new varieties.

Table 4.8a Factors that influence farmers' decisions regarding adoption of new HBVs adoption: results of the Probit Model

Variable	Coefficient	Robust Std. Error	P>z	Average Marginal effects (dy/dx)
Sex of farmer	0.182	0.255	0.475	0.058
Age of farmer	0.004	0.010	0.689	0.001
Education of farmer	-0.075	0.041	0.067	-0.024
Total household size	0.008	0.048	0.864	0.003
Land allocated to other crops	0.045	0.064	0.485	0.014
Land allocated to Banana	0.363	0.133	0.006	0.115
Access to information	1.023	0.297	0.001	0.335
Experience with HBVs	-0.131	0.040	0.001	-0.042
Average number of times a household interacts with other actors	0.016	0.019	0.397	0.005
Number of groups a household belongs to	0.157	0.151	0.297	0.050
Neighborhood effects	0.113	0.043	0.009	0.036
Production biotic and abiotic traits related index	1.097	0.175	0.000	0.348
Agronomic traits related index	0.053	0.111	0.633	0.017
Consumption attribute related index	0.484	0.125	0.000	0.154
Constant	-1.436	0.641	0.025	
Number of observations	242			
Log likelihood	-63.62			
Wald chi-square	93.18***			
Mean VIF	1.34			

Dependent variable: Adoption measured as a binary

As expected, access to information had a positive effect on adoption of new hybrid banana varieties. Households that had access to information about hybrid banana varieties were 33.5% more likely to adopt HBVs compared to those that did not have access to information. In most cases, farm households tend to adopt a technology that they have heard about and on which they have sufficient information. Following the works of Doss (2006), farmers must have access to information about new technologies before they can consider adopting them.

Surprisingly, the study found the number of years a farm household had known the new HBVs to have a negative influence on the likelihood of adopting new HBVs. A one year increase in a household's experience with HBVs reduces the expected likelihood of adoption by 4.2%. This could be attributed to the risk averseness behavior of

farmers. As farmers observe undesirable attributes as they experiment with HBVs, they may be less able to undertake production risks. This corroborates with the descriptive results that indicated that 61% of the farmers were aware of new HBVs but did not grow these varieties. Farmers are in most cases less willing to continue to grow new varieties that do not adequately meet their needs, preferences and farming objectives. In some cases, farmers tend to drop a newly adopted technology when they fail to achieve their expected benefits it (Ainembabazi & Mugisha, 2014).

The results also indicate that residing in a community that has more adopters of HBVs is associated with increasing adoption of HBVs. Having at least one HBVs adopter in the community (parish) increases the likelihood of adoption by 3.6%. Farmers tend to learn about new crops from the choices of other farmers cultivating the same crop (Foster & Rosenzweig, 2010). Therefore, having neighbors growing HBVs can facilitate access to information and access to planting materials. Indeed, descriptive results of this study indicated that most of the farmers growing new HBVs received the planting materials from their fellow farmers. Also, through social interactions that happen between farmers in the same location (proximity), farmers feel more secure that the new HBVs will not fail if they tried them out (Bandiera & Rasul, 2006). The non-adopters too learn and potentially adjust their choices to align with those of their neighbors (Moser & Barrett, 2003; Conley & Udry, 2010).

4.3.6.2 Factors associated with intensity of adoption

Although not a significant predictor of adoption of new HBVs, household size had a positive influence on the intensity of adoption of new HBVs. Households with more members tend to adopt new HBVs more than those with less members. The results show that as the household size increased by one member, the size of land allocated to HBVs increases by about 11% other factors (e.g. land availability) held constant. Household size may affect family labor supply for production (Feder et al., 1985; Suvedi, Ghimire & Kaplowitz, 2017). A larger household provides cheaper family labor if engaged in agricultural production and may produce more output in absolute terms to meet the food consumption requirements. However, the high food consumption requirements for larger household may also drive them to adopt new HBVs due to their bigger bunch and finger size (Akankwasa et al., 2015). The high

yield achieved from the hybrids provides a farm household with a reliable source of food for the larger household size.

Table 4.8b Factors that influence intensity of adoption of new HBVs: results of the truncated regression model

Variable	Coefficient	Robust Std. Error	P>z	Average Marginal effects (dy/dx)
Sex of farmer	-0.325	0.261	0.213	-0.325
Age of farmer	0.000	0.011	0.973	0.000
Education of farmer	-0.014	0.042	0.744	-0.014
Total household size	0.109	0.060	0.067	0.109
Land allocated to other crops	-0.219	0.055	0.000	-0.219
Access to information	-0.213	0.385	0.580	-0.213
Experience with HBVs	0.028	0.060	0.639	0.028
Average number of times a household interacts with other actors	0.024	0.012	0.044	0.024
Number of groups a household belongs to	-0.225	0.156	0.151	-0.225
Neighborhood effects	-0.040	0.044	0.368	-0.040
Production biotic and abiotic traits related index	0.404	0.174	0.020	0.404
Agronomic traits related index	-0.005	0.084	0.949	-0.005
Consumption attribute related index	0.206	0.104	0.047	0.206
Constant	-4.011	0.862	0.000	
Number of observations	87			
Log likelihood	-135.50			
Wald chi-square	40.44***			
Mean VIF	1.3			

Dependent variable: Proportion of land planted with new HBVs

Having more land in acres allocated to other crops is associated with decreasing intensities of adoption of HBVs. When land allocated to other crops other than bananas increase by one acre, the land allocated to HBVs reduces by 22%. This implies that farm households with more land allocated to other crops are less likely to intensify production of new hybrids. Two possible explanations could be advanced for this result. First, the increase in area planted with other crops diminishes the available land and other production resources such as labour for production of new HBVs. Secondly,

farm households may choose to grow other crops to spread risks and meet their diverse food and income needs. This is consistent with Feder et al. (1985) and Doss (2006) who noted that adoption of new technologies entails subjective risk, which smallholder farmers may not be willing to undertake since they have fewer resources to fall back on.

Intensity of interaction (measured by the number of times a banana farm household interacts with other actors especially those in agricultural research and extension) had a positive and significant influence on the intensity decision once the adoption decision had been made. Farm households that interact more with other actors such as agricultural research, extension agents and traders among other actors had more land allocated to HBVs than those that did not interact with any other actors at all. A unit increase in the frequency of interaction with such actors increases the land allocated to HBVs by 2%. The findings corroborate previous research about interactions and adoption of new technologies including improved crop varieties (Feleke & Zegeye, 2006; Mugisha & Diiro, 2010, Diiro, 2012). Particularly, Diiro (2012) found that the probability of adoption of improved maize seeds increases with the number of interactions between the farmer and agricultural extension agents. This underscores the role played by research, extension and actors in dissemination, promotion and commercialization of new technologies. Such linkages and interactions are important for flow of information about variety attributes and utilization which enhances a banana farm household's knowledge and confidence in the new technology therefore promoting use. Another possible explanation could be the fact that most times, the farm visits by actors mainly target households that have adopted and thus, the interactions provide useful linkages that serve to motivate a farm household to intensify production of the new technology.

4.3.6.3 Factors associated with both the adoption and intensity decisions

As expected, results indicate that the biotic and abiotic related trait index and the consumption related index had a positive influence on adoption decision and the proportion of land allocated to HBVs in central Uganda. The results show that the likelihood of a farmer to adopt HBVs and allocate more land to them increased with perceived importance of the biotic and abiotic traits of the HBVs. Specifically, when

the aggregate index of biotic and abiotic traits increased by one unit, the likelihood to adopt HBVs and size of land allocated to them increased by 35% and 40% respectively. HBVs biotic and abiotic related traits of; resistance to diseases, drought, poor soils, maturity period are associated with 34.8% likelihood of adoption and 39.8% adoption intensity. A possible explanation could be that these hybrids tolerate poor drought, soils and disease pressure better than the local varieties and hence an incentive for adoption and intensity decisions since most farmers in the central region of Uganda considers, in most cases, tolerance to marginal soils and drought-prevalent characteristics during variety selection (Edmeades, Smale & Karamura, 2005).

The consumption attributes (taste, texture, flavor, color) increases the likelihood for the farmers to adopt HBVs by 15.4 % and adoption intensity by 20%. Farmers seem to prefer new hybrid banana varieties that combine both tolerance to major production constraints and with better consumption attributes. This is consistent with other studies (Edmeades, 2003; Katungi et al., 2011; Akankwasa et al., 2013) that have found variety attributes to be significantly associated with variety choice and land share allocation to new varieties. In particular, this validates the findings of the study on early-stage adoption of the hybrids by Akankwasa et al (2015) who found that farmers were more likely to plant more mats of hybrid varieties with better sensory qualities such as soft food and color when cooked. Beyond production related attributes, farmer attach high importance to consumption attributes implies that breeding effort should target producing varieties with superior production and desirable consumption traits. This underscores the importance of clearly understanding farmers' preferences in breeding for new banana varieties. Farmers normally prefer new varieties that are comparable to their local varieties in supply of desirable consumption attributes such as soft food, color when cooked, flavor and taste embedded in their culture (Lunduka, Fisher & Snapp, 2012). Therefore, improvement of the current hybrid banana varieties to supply better production and consumption attributes desirable to end-users than is currently would increase both adoption and intensity decisions.

4.4 Conclusion and implications

This chapter sought to establish the factors that contribute to adoption and intensity of adoption of new HBVs among smallholder farm households in Central Uganda. Only 36% of the farm households sampled were using new HBVs, mostly the M9 variety.

Based on the probit model estimates, the factors that positively and significantly increase the likelihood of adopting new banana hybrids were; allocation of relatively more land to banana production, access to relevant information and neighborhood effects. The intensity of adoption of the HBVs, inferred from the size of land allocated to them, was positively influenced by the household size and farm household interactions with other actors. These findings therefore suggest that developers and promoters to be aware of the social and institutional context that drives uptake of HBVs, thus deliberately target smallholder farmers using communication strategies that aggressively stimulate and catalyze uptake.

Similarly, the positive influence of interactions of households with actors on their HBV adoption intensity signals the need to promote HBVs through multi-actor platforms which provide more opportunities for formal and informal interactions between farmers and other actors. Such fora will not only serve to offer end-users with opportunities to access adequate information but also provide useful linkages that are important to support and guide the adoption and intensity of adoption decision processes.

This study has demonstrated that farmers in central Uganda perceive both production attributes (biotic and abiotic traits) and consumption related traits to be important considerations in deciding to adopt and allocate more land to HBVs. This reinforces the need for researchers especially breeders to focus on both the production attributes and consumption traits in the breeding process in order to develop banana varieties that are widely acceptable and subsequently adopted by the end-users. Breeders should prioritize multiple traits with end-users right from the early stages of the evaluation and selection process. Integration of both production (technical) and consumption (social/quality) related attributes in the breeding processes will however require close collaboration between breeders and other disciplines especially those in the social sciences including gender experts during the entire variety development process. Knowledge of the trait preferences by men and women end-users will be useful to inform breeders of the gender-specific preferences for banana varieties across agro-ecological zones.

References

- Ainembabazi, J. H., & Mugisha, J. (2014). The Role of Farming Experience on the Adoption of Agricultural Technologies: Evidence from Smallholder Farmers in Uganda. *Journal of Development Studies*, 50 (5), 666-679, doi: 10.1080/00220388.2013.874556
- Akankwasa, K., Ortmann, G., Wale, E., & Tushemereirwe, W. (2013a). Determinants of consumers' willingness to purchase East African Highland cooking banana hybrids in Uganda. *African Journal of Agricultural Research*, 8(9), 780-791.
- Akankwasa, K., Ortmann, G., Wale, E., & Tushemereirwe, W. (2013b). Farmers' choice among recently developed hybrid banana varieties in Uganda: A multinomial logit analysis. *Agrekon*, 52(2), 25-51.
- Akankwasa, K., Ortmann, G., Wale, E., & Tushemereirwe, W. (2015). Early-Stage Adoption of Improved Banana" Matooke" Hybrids in Uganda: A Count Data Analysis Based on Farmers' Perceptions. *International Journal of Innovation and Technology Management*, 13(1), 1650001-1 – 26, doi:10.1142/S0219877016500012
- Amemiya, T. (1981). Qualitative response models: A survey. *Journal of Economics Literature*, 19(4), 1483-1536. <http://dx.doi.org/10.2307/1241687>
- Bandiera, O., & Rasul, I. (2006). Social Networks and Technology Adoption in Northern Mozambique. *Economic Journal*, 116:869-902.
- Barekye, A. (2009). Breeding investigations for black Sigatoka resistance and associated traits in diploids, tetraploids and the triploid progenies of bananas in Uganda. PhD Thesis, University of KwaZulu-Natal, Pietermaritzburg, South Africa.
- Barungi, M., Edriss, A., Mugisha, J., Waithaka, M., & Tukahirwa, J. (2013). Factors influencing the adoption of soil erosion control technologies by farmers along the slopes of Mt. Elgon in eastern Uganda. *Journal of Sustainable Development*, 6(2), 9.
- Bezu, S., Kassie, G. T., Shiferaw, B., & Ricker-Gilbert, J. (2014). Impact of improved maize adoption on welfare of farm households in Malawi: a panel data analysis. *World Development*, 59, 120-131. <http://dx.doi.org/10.1016/j.worlddev.2014.01.023>
- Cavatassi, R., Lipper, L., & Narloch, U. (2011). Modern variety adoption and risk management in drought prone areas: insights from the sorghum farmers of eastern Ethiopia. *Agricultural Economics*, 42: 279-292.
- Conley, T. G., & Udry, C. R. (2010). Learning about a New Technology: Pineapple in Ghana. *American Economic Review*, 100:35-69.
- Cragg, J. G. (1971). Some statistical models for limited dependent variable with application to the demand for durable goods. *Econometrica*, 39, 829-844. <http://dx.doi.org/10.2307/1909582>

- Doss, C. R. (2006). Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. *Agricultural Economics* 34: 207-219. <http://dx.doi.org/10.1111/j.1574-0864.2006.00119.x>
- Edgerton, M. D. (2009). Increasing crop productivity to meet global needs for feed, food, and fuel. *Plant Physiology*, 149: 7-13.
- Edmeades, S. (2003). Variety choice and attribute trade-offs within the framework of agricultural household models: The case of bananas in Uganda. A PhD Dissertation, North Carolina State University.
- Edmeades, S. Smale, M., Kikulwe, E. M., Nkuba, J.M., & Byabachwezi, M.S.R. (2007). Characteristics of banana-growing households and banana cultivars in Uganda and Tanzania. In: Smale M. and Tushemereirwe, W. K. (eds). An economic assessment of banana genetic improvement and innovation in the Lake Victoria Region of Uganda and Tanzania. Research Report No. 155, 49-74. IFPRI, Washington, D.C.
- Edmeades, S., Phaneuf, D. J., Smale, M. and Renkow, M. (2008). Modelling the crop variety demand of semisubsistence households: Bananas in Uganda. *Journal of Agricultural Economics*, 59, 2: 329-349.
- Edmeades, S., Smale, M., & Karamura, D. (2005). Demand for cultivar attributes and the biodiversity of bananas on farms in Uganda. *Valuing Crop Biodiversity: On-Farm Genetic Resources and Economic Change*, ed. M. Smale. CAB International, Wallingford, UK.
- Eledu, C. A., Karamura, E. B., & Tushemereirwe, W. (2004). Agroecological distribution of banana systems in the Great Lakes region. *African Crop Science Journal*, 12: 33-42.
- FAO IFAD & WFP. (2015). The State of Food Insecurity in the World 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress. Rome: FAO.
- Feder, G., & Slade, R. (1984). The acquisition of information and the adoption of new technology. *American Journal of Agricultural Economics*, 66, 3: 312-320.
- Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in Developing Countries: A Survey. *Economic Development and Cultural Change*, 33(2), 255-298. <http://dx.doi.org/10.1086/451461>
- Feleke, S. & Zegeye, T. (2006). Adoption of improved maize varieties in Southern Ethiopia: Factors and strategy options. *Food Policy*, 31: 442-457.
- Field, A. (2013). *Discovering statistics using IBM SPSS statistics*: Sage.
- Foster, A.D.W. & Rosenzweig, M.R. (2010). Micro-economics of technology adoption. *Ann.l Rev. Econ*, 2: 395-424.
- Greene, W. H. (2008). *Econometric analysis*. Sixth edition. Pearson Edition, New Jersey 1178p.

- Kagezi, G., Mpiira, S., Jogo, W., Karamura, E., Gotor, E., Garming, H., & Johnson, V. (2012). Adoption of New Banana Cultivars in Uganda. A Report for the DIVA Project (Unpublished report).
- Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement*, 20, 141-151.
- Karamura, E. B., Tinzaara, W., Kikulwe, E., Ochola, D., Ocimati, W., & Karamura, D. (2016). Introduced banana hybrids in Africa: seed systems, farmers' experiences and consumers' perspectives. XXIX IHC- Proc. Int. Symp. Banana: ISH-ProMusa Symposium on Unravelling the Banana's Genomic Potential. Eds.: I. Van den Bergh et al, *Acta Hortic.*, 1114 (ISHS 2016), 239-244.
- Karamura, E., Frison, E., Karamura, D., & Sharrock, S. (1998). Banana production systems in eastern and southern Africa. In: PICQ, C., Foure, E. & Frison, E. A. (Eds). Bananas and Food Security International Symposium, Cameroon. pp. 401-412.
- Katungi, E., Sperling, L., Karanja, D., Farrow, A., & Beebe, S. (2011). Relative importance of common bean attributes and variety demand in the drought areas of Kenya. *Journal of Development and Agricultural Economics*, 3, 8: 411-422.
- Kikulwe, E. M., Birol, E., Wesseler, J., & Zepeda, J. F. (2011). A latent class approach to investigating demand for genetically modified banana in Uganda. *Agricultural Economics*, 42, 5: 547-560.
- Kiyingi, I., Edriss, A., Phiri, M., Buyinza, M., & Agaba, H. (2016). Adoption of on-farm plantation forestry by smallholder farmers in Uganda. *Journal of Sustainable Development*, 9(2), 153.
- Lunduka, R., Fisher, M., & Snapp, S. (2012). Could farmer interest in a diversity of seed attributes explain adoption plateaus for modern maize varieties in Malawi? *Food policy*, 37(5), 504-510. <http://dx.doi.org/10.1016/j.foodpol.2012.05.001>
- MAAIF (Ministry of Agriculture, Animal Industry and Fisheries). (2010). Agriculture Sector Development Strategy and Investment Plan: 2010/11-2014/15. *Agriculture for Food and Income Security*. Republic of Uganda.
- Moser, C.M., & Barrett C.B. (2003). The Complex Dynamics of Smallholder Technology Adoption: The Case of Sri in Madagascar. *Agricultural Economics*, 35:373-388.
- Mugisha, J., & Diro, G. (2010). Explaining the adoption of improved maize varieties and its effects on yields among smallholder maize farmers in eastern and central Uganda. *Middle-East Journal of Scientific Research*, 5(1), 06-13.
- Nalunga, A., Kikulwe, E., Nowakunda, K., Ajambo, S., & Naziri, D. (2015). Structure of the Cooking Banana Value Chain in Uganda and Opportunities for Value Addition and Postharvest Losses Reduction, RTB-ENDURE Technical report <http://www.rtb.cgiar.org/endure/>

- Nkonya, E. M., Schroeder, T., & Norman, D. (1997). Factors affecting adoption of improved maize seed and fertilizer in Northern Tanzania. *Journal of Agricultural Economics*, 48: 1-12.
- Nowakunda, K., Barekye, A., Ssali, R. T., Namaganda, J., Tushemereirwe, W. K., Nabulya, G., Erima, G. R., Akankwasa, K., Hilman, E., Batte, M., & Karamura, D. (2015) 'Kiwangaazi'(syn 'KABANA 6H') Black Sigatoka Nematode and Banana Weevil Tolerant 'Matooke'Hybrid Banana Released in Uganda. *HortScience*, 50(4): 621-623.
- Olson, M. B., Morris, K. S., & Méndez, V. E. (2012). Cultivation of maize landraces by small-scale shade coffee farmers in western El Salvador. *Agricultural Systems*, 111:63-74.
- Shiferaw, B. A., Kebede, T. A. & Youc, L. (2008). Technology adoption under seed access constraints and the economic impacts of improved pigeonpea varieties in Tanzania. *Agricultural Economics* 39: 309-323.
- Sodjinou, E. (2011). Poultry-based intervention as tool for poverty reduction and gender empowerment: empirical evidence from Benin. PhD Thesis, Institute of Food and Resource Economics, University of Copenhagen.
- Suvedi, M., Ghimire, R., & Kaplowitz, M. (2017). Farmers' participation in extension programs and technology adoption in rural Nepal: a logistic regression analysis. *The Journal of Agricultural Education and Extension*, 1-21. DOI:10.1080/1389224X.2017.1323653
- Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica*, 26, 24-36. <http://dx.doi.org/10.2307/1907382>
- Tushemereirwe, W., Tumuhimbise, R., Kubiriba, J., Batte, M., Barekye, A., Lorenzen, J., Nyine, M., Ssali, T.R., & Swennen, R. (2014). Performance of NARITA Banana Hybrids in the Preliminary Yield Trial, Uganda. Project Report.
- Uganda Census of Agriculture (UCA). (2010). Summary Report on Uganda Census of Agriculture 2008/2009. <http://www.ubos.org/onlinefiles/uploads/ubos/pdf%20documents/UCASummary.pdf>
- van Asten, P. J. A., Wairegi, L. W. I., Mukasa, D. & Uringi, N. O. (2011). Agronomic and economic benefits of coffee-banana intercropping in Uganda's smallholder farming systems. *Agricultural Systems* 104(4): 326-334.
- Viljoen, A. (2010). Protecting the African banana (*Musa* spp): prospects and challenges. *ISHS Acta Horti*, 879:305-319.
- Wooldridge, J. M. (2009). Introductory Econometrics (4th Ed.). South-Western Cengage Learning.
- Yaron, D., Dinar, A., & Voet, H. (1992). Innovations on family farms: The Nazareth Region in Israel. *American Journal of Agricultural Economics*, 361-370. <http://dx.doi.org/10.2307/1242490>

Yen, S. T., & Jones, A. M. (1997). Household Consumption of Cheese: An Inverse Hyperbolic Sine Double-Hurdle Model with Dependent Errors. *American Journal of Agricultural Economics*, 79(1), 246-251.
<http://dx.doi.org/10.2307/1243958>

Zavale, H., Mabaya, E., & Christy, R. (2005). Adoption of Improved Maize Seed by Smallholder Farmers in Mozambique. SP 2005-03, Department of Applied Economic and Management Cornell University, Ithaca, New York.

CHAPTER 5: GENERAL DISCUSSION OF RESEARCH FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The agricultural sector in SSA remains central to achieving the Sustainable Development Goals (SDGs) which aim to end poverty, hunger as well as to achieve food security. Over 75% of the population in SSA directly or indirectly depend on agriculture for their livelihoods. Agricultural research is therefore part and parcel of the strategy to increase productivity and to effectively contribute to the sustainable development agenda. As such, improved technologies, innovations and management practices are seen offer potential solutions to increase total factor productivity and hasten agricultural transformation (World Bank 2013; FARA, 2014). Although the National Agricultural Research System (NARS) in Uganda has embraced development of new agricultural as the most efficient way to increase crop productivity, uptake of new technologies by farmers remains a considerable challenge (Kasirye, 2013). Research has observed that there is low uptake of most of the improved crop technologies. While a range of explanations have been advanced for this trend (World Bank, 2008), limited emphasis has been placed on understanding the technology development processes. Therefore, the goal of this study was to examine how the social dynamics in the technology development process influence the uptake of new technologies using the Banana Technology Development (BTD) process in Uganda as a case. Specifically, this study sought to (i) analyze the process that led to the development of new Hybrid Banana Varieties (HBVs); (ii) examine the diversity of actors and their interactions in the process and how these elements influence farmers' uptake of new HBVs; (iii) determine the socio-economic, farm and farmer characteristics, institutional factors and varietal attributes that influence the uptake of new HBVs among smallholder farmers in Central Uganda. This chapter provides a summary of the findings, general conclusions and recommendations for policy, practice and further research.

5.2 Overview and general discussion of research findings

Findings from the study show that the process that led to the new HBVs consisted of five stages, namely: i) *setting the research agenda*; ii) *breeding*; iii) *trait evaluation and selection*; iv) *variety naming, release and registration*; and v) *promotion and commercialization*. At each stage, different activities were performed that influenced actor involvement, including the roles and interactions of the actors in the process. An analysis of the different stages along the entire process highlighted various complexities and gaps that ultimately impact on the development, promotion, commercialization and uptake of new HBVs.

The BTD process was complex in terms of the diversity of the actors, their influence and interests. The key actor categories that were involved included agricultural researchers, extensionists, producers (farmers), training institutions, private tissue culture laboratory operators/entrepreneurs and policy makers. However, there were differences among the actors involved in the BTD process in terms of their influence and interests. Along the entire BTD process, researchers were the most prominent, dominant and influential actors and their interests were largely shaped by commitments with funding agencies and they emphasized mainly quantitative and technical aspects, including number, yields, disease and pest resistance of new HBVs developed and released. Accordingly, findings show that the BTD process placed limited emphasis on social aspects, quality attributes, end-users' trait preferences and perceived economic benefit of the new varieties. Although actors such as farmers, extensionist and private tissue culture laboratory entrepreneurs were involved, their level of involvement was diminishing at the different stages of the process. Other actors including local leaders, commodity traders, agro-processors, financial institutions and the media were identified as missing actors. Most of the actors that were excluded in the BTD process were those that would have been key in; disseminating information about HBVs and providing needed services like financial credit and market for those interested in investing in HBVs. The limited involvement and/or exclusion of some of the actors in the BTD process results into a mismatch between breeding and end-user priorities, which also explains their low rating of the acceptability of the new HBVs. The low rating of the acceptability of the HBVs by the different actors adversely affects their willingness and level of support to the BTD process and uptake of its outputs.

With regard to consideration of social aspects in the BTD process, the findings reveal that there was no major indication of gender integration at the different stages of the BTD process. There were no efforts to identify trait preferences of men and women along the BTD process yet these two gender groups select and grow bananas for different purposes. Disregard of social aspects and end-users' trait preferences in the BTD process increases the likelihood of the outputs from the process not being aligned to end-users expectations and needs. Indeed, findings of this study demonstrate that the new HBVs are not meeting some of the end-users' preferences in terms of food color, texture, flavor and taste. The development, ultimate release and promotion of HBVs that do not meet some of the end-user preferences depict an element of a top-down approach in the BTD process. The top-down approach thrives in circumstances of imbalanced power relations among the different actors where some of them are core and the others take on peripheral and passive positions and roles in the system.

Analysis of actor diversity and interactions reveal existence of power asymmetries within the BTD process. The findings indicate that research-oriented actors, especially breeders, were the most prominent and dominant at all the five stages of the BTD process; while the other actors, including end-users, played peripheral roles. The power asymmetries seemed to limit the nature and strength of interactions between the different categories of actors. Close and strong ties existed among research-oriented actors and weak ties between the research-oriented actors and the other categories of actors in the BTD process. Having weak ties between core actors and the peripheral actors who play key roles in facilitating knowledge diffusion and uptake adversely affects information flow and exchange in a network. Fritsch and Kauffeld-Monz (2010) stress that although peripheral actors tend to have weak ties in a network, they are the most important to facilitate knowledge diffusion and influence uptake. Weak ties between different categories of actors in the BTD process deters optimal harnessing of the experiences, knowledge and innovations of each actor and this ultimately compromises the uptake of the HBVs.

The findings demonstrated that the adoption of new HBVs among households that were involved in the study is still low. Only 36% of the farm households grew the new HBVs, mainly the M9 (KABANA 6H) variety that has been widely promoted through on-farm demonstrations and farmer-to-farmer seed multiplication. Although the new

HBVs scored highest in production related attributes, they were significantly inferior to the local banana cultivars in terms of consumption and market related attributes. These attributes largely determine the intra-household decision-making processes regarding uptake. Men's enthusiasm for HBVs had reportedly waned because the HBVs did not meet the market-oriented expectations due to their inferiority to local cultivars in terms of consumption and market attributes. On the contrary, women had more enthusiasm in the uptake of HBVs because of the ability of HBVs to produce bigger bunches that enable women to fulfill their key responsibility of ensuring household food availability. As such, women significantly provided more input than men in decisions regarding the uptake of new HBVs. It is therefore not surprising that the varietal attributes of HBVs especially those related to production had a statistically significant positive influence on both the adoption and intensity of adoption of the new HBVs. Additionally, the probability of adoption of the new HBVs was largely influenced by the amount of land allocated to banana production, access to relevant information and neighborhood effects. However, farmers who are more educated and those with more experience with banana hybrids, are less likely to adopt. Once the adoption decision had been made, household size and farm household interactions with other actors are the most significant factors influencing the intensity of adoption, although farmers with more land allocated to other crops are less likely to increase the proportion of their land allocated to hybrids. These findings demonstrate that the uptake of HBVs is influenced by a combination of factors including socio-economic, farmer and farm characteristics, varietal attributes, and institutional factors. This implies that technology development and promotion processes should be customized to the specific physical, social, and economic contexts of a community to achieve optimal impact.

5.3 General conclusions

It is evident from the study that the focus of the BTD process was largely technological output-oriented rather than holistic impact-oriented. The process that aimed to deliver new banana varieties that were technically sound was not fully tailored to the needs and preferences of the end-users. Selection of the varieties across all the stages of the BTD process was largely guided by the technical attributes and considerations. The process was mainly researcher-driven, top-down and gender '*blind*' and or '*neutral*' at most of the breeding stages leading to development and release of new HBVs that did not meet end-user preferences. Although the process seemed to be cyclic in nature, it was less

dynamic, iterative and flexible. The forward feedback loops that aim to inform successive breeding processes existed but with limited backward loops and iterations. This was due to the pressure exerted by the donor agencies on researchers (particularly, breeder) to deliver tangible outputs in a given period of time. Therefore, beyond breeding for new technologies, there is need for researchers to provide accountability in terms of uptake and impact of the technologies developed. This will require donor agencies to provide support to researchers, especially breeders, to engage with end-users in prioritization at every stage of breeding so that new technologies meet the needs and preferences of both men and women end-users along the BTD process.

The NBRP largely determined inclusion and exclusion of actors along the different stages based on the perceived capacities and interests of the actors in the BTD process. As such, researchers performed evolving roles as the process of developing new HBVs progressed from one stage to the other. Involvement of non-research oriented actors including farmers and extensionists was minimal and more passive in the process. Even among the researcher category of actors, there was minimum involvement of social related disciplines (including gender scientists) and the zonal level research scientists that limited the integration of social perspectives of end-users throughout the BTD process. Absence of such relevant actors in the process can lead to systemic problems that may affect development of appropriate banana varieties; thus limiting the uptake of new HBVs. This study concludes that the NBRP had a significant influence on the functioning of the BTD process. The research-oriented actors (mainly breeders) tend to exert a relatively strong influence over the process, crowding out other actors including the smallholder farmers who are pivotal end-user actors of new technologies. Particularly, the current position of farmers in the BTD network implies that they have low access to information and resources, in addition to limited feedback and fewer connections to other actors. Therefore, farmers are still seen as recipients of technologies rather than active partners in the technology development process.

It is further noted that sparse ties exist among actors in the BTD process, which is an indication of weak interactions, exchange and flow of information among actors. Such weak interactions limit integration of knowledge from the different actors. All possible ties are not fully utilized in the BTD process to support development, promotion, commercialisation and uptake of new HBVs. For an effective process that delivers

user-driven technologies, all possible links need to be fully utilised, which will necessitate strong linkages among actors in the BTD process. This can be achieved by strengthening application of the systems approach to banana technology development. This further calls for active involvement of diverse actors in prioritisation at the different stages of the breeding process, which implies the need to recognize the influencers and power brokers in the process, and examine their roles in the network for successful development, diffusion and triggered acceptance of technologies.

This study has demonstrated that farmers in Central Uganda perceive both production and quality related traits to be important considerations in deciding to adopt banana varieties and to allocate more land to them. This corroborates with other studies (Edmeades, 2007; Katungi et al. 2011; Akakwasa et al. 2013) that have found varietal attributes to be critical to the choice decision for new banana varieties. It is concluded that a combination of factors, including socio-economic, farmer and farm characteristics, institutional factors and varietal attributes play a critical role in the adoption of new HBVs. Therefore, adequate targeting of technology development and dissemination efforts is likely to enhance uptake.

Overall, the study concludes that the dynamics in the BTD process in terms of actor inclusion and exclusion, interests and power relations have an influence on the uptake of the outputs from the process. Largely, the BTD process in Uganda is still researcher-driven and not end-user responsive. This corresponds with other studies (e.g Mgumia et al., 2015) that have established that breeding efforts continue to be essentially researcher-driven. Along the entire BTD process in Uganda, research-oriented actors wield more power and as a result there are tendencies towards a latent use of the top-down approach depicted by the exclusion of some of the key actors, limited attention to key social aspects and some of the end-user preferences. As a result, the HBVs developed and promoted by the BTD process in Uganda have not fully met the preferences and expectations of some of the actors in the process and as such they experience a low adoption rate among the targeted farming communities. However, besides the attributes of the HBVs themselves, adoption is also influenced by several social, economic and institutional factors at and beyond the farming household. This therefore implies that achieving optimal uptake of technologies requires the process to

be realigned and designed in ways that are more inclusive, interactive and flexible to respond to the social and economic needs and circumstances of the different actors.

5.4 General recommendations

The following recommendations are suggested based on key findings of the study.

From a practitioner's perspective, researchers should put in place a rigorous process for prioritization of end-users' needs and preferences at the different stages of banana breeding. Such prioritization should be based on a clear understanding of the target end-users and their needs and preferences. This requires researchers to engage end-users and other actors in the innovation system in a participatory process involving both men and women of different ages to properly understand their context, needs and preferences with regard to banana varieties. Involvement of both men and women of different age groups is especially important given that this study has demonstrated existence of gender differences in-terms of acceptability and utilization of bananas. Effective use of participatory processes that involve both men and women may require researchers undergoing capacity building especially in soft skills, end-user oriented and gender-responsive research.

The selection criteria used to identify new lines to proceed with in the breeding process should be broadened to include social and economic attributes in addition to the technical attributes that are emphasized in the existing breeding processes. This will require mapping and involving different actors along the stages of varietal development pipeline to obtain a whole range of attributes that the HBVs should exhibit if they are to be acceptable to all actors. A well mapped BTD process will be useful to clearly benchmark when to apply technical and social attributes either singularly or in combination to enhance uptake. In addition to the actors, mapping of stakeholders along the banana value chain such as media and financial service providers should be conducted to pave way for capturing their input, identifying and harnessing synergies that are critical to expanding and sustaining uptake of the HBVs.

Further, breeding efforts should target new cooking banana varieties with multi-traits. Although quality attributes such as taste, texture and food color are already a component of the breeding process, research efforts should be geared towards profiling

and defining these traits to complement farmers' assessment during the sensory evaluation studies. This will require better understanding of quality traits such as taste, colour and texture identified in this study to be critical to uptake of new banana hybrids and define the traits and their ranges to guide future banana breeding programs. Attaining a better texture, taste, food color and ability of the cooked food to retain heat for most of the new HBVs especially M9 (KABANA 6H) which is relatively acceptable among end-users and being widely disseminated across the agro-ecological zones, is more likely to increase uptake levels. Application of breeding techniques such as genomics will be useful in improving the breeding pipeline, identifying preferred traits and shortening the breeding cycle. Breeders' recommendations indicated a need to develop methods that can enable them to select for various traits at once instead of multiple evaluations of lines which slows the process. Additionally, application of novel methods such as PAPRIKA (*Potentially All Pairwise Rankings of all possible Alternatives* (Hansen & Ombler, 2008) that have proved to be useful in developing weights for different traits as well as determining trait trade-offs associated with local and hybrid bananas will be useful across agro-ecological zones in Uganda. To effectively understand the trait preference, close collaboration between breeders and other disciplines, especially those in the social sciences including gender experts, will be necessary during the variety development process.

The study has demonstrated that researchers need to re-orient their role and position in technology development to provide space for other actors (including end-users) to effectively engage in the process, if uptake is to be improved. This calls for a need to address existing power inequities between different actors in the BTD process. Addressing the power inequities will promote a BTD process that is flexible and iterative to accommodate the interests, knowledge and other resources of different actors. This will however require transparent and regular interactions among the different actors at all stages of the BTD process. The interactions among different actors will only be possible if the actors are organized. In particular, smallholder farmers need to be better organised if they are to meaningfully participate and influence the BTD process and its outcomes. Farmers need to achieve a favored position of prominence and influence in the process such that they are able to articulate their

demand and influence researchers to make informed decisions and to develop relevant technologies.

Findings from this study have further revealed that farmers as end-users of the HBVs were largely excluded in the process of variety naming and release and this triggered negative attitudes and misconceptions towards HBVs. Therefore, a more inclusive and tailored approach of naming and releasing of varieties should be adopted. The approach should take into account differences between communities, implying that release of tailor-made varieties targeting specific regions would require decentralized release processes that take place in the actual locations with active involvement of key actors and stakeholders, such as extensionists, processors and local leaders, among others. This will accelerate diffusion and also serve as a promotion strategy for enhancing technology uptake.

This study has highlighted various factors including production and consumption related attributes as well as information access to HBVs that enhance uptake. Therefore, a communication strategy that seeks to widely disseminate information about HBVs is necessary. Such a communication strategy should focus on constant provision of information customized to the different actors such as farmers, consumers and traders so as to change their attitudes and misconceptions about HBVs.

From a policy perspective, this study highlights the need to strengthen both horizontal and vertical linkages among actors in the BTD and dissemination chain. Close linkages among actors will potentially promote levelled understanding through information and knowledge sharing. Policies, approaches and strategies that enhance actor interactions in a technology development process, but which also create more space for smallholder farmers and other actors to participate effectively in technology development networks as a strategy to improve uptake need to be explored. This could be achieved by facilitating establishment of multi-actor platforms as well as strengthening the existing private-public partnerships in technology development, promotion and commercialization. The multi-actor platforms will not only serve to offer end-users with opportunities to access adequate information but also provide useful linkages that are important to support and guide adoption of HBVs.

Further, the NARS should streamline engagement of actors in technology development processes while empowering them to support and sustain the new technologies. It is also important that the National Agricultural Research Institutes (NARIs) streamline their collaboration with Zonal Agricultural Research and Development Institutes (ZARDIs) in research processes since these were established to adapt and disseminate research and technology outputs in particular agro-ecological zones. Stronger collaboration between the NARIs and ZARDIs will not only tap into the potential of ZARDIs to create wider impact but will also serve to build capacity and to mentor the zonal level scientists in emerging novel research and dissemination approaches. Such collective and collaborative arrangements that support efficient and effective exchange of information would enhance the use of new HBVs.

Overall, the results and above mentioned recommendations of this study point to a need for a change in the BTD process. Therefore, as a key output from this study, a multi-dimensional integrated model that seeks to enhance the inclusiveness and responsiveness of the BTD process and its outcomes is proposed as presented in Figure 5.1.

The proposed model aims at broadening actor diversity, multi-level prioritization, strong linkages and interactions among actors, and integration of both technical and social aspects, including gender during technology development and dissemination to enhance acceptance and use (uptake). Thus, the approach provides a holistic framework with a social perspective for agricultural technology development and uptake. From the AIS perspective, it postulates that new technologies should be a result of an iterative process that fosters feedback while allowing for diverse actor involvement at different relevant stages and ultimately aiming at increased acceptance and use of new varieties technologies. The proposed model differs from the existing BTD process and this section summarizes the key features and requirements as discussed within the recommendations section.

1. Situational analysis that is gender-focused to understand the different dimensions of the problems and generate input to guide technology development efforts.
2. Priority setting for trait selection informed by end-users' needs and preferences (including clear definition of traits and their ranges to guide breeding efforts)

3. Broadening actor diversity and involvement at the different stages in the process with close interactions and enhanced linkages among these actors
4. Integration of gender at the different stages of the technology development process to improve responsiveness and targeting of breeding products
5. Interdisciplinary approach to breeding (explicit consideration and inclusion of social scientists including gender experts at the different stages of the process)
6. Integration of social and technical (biophysical) attributes and priorities both in trait selection criteria.

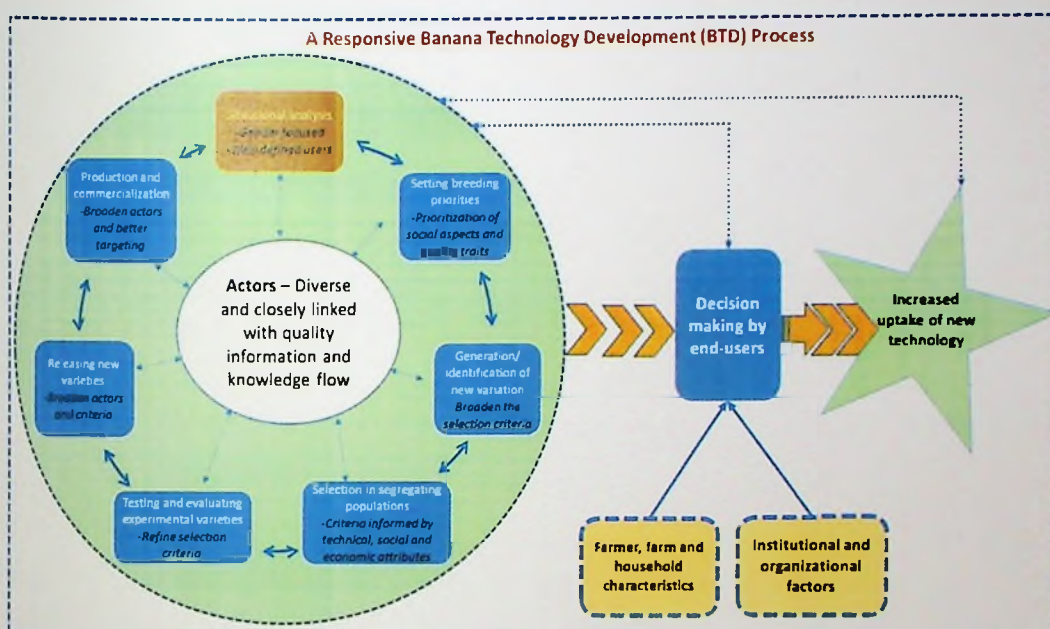


Figure 5.1 A Multi-Dimensional Integrated Model for Technology Development

5.5 Contribution of the research

This research contributes to the existing literature by providing an integrated view of uptake and its inducing factors in the ATD context. Most of the available frameworks focus on farmers' participation in ATD yet other actors besides farmers are critical for the success of this process. This research has attempted to fill the gap by generating a model that provides for broadening of actor involvement at the different stages of the process. Application of the systems approach to technology development requires a

dynamic process that supports involvement of a diverse range of actors. This model can potentially be applied to other crop-based technology development processes to address potential causes and limitations of non-responsive technologies – most new technologies especially in SSA face the risk of low uptake among end-users amidst low levels of total factor productivity.

Secondly, the research makes a contribution to the existing body of knowledge in the area of adoption and intensity of adoption of technologies and systems approaches to agricultural and rural development. The study demonstrates that actor diversity and interactions are critical in technology development and uptake. It advances knowledge on effects and value of networks in research and development processes, and nuancing power relations accompanying the network of actors. The study provides a deeper understanding of the dynamics in ATD and opens new research areas. Although the concept of technology development and uptake is not new, this could be the first study of its kind in agricultural research in Uganda to focus on the key processes in technology development and how these shape uptake of new technologies.

Lastly, this research categorizes the existing actors in BTD according to the domains of the AIS. The research indicates the critical missing actors at the different stages of the process particularly actors in the enterprise, intermediary and support service domains and how these can be involved to enhance uptake of new varieties. It further shows the linkages among actors that need to be strengthened within the BTD process as a key strategy to enhance uptake.

5.6 Areas for further research

One of the key issues identified for better uptake of new technologies is the consideration of social aspects in the breeding process, particularly the social attributes. Further research should seek to understand such attributes which could be traits preferred by end-users in the banana values chain along with levels that define each trait. This will require better understanding and defining of the traits, such as taste, colour and texture identified in this study to be critical to uptake of new banana hybrids and their ranges to guide future banana breeding programs. Application of novel methods such as PAPRIKA that have proved to be useful in developing weights for

different traits as well as determining trait trade-offs associated with local and hybrid bananas will be useful across agro-ecological zones in Uganda.

Further, since gender considerations were identified as being key in the process of banana technology development and uptake, there is need for further studies that focus on analysis of gendered preferences and needs in banana selection and production. The gender component largely relied on in this study did not adequately explain the power relations in terms of access to resources towards HBVs production and control of benefits from the value chain. Further research should also specifically seek to assess trait preferences for men and women actors along the BTD process as a pre-requisite to developing gender-responsive technologies.

This study has indicated that the actors in the support domain were largely lacking while those in the enterprise and intermediary domains had minimum influence in the BTD process. This study has however not provided precise insights about why these actors are still peripheral with regard to the BTD process and how this influences uptake. Therefore future research could focus on assessing the factors that affect involvement of different actors' in the BTD process. Such studies should also analyze the perspectives of different actors in agricultural technology development networks and how this affects their level of commitment to commercialization and uptake of the resultant new technologies.

Although the results indicate that uptake of new HBVs is increasing, similar research in other agro-ecological zones is needed to understand the uptake levels and to document experiences of men and women farmers with the new HBVs. Such studies should also aim at establishing whether the observed increase in cultivation of hybrid banana varieties by the adopting households merely reflects access to free planting materials from the on-going project interventions or farmers' enhanced adaptive capacity. Furthermore, it is also necessary to identify the factors that influence sustained use of HBVs.

References

- Akankwasa, K., Ortmann, G., Wale, E. & Tushemereirwe, W. (2013). Farmers' choice among recently developed hybrid banana varieties in Uganda: A multinomial logit analysis. *Agrekon*, 52 (2), 25-51.
- Edmeades, S. (2007). A hedonic approach to estimating the supply of variety attributes of a subsistence crop. *Agricultural Economics*, 37: 19-28.
- Fritsch, M., & Kauffeld-Monz, M. (2010). 'The impact of network structure on knowledge transfer: an application of social network analysis in the context of regional innovation networks', *The Annals of Regional Science* 44(1): 21-38.
- Hansen, P., & Ombler, F. (2008). A new method for scoring additive multi-attribute value models using pairwise rankings of alternatives. *Journal of Multi-Criteria Decision Analysis*, 15(3-4), 87-107. doi: 10.1002/mcda.428
- Kasirye, I. (2013). Constraints to Agricultural Technology Adoption in Uganda: Evidence from the 2005/06-2009/10 Uganda National Panel Survey. Research Series No. 102, Economic Policy Research Centre (EPRC). Kampala, Uganda.
- Katungi, E., Sperling, L., Karanja, D., Farrow, A. and Beebe, S. (2011). Relative importance of common bean attributes and variety demand in the drought areas of Kenya. *Journal of Development and Agricultural Economics*, 3, 8: 411-422.
- Mgumia, A. H., Mattee, A. Z. & Kundi, B. A. (2015). The application of the agricultural innovation system approach in technology development in Tanzania: researchers' perceptions and practices. *African Journal of Science, Technology, Innovation and Development*, 7(3), 211-219.
- World Bank. (2008). *World Development Report 2008: Agriculture for Development*. World Bank, Washington, DC
- World Bank. (2013). *World development report 2013: Agriculture for Development*. The World Bank, Washington DC.

Appendix 1: Map Showing the Study Area

Central Region of Uganda



Appendix 2: Guide for the Key Informant and In-depth Interviews

Process:

- Record date and location of the interview (general setting)
- Introduce yourself (name, organization/institution)
- Explain purpose of the interview
- Read out the content of the consent form and request for consent to; a.) participate, b.) take notes, 3.) photos, and 4.) recordings
- Re-assure the key informant of confidentiality of the information collected
- Be observant to capture non-verbal expressions

Guiding questions

1 Background information

- 1.1 What is your name? *Record contact of interviewee* (optional)
- 1.2 What is the name of your organization/institution/programme?
- 1.3 What position do you hold in the organization/institution/programme? (*Probe: for professional background, how long the interviewee has worked with the organization and in which positions*)
- 1.4 What was your role in the banana technology development process?

2 Identification of research area and process

- 2.1 How are research needs and or focus identified? (*Probe: how priorities are identified, who is involved and why*)
- 2.2 Briefly describe the banana technology research process? (*Probe: stages, activities at each stage, methods/procedures used at the different stages of the process*).
- 2.3 What changes have occurred in the processes/techniques/methods/procedures of research on banana? (*Probe: what changed, how the changes occurred, when and why?*)

3 Actors and their roles in the BTD process

- 3.1 Which actors* (*individual or organization*) have you worked with in the BTD process? (*Probe: a.) Specify actors involved at the different nodes/stages of the BTD process, b.) farmer involvement and their role in the process*)

** Actors could include among other; Farmers, Researcher, Community leaders, Extension, Traders, Input suppliers, Processors, Financial institutions, policy agencies/regulatory bodies like MAAIF*

3.2 How were the actors identified, selected and involved? *(Probe: how linkages are initiated)*

3.3 What tasks/functions/roles are (were) performed by the respective actors at different stages of technology development process?

3.4 On a scale of 1-5, rank each of the actors you worked with in the BTD process in terms of importance and influence

Note:

- **Importance:** Define and rank actors who were regarded priority (and probably had interest) at the different stages of the process
- **Influence:** Define and rank actors who had the power to guide what happened (control the decisions making process) at the stage

3.5 In your own opinion, who takes lead of the BTD process and activities at each stage? *(Probe: how and why?)*

3.6 Which actors do consider to have been important but were not involved in the process? *(Probe: a) specify the actor and their perceived/expected roles at each stage of the process; actors not involved but got interested in matooke hybrids and hence came on board – specify who they are and why they got involved)*

3.7 In your own opinion, what is the critical stage for involving different types of actor in BTD process? *(Probe: Reasons why specific actors at certain stages)*

3.8 Specify any challenges encountered dealing with actor

3.9 Describe your suggestion of how actors' involvement in the BTD process can be enhanced?

4 Actor Interaction and linkages

4.1 How do the different actors (individual and or organizations) in the BTD process interact? *(Probe: nature of linkages and interaction and frequency of interaction, what forms the core (reasons/areas) of the interactions in the process; intensity of the interaction)*

4.2 What factors influence the interaction among actors in the BTD process?

4.3 What mechanisms are used to enhance interactions among actors

- 4.4 What kind of support do actors offer each other (including farmers if any)?
- 4.5 In your own opinion, how do you think involvement of these actors has been beneficial to the BTB process? *(Probe: Collective learning, knowledge sharing, access to necessary inputs, building social capital/networks, change in attitude and perception, change in practice (the way research is conducted)).*
- 4.6 Which kind of change have you observed in the way different actors operate, act or do business due to their involvement in the process?
- 4.7 What are the major challenges and limitations to actor linkages and interactions in the process? *(Probe: How these can be addressed and suggestions for improvements in the linkages and interaction available to foster farmers' uptake of new technologies)*

5 Actor's perception about uptake of new HBVs

- 5.1 How do you perceive the new HBVs
- 5.2 On a scale of 1-5, how would you rate each of the different dimensions (acceptance and use) of uptake of new HBVs?
- 5.3 From your opinion, what factors influence decision making processes for uptake of new HBVs?

6 Knowledge sharing in the BTB process

- 6.1 Are there any deliberate efforts for knowledge sharing in the process? If yes,
- 6.1.1 How (mechanisms) is knowledge shared among actors?
- 6.1.2 What kind of information/knowledge is shared with other actors in the BTB process? Probe for information shared with specific actors
- 6.1.3 To what extent is farmer's knowledge integrated in the process
- 6.2 *How is feedback provided in the process? Probe: type of actors provided feedback, type of feedback provided and how the feedback integrated in the BTB process?*
- 6.3 If no, give limitations for knowledge sharing in the process
- 6.4 Can you please give suggestions for improving knowledge sharing in the technology development process

7 Dissemination and communication strategies for new banana technologies

- 7.1 What dissemination channels/methods have been used to reach out to the farmers (capture methods used to disseminate technologies)

- 7.2 What communication strategies (pathways) are used to reach out to the farmers
- 7.3 In your own opinion, how have the different methods and strategies mentioned above influence farmers decisions to use new HBVs?
- 7.4 How do you get feedback from end-users about the technologies disseminated
- 7.5 To what extent does this feedback inform the research process and your role in the
BTD process in particular
- 7.6 Can you please give suggestions for improving technology dissemination and
communication strategies to enhance uptake of HBVs

8 Conclusion

- 8.1 In your own opinion, what is the weakest node of the BTD process? (*probe: why*)
- 8.2 What strategies and or improvements can be made in the BTD process to enhance
uptake of new banana technologies?

Concluding remarks

General note/observation

THANK YOU VERY MUCH FOR YOUR TIME AND RESPONSES

Appendix 3: Guide for the Focus Group Discussions

Process: Introduction session and setting of FGD

- a) Record date and location of the FGD (general setting)
- b) Opening remarks and introductions
- c) Explain purpose of the FGD
- d) Read out the content of the consent form and request for consent to; a.) participate, b.) take notes, 3.) photos, and 4.) recordings
- e) Record number of participants (Total, Number of males and females) and take attendance list
- f) Re-assure the participants of confidentiality of the information collected
- g) Be observant to capture non-verbal expressions

Tool Box: *Power/Influence and Importance (or interest) matrix, Actor Analysis Matrix, Information flow map, Actor Linkage and Network Map, Perception matrix and Pair-wise ranking*

Guiding questions (conducted in a participatory and interactive way)

1 *Actors, their roles and linkages*

- 1.1 How has this community been involved in banana research activities?
- 1.2 Which actors have you work with in the process of BTD and dissemination at different institutional levels (list and rank on a scale of 1-5, where 1 is the most important)
 - **Tool:** Power/Influence and Importance (or interest) ranking and matrix
- 1.3 What roles do different actors perform in development and dissemination for uptake
 - **Tool:** Actor Roles Matrix (focus on present and future/desired roles)
- 1.4 How do the different actors in the process link and interact? Specify the type of linkages that exist in the community (information, input, funds, decisions)
 - 1.4.1 **Tool:** Actor linkage/Network map (s) and Information flow maps
- 1.5 How has the involvement of this community in the BTD process influenced uptake of HBVs/matooke hybrids?
- 1.6 Has this community observed any change (s) in the way research on banana is conducted? explain the changes

2 *Information, Knowledge and communication*

- 2.1 What kind/type of information do you access about new technologies
- 2.2 How do you as farmers in this community access/obtain this information about new technologies? Specify; Source and Frequency
- 2.3 How have these sources/channels served the needs of farmers? Record the *Advantages and disadvantages* of each source of information for enhancing uptake
- 2.4 How accessible is this information?
- 2.5 How useful (relevant) is this information in improving uptake and the BTD process generally

NB: Probe for any gender differences in access to information about banana varieties

- 2.6 How do farmers share/exchange information/knowledge about new technologies within this community?
- 2.7 What are the limiting factors to getting and sharing of useful information/knowledge?
- 2.8 How does information and the sharing mechanisms impact on uptake of new hybrids?
- 2.9 What kind of information would be important (is required) for enhancing uptake of new varieties? (main information gaps that exist)
- 2.10 How can flow and sharing of information and knowledge about new technologies be enhanced in this community?

3 *Production*

- 3.1 List and rank major crops grown, banana varieties grown
- 3.2 Average acreage per farm household, average acreage grown with banana, Acreage (No. of mats) for banana hybrids
- 3.3 Out of 10 households, what is the current proportion of households growing new hybrid banana varieties in the community?
- 3.4 Most preferred hybrid varieties and why (Tool: *Pair-wise ranking*)
- 3.5 How has the use of matooke hybrids spread throughout the community/village? From 1st year till now 2015 (Record if decline or increase in number has been observed and reasons for trend)

3.6 Community perception: How do farmers in this community perceive hybrid banana varieties [yield, taste, resistance to pests and diseases, management, labour requirements]

3.6.1 Tool: *Perception matrix*

3.7 Which perceptions and attitudes enable/promote or restrict/inhibit uptake of new banana hybrids (Probe: Why do you think members of this community don't widely grow banana hybrids?)

4 Changes in the community

4.1 Generally, what changes and or innovations have been observed in the community or at household level as a result of introduction of new banana hybrid varieties? i.e. in banana management and utilization?

4.2 In which months of the year do households in this community mainly experience insufficient food?

4.2.1 Tool: *Food Availability Calendar*

4.3 Explain changes that have occurred in community food security situation with the introduction of hybrid banana varieties (Contribution of hybrids to food availability)

5 General

5.1 What suggestions or areas for improvement do you have as a community regarding development and dissemination of new technologies?

Concluding remarks

General note/observation

THANK YOU VERY MUCH FOR YOUR TIME AND RESPONSES

Appendix 4: Survey instrument for banana growing households

Questionnaire number..... Household ID.....

Name of the Enumerator..... Date: ----- / ----- / -----

Checked by Entered by

Location of household surveyed

District:..... Sub-county:.....

ParishVillage.....

1. Details of demographic and socio-economic characteristics of Household

(A 'household 'includes all members of a common decision making unit, usually in one residence (including resident workers and servants) that constantly live together and share meals, income and other resources)

ID COD E	Name of househol d member [Start with responde nt]	Gend er 1 = M 2 = F	Relations hip to the househol d head CODE 1	Age (compl ete years)	Ma rita l stat us? CO DE 2	Educati on (numbe r of years of Schooli ng)	Prima ry occup ation COD E 3	How many months in the past year (2015) was [NAME] present in the HH?
1.								
2.								
3.								
4.								
5.								

CODES

Code 1	Code 2	Code 3
1.Household head, 2.Spouse, 3.Son/daughter, 4.Parent, 5.Son/daughter-in-law, 6.Grandson/granddaughter, 7.Other relative, 8. non-relative, 9.Hired worker, 10.Other, specify....	1=Single, 2= Married 3= Widowed 4=Divorced /separated	0=None, 1=.Farming (crop+ livestock), 2=Salaried employment, 3=Self-employed off-farm, 4=Casual labourer on-farm, 5=Casual labouer off-farm, 6=School/college child, 7= Non-school child, 8=Other (Specify) -----

2. Basic Household related information

2.1 Household size and composition in 2015: In the table below indicate the number of people who live in the respondent’s household.

Age group (years)	Household composition			No. of HH members' participating in banana production activities			No. of HH members having off-farm jobs		
	Total	Males	Females	Total	Males	Females	Total	Males	Females
0-8									
9-17									
18-35									
36-64									
65+									
Total									

2.2 Household Land access, allocation and utilization in 2015 (2015A & 2015B):

How much land (acres) in total did the HH have access to in 2015 for agricultural production (including rented-in, rented-out, sharecropped in, borrowed land, fallowed land etc) and how was it allocated?

Variable	Total Acreage (in Acres)
2.2.1 Total land accessed in 2015	
2.2.2 <i>Owned</i> (inherited/bought) by the household of the total land	
2.2.3 Area under <i>crops</i> during the year 2015 (Season A&B)	
2.2.4 Area under <i>banana crop</i> during the year 2015 (Season A&B)	
2.2.5 Area under <i>cooking bananas</i> during the year 2015 (Season A&B)	

2.3 Major crops grown: List and rank the five major crops grown by HH in 2015, Season A&B

Crop	Rate on 5 point scale importance for Income (<i>1=most important</i>)	Rate on 5 point scale importance for Food security (<i>1=most important</i>)
1.		
2.		
3.		
4.		
5.		

Codes: 1 = Bananas, 2 =Coffee, 3= Beans, 4= Cassava, 5= Maize, 6= Sweet potatoes, 7=Tomatoes, 8=Leafy Vegetables (Nakati, Bugga, Ddodo, Jobyo...), 9=Cabbage, 10=Irish potato, 11=ground nuts, 12=Other (Specify) _____

3 Banana Production in 2015 (season A & B)

3.1 Varieties grown and their acreage

3.1.1 What are the *five (5) most important local cooking banana cultivars* grown by this HH? Please in the table below details of varieties and acreage planted with each of the varieties?

Name of Local Banana cultivar (Use Codes)	Rank	Total number of mats	Main Spacing Used	Acreage for all local varieties (Record in Acres)
1)				
2)				
3)				
4)				
5)				

Codes: 1=Kisansa, 2=Nakitembe, 3= Musakala, 4= Mbwazirume, 5=Muvubo, 6=Mpologoma, 7=Muyovu, 8=Nakyatengu, 9= Nakabululu, 10=Kibuzi, 11=Muzira Nyama, 12=Nakawere, 13=Others (Specify).....

3.1.2 Generally, on whose *plot* are *local banana cultivars* usually planted in your HH?-----

1=Jointly-owned plots (husband/wife), 2=Women/wife's plots, 3=Man/Husband's plot

3.1.3 Has the respondent's household ever heard about *improved banana varieties/Hybrid Banana Varieties/matooke hybrids (HBVs)*? (HBVs are sometimes referred to as *ebitooke* by 'kawanda or *ebitooke ebirogosemu*)

1=Yes, 2=No, skip to Qn. 3.2

3.1.3.1 If yes, in which *year* did your HH first get to know about the HBVs? -----

3.1.4 **How (source of info.)** did this household first get to know about the HBVs?

1=Research Institute, 2=NGO, 3=Fellow farmer, 4=Extension, 5=Local leader, 6=Community leader, 7=other (specify) -----

3.1.5 Has the respondent's household ever grown *Hybrid Banana Varieties (HBVs)* on their farm? 1=Yes, 2=No, ask why not and then skip to Qn. 3.2

.....

3.1.6 If yes, Please fill in the table below the *HBVs* grown by the respondent's HH and the acreage planted for each of the HBVs

Hybrid Banana Variety (use codes A)	Rank in order of preference	Year first planted	Source of first planting materials (use codes B)	Quantity first planted (suckers/ plantlets)	Still growing variety (1=yes, 2=No)	If yes, Current Total number of mats	Current Acreage for all HBVs (In Acres)
1)							
2)							
3)							
4)							
5)							

Codes A: 1= M9 (Kabana 6H or Kivanganzi), 2=M2, 3=M14, 4=M17, 5=M3, 6= FHIA 17 (both but mainly desert), 7= FHIA 25 (both but mainly juice), 8= Kilometer5/Kabana 5, 9=others (Specify).....

Codes for source B: 1=Research Institute, 2=NGO, 3=Fellow farmer, 4=Extension, 5=Local leader, 6=Input dealer, 7=NAADS, 8= Community leader, 9=other (specify)

3.1.7 Generally, on whose *plot are HBVs* planted in your HH? -----

1=Jointly-owned plots (husband/wife), 2=Women/wife's plots,

3=Man/Husband's plot

3.1.8 What is the *size (in acres)* of the main plot on which HBVs are planted? -----

3.1.9 What is the *distance (walking minutes)* to the main plot where HBVs are grown? -----

3.1.10 Give main reason why HBVs are planted on this plot? -----

1=Hybrid varieties received by the person, 2=Main decision maker for land allocation, 3=main decision maker in what to grow, 4=Sole responsibility for food consumption, 5=Other specify.....

3.1.11 What was your *acreage of cooking bananas* in the year you started to grow HBVs? -----

3.2 Variety Preferences

3.2.1 Score the following production and consumption attributes you prefer in the main HBVs and local varieties grown by your household scale of 1 to 5 (*1 as most important, Do not repeat any of the scores*). Score production and consumption attributes seperately

Variety Attribute	1 st most important HBV -----	2 nd most important HBV -----	1 st Most important <u>Local variety</u> -----	2 nd Most important <u>Local variety</u> -----
Production/field		--		
Resistance to pests & diseases				
Tolerance to drought				
Tolerance to poor soils				
Maturity period				
Yield (Gives many bunches)				
Bunch size				
Finger size				
Skin color				
Sucker production				
Plant height				
Resistance to wind				
Other, <i>specify</i>				
Consumption and market				
Easy to peel				
Inside color when cooked				
Texture (Softness) when cooked				
Flavor				
Taste				
Market demand				
Longevity after harvest				
Other, <i>specify</i>				

3.2.2 List three (3) main banana varieties discontinued (Dis-adoption) since you started to grow HBVs and reasons why

Variety	Reason for Dis-adoption: 1=Susceptible to pests & diseases, 2=Not tolerant to drought, 3= Not tolerant to poor soils, 4=Takes long to mature, 5=Low yield, 6=Small bunch size, 7=Small finger size, 8=Skin color, 9=Difficult to peel, 10=Inside color when cooked not appealing, 11=Texture, 12=Flavor , 13=Taste, 14=limited Sucker production, 15=low market demand, 16=Low price, 17=Others (Specify).....				
	Reason 1	Reason2	Reason 3	Reason 4	Reason 5

3.3 Gender and Decision Making

3.3.1 How do the different gender categories contribute to decision making for HBVs production and dissemination in the respondent's household

Issues	Involvement in decision Making <i>(Use codes below)</i>	
	Women	Men
1) Participate in Banana research activities		
2) Start growing banana hybrids varieties		
3) Variety of the hybrid banana to grow		
4) Allocation of specific land/plot on which to grow the HBVs		
5) Continue growing hybrid bananas		
6) How to utilize the banana hybrids		
7) Consumption of hybrid banana varieties (Quantity to consume)		
8) Marketing of HBVs (quantity sold)		
9) Disseminate banana hybrids varieties		

Codes for Involvement: 0 =No input in the decision, 1 =Provides some input in the decision, 2=Provides most of the input in the decision, 3=Provides all the input in the decision

3.3.2 How do the different gender categories in the respondent's HH perceive and rate HBVs?

Gender category	Perception on the importance of HBVs for food security <i>(Use codes)</i>	Main reason for the rating selected for the gender category	Perception on the importance of HBVs for income <i>(Use codes)</i>	Main reason for the rating selected for the gender category
Adult Male				
Adult Female				

Codes for Perception: 1=No importance, 2= Very low importance, 3=Low importance, 4=High importance, 5= Very high importance

3.3.3 What factors facilitating and or inhibiting use of HBVs in the respondent's HH?

Issue	Response
a.) What were the <i>enabling factors</i> for your household to start growing new hybrid banana varieties?	1. ----- 2. -----
b.) Which factors <i>motivate</i> your HH to continue growing HBVs?	1. ----- 2. -----
c.) List main <i>challenge, limiting or constraining factor</i> to growing hybrid banana varieties?	1. ----- 2. -----

3.4 List areas of hybrid banana varieties that need further improvement by research?

Variety Name	Aspect that require further improvement by research		
	<i>1st most important aspect</i>	<i>2nd most important aspect</i>	<i>3rd most important aspect</i>

3.5 Participation in banana production related activities in 2015

3.5.1 How did the different gender categories in the respondent's HH participate in banana production and marketing related activities in 2015, season A & B (*ONLY applies to banana gardens with some bananas being harvested*)

Activity	Did this HH carry out this activity in 2015 (A&B) <i>1=Yes, 2=No</i>	If yes, who is the main actor when it comes to this activity in banana production? <i>Codes: 1=Adult males, 2=Adult females, 3=Both adult males & female, 4=Youth, 5=children</i>
Weeding		
De-Suckering		
Pruning		
De-leafing		
Propping/staking		
Mulching		
In-organic fertilizer application		
Organic fertilizer application		
Disease control/management		
Pesticide application		
Herbicide application		
Soil and water management		
Stabilization of soil bands (by planting grass or leguminous plants)		

Harvesting		
Splitting of pseudostem		
Corm removing		
Marketing		
Other activities (Specify)		

3.6 Harvest and Utilization:

3.6.1 How are cooking bananas utilized at household level? (*Circle all that may apply*)

[1=Food, 2=Animal Feed, 3=Processing, 4=Brewing, 5=Sell, 6=Others
(Specify) -----]

3.6.2 Please fill in the table below information related to harvest and utilization of banana varieties grown in the respondents HH in the year 2015

3.6.2.1 Local cooking banana varieties

Variable	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
No. of bunches harvested												
Average Bunch Size (1=Small, 2=Medium, 3=Large/big)												
No. of clusters for average bunch size												
Av. weight of bunch (in kg)												
No. of bunches consumed												
No. given out												
No. of bunches sold												
Average sale Price/bunch												
Where do you sell your bananas*												
Main buyer**												

3.6.2.2 Matooke Hybrids (HBVs)

Variable	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
No. of bunches harvested												
Av. Bunch Size (1=Small, 2=Medium, 3=Large/big)												
No. of clusters for average bunch size												
Av. weight of bunch (in kg)												
No. of bunches consumed												
No. given out												
No. of bunches sold												
Average sale Price/bunch												
Where do you sell your bananas*												
Main buyer**												
If HH sells HBVs, specify how the money is spent	1.....2.....											

*Codes where sold: 1=At home, 2=Roadside, 3=Rural Market, 4=Urban Market

**Codes main buyers: 1=Consumers, 2=Retail traders, 3=Wholesaler traders, 4=Institutions, 5=association/cooperative, 6=processors, 7= NGOs

3.6.3 What proportion (Out of 10 parts) of total Banana income is contributed by HBVs? ---

3.6.4 If banana are not sold at home, please indicate;

3.6.4.1 What is the *distance* to market (in KMs)? Rural Market----- Urban Market-----

3.6.4.2 What *method/mode* of transport do you use to take bananas to the market? ---

Codes: 1=Walk/head, 2=Bicycle, 3=Motorcycle, 4=Vehicle, 5=Others, Specify.....

3.6.5 How long (*Time*) does it take you to reach the market? -----

3.6.6 **Other Banana Products:** In the table below, list all the other banana (including HBV) products produced by the respondents HH in the last one year (2015)

Product	Did you produce this product? 1=Yes, 2=No	Did you sell product? 1=Yes, 2=No	Quantity produced	Quantity Sold	Average price	Annual revenue (UGX)
Suckers						
Leaves						
Fibers						
Other, specify						
...						

4 Contribution of Hybrid Banana Varieties to Household Food Security

4.1 Which months of the year are mainly characterized by banana surplus and scarcity? Also specify the food supply situation of the HH throughout the year 2015

Variable	Codes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Food Availability	1=Adequate 2=Inadequate												
Local cultivar Supply	1=Surplus, 2=Scarcity												
HBVs Supply	1=Surplus, 2=Scarcity												

4.2 Has your HH food availability situation changed due to HBVs? *Circle response:*

1=Yes, 2=No

4.3 If yes, how many parts out of 10 does HBVs contribute to this household food availability? --

4.4 Give main reason for the proportion, -----

Codes: 1=Constant supply, 2=Longevity of plantation, 3=Big Bunch size, 4=Not Palatable for food, 5=others, specify.....

4.5 Contribution of bananas to food availability in respondent's HH (*Ask all farmers*)

Variable	Period/season			
	NOW		BEFORE starting to grow HBVs	
	Peak	Low/bad	Peak	Low/bad
No. of months				
Total No. of times bananas consumed per week				
Total No. of times HBVs consumed per week				
Total No. of bunches consumed per week				
Total No. of bunches of HBVs consumed per week				

4.6 Major Staple Food Consumption and Expenditure during the last 7 days

(Estimating the contribution of Bananas to the HH Food basket in a week)----

(Ask all farmers)

Item Consumed/ Purchased	Consumption from own production in a week (members of the family only)				Bought in the last one month only for home consumption						Quantity of food aid/ borrowed/gifts received in a month
	No. of meals per week	QTY per meal	Specific Unit (e.g. kg, tubers, bunch)	Convert quantity to Kg	Freq. of buying per month	Avg. QTY bought each time	Specific Unit (e.g. kg, liter, packet, bundle)	Total QTY bought per month	Avg price per unit (UGX)	Total cost of purchased (UGX)	
	A1	A2	A3	A4	A5	A6	A7	A8=(5x6)	A9	A10=(8x9)	
Hybrid bananas (HBVs)											
Local Matoke Cultivars											
Cassava (Fresh form)											
Cassava (Processed)											
Sweet potatoes											
Maize grain											
Maize meal/flour											
Rice											
Irish potatoes											
Other staples (any)											

**If the household does not purchase the item, ask how much the household would pay for the item per Specific UNIT and record in column A9*

4.7 Perceptions: To what extent do you think HBVs have contributed in the respondent's HH?

Variable	Rating 1. Not Minimal 4. To very
4.7.1 Food situation since the time you started to grow HBVs	
4.7.2 Having enough food (availability) at all times	
4.7.3 The number of times we eat bananas in a week	
4.7.4 The quantity of bananas eaten at every meal	
4.7.5 Banana preparation methods (give example)	

5 Farmer's involvement and interaction in the Banana Research

5.1 Have you or any member of your household ever been involved in banana research activities?

(By Banana research activities we mean, participation in evaluation trials, demos, training, testing sessions among others)
1=Yes, 2=No (Circle response, If No, Skip to → Question 5.2)

5.2 In which year did your household start getting involved in banana research activities? -----

5.3 Who in the respondent's household participated in banana research activities? -----
Codes: 1=HH head, 2=Spouse, 3=Children, 4=Others (specify).....

5.4 How did you come to participate in the banana research activities? -----
Codes: 1=selected, 2=Self-selected, 3=others (specify).....

5.5 If selected, who selected you or another household member for banana research activities?

Codes: 1=Research Institute, 2=NGO, 3=Community meeting, 4=Extension, 5=Local leader, 6=Other (specify).....

5.6 Why were you selected to participate in the banana research activities?

Codes: 1=Had accessible land, 2=Status in the community, 3=Other (specify) -----

5.7 What was your role in the banana research activities?

1=Host farmer, 2=Community mobiliser, 3=Trainer, 4=Trainee, 5= Other
(specify) -----

5.8 Which banana research activities have you been involved in since you started to be involved in banana research activities? *List activities and frequency of involvement for each activity*

Activity	Frequency (No. of times)
1.	
2.	
3.	

Codes for activities: 1=Host farmer of on-farm evaluation trial, 2= Demonstrations, 3=Training, 4 =Sensory and acceptability Analysis, 5= Exposure visits, 6=Agricultural Shows, 7=Field days, 8= Other (specify)-----

5.9 Feedback:

5.9.1 Did you ever share any information or knowledge with any actors during the research process? 1=Yes, 2=No (If No, Skip to 5.10)

5.9.2 If yes, specify below information related to feedback provided by the respondent's HH

Variable	Codes	Response
5.9.2.1 Specify the kind of information you shared?	1=Performance of matooke hybrids, 2=Response to diseases and pests, 3=Tolerance to drought, 4=Tolerance to poor soils, 5=Crop Management aspects, 6=Crop agronomic aspects, 7=Acceptability (best lines), 8=Palatability of hybrids, 9=Needed variety modification, 10=Other (specify)	
5.9.2.2 With whom specifically did you share information or knowledge?	1=Researchers, 2=community mobilizer 3=other farmers, 4=Extension, 5=Local leader, 6=Other (specify)	
5.9.2.3 To what extent do you agree your feedback was integrated in the development of the new HBVs?	1=Strongly disagree, 2=Disagree, 3=No comment/neutral/not sure, 4=Agree, 5=Strongly agree	

5.10 Actors and their perceived contribution to uptake of HBVs

5.10.1 With which actors (individual and or organizations) have you established linkages regarding banana research activities? Please, specify the nature and frequency of linkage/interaction

Actor (individual and or organizations)	Do you interact with this actor <i>1=Yes, 2=No</i>	No. of times HH has interacted with actor since start of growing HBVs	Nature of linkage (s) with actor regarding HBVs (Use codes)	Value of the relationship <i>Scores: 1=bad 2=moderate 3=Good 4=very good</i>	Did this actor contribute in any way to your HH uptake of HBVs <i>1=Yes, 2=No</i>
1) Other Farmers					
2) Researcher					
3) Community leaders					
4) Extension					
5) Traders					
6) Input suppliers					
7) Processors					
8) Financial institution/service					
9) NGOs (specify).....					
10) Other actor (specify)...					

Codes for Nature of linkages: 1= Test/evaluate new lines, 2=Access new banana varieties, 3=Access planting materials, 4=Access to training, 5= Marketing hybrids, 6= Access Production inputs, 7=Access to information, 8=other (specify)....

5.10.2 Who of the actors above have been the most important contributors to your HH use/uptake of new HBVs? Please, give reasons why

Contribution	Actor (Use codes)	Main Reason why
Highest contributor		
Second highest contributor		
Least contributor		

Codes for actors: 1=Other Farmers, 2=Researcher, 3=Community leaders, 4=Extension, 5=Traders, 6=Input suppliers, 7=Processors, 8=Financial institution/svs, 9=NGOs, 10=Other actor (specify).....

6 Information flow, Knowledge sharing and learning networks regarding new HBV

6.1 From time to time, people discuss matters with others to get information. Thinking about HBVs, did your HH discuss with anyone to get information in the *past 5 years*?

1=Yes, 2=No (*Skip to question 6.10*)

6.2 What kind of Extension and advisory related advice on HBVs has the respondent's HH received in the past 5 years? (*Extension is an informal out of class exchange of information between extension agents/other actors and farmers and takes a short duration per contact*)

Extension advice related to	Did you receive any advice related to 1= Yes , 2= No	Main Source of advice(use codes A below)	Main Channels used to receive the advice (Use	Adequacy of the service received 1=Very Satisfactory 2=Fairly satisfactory
Type of variety				
Variety Name				
Attributes of variety				
Where to get planting materials				
Disease and pest control/management				
How to plant the variety (Agronomy)				
How to manage the variety in the field (management)				
Harvest related information				
Utilization of the variety				
Others (specify)-----				

Codes A for sources of Advice: 1= Fellow farmers 2=Research 3= Community leaders, 4= Local Leaders 5=Traders 6= Input dealers 7=Farmers' groups/assoc. 8=Gov't extension agent 9= Opinion leaders 10=NAADS, 11=Others (Specify

Codes B for channels used: 1= One-on-one meeting 2= Group meeting 3= Trainings 4= Radio 5= Television 6=Printed material 7= Mobile phone 8= Videos 9= Exposure/exchange visits 10= Demonstration plots

6.3 Which channel among those used influenced most your HH choice of new hybrids?

6.4 Why was this the most influential? -----

6.5 In your household, who normally gets this information about HBVs? -----

1=Husband, 2=Wife, 3=Both the Husband and Wife, 4=Others

(Specify.....)

6.6 Explain why this particular person is the one who gets the information?

6.7 Does the person who gets information share with other HH members? 1=Yes,

2=No

6.8 How is the information shared among household members? -----

6.9 Please, fill in the table below to what extent the respondent agrees with the following statements regarding access and use of information

Variable	Codes	Responses
6.9.1 Information received is adequate to meet my needs for uptake of new HBVs	1=Strongly disagree, 2=Disagree, 3=No comment/neutral/not sure, 4=Agree, 5=Strongly agree	
6.9.2 Information about new HBVs' is easily available	1=Strongly disagree, 2=Disagree, 3=No comment/neutral/not sure, 4=Agree, 5=Strongly agree	
6.9.3 Access to information is a key motivator to use of new technologies particularly hybrid varieties?	1=Strongly disagree, 2=Disagree, 3=No comment/neutral/not sure, 4=Agree, 5=Strongly agree	

6.10 What are the three (3) most important type of information considered/perceived important for use of new technologies especially varieties? (Multiple response, please circle only three (3) responses)

1=Where to get the planting materials 2=Agronomy (e.g. How to plant/grow the variety), 3=Crop variety management, 4=Attributes of the variety, 5=Utilization of the variety, 6=Marketability of the variety, 7=Others (specify)-----

6.11 Which is your HH most preferred channel for receiving information about new varieties? (*Circle only one most important*)

Codes: 1=One-on-one meeting 2= Group meeting 3= Trainings 4= Radio 5= Television 6=Printed material 7= Mobile phone 8= Videos 9= Exposure/exchange visits 10= Demonstration plots

6.12 If you had a question about new varieties, what would be the FIRST thing you would do to get information (*Please, circle only one*)

- 1) Ask someone I know (for example: friend, relative, neighbour, acquaintance)
- 2) Check media sources (for example radio, TV, newspapers, magazines, internet)
- 3) Approach an extension, organisation or group (for extension officer, CBO, NGO, Research Institute)

7 Memberships in organizations/groups/associations by HH HEAD and or SPOUSE

7.1 Does any member of the respondent's HH farmer belong to any community organization, association/ group (*including cooperatives, farmers groups, SACCOs, women's associations, youth groups, self-help mutual support groups, input/marketing groups*)? circle response

1=Yes, 2=No, (if No, proceed to 8)

7.2 In which year did your HH first gain membership in any organizations/groups/associations?--

7.3 Is the household head a member of any organizations/groups/associations ? 1=Yes, 2=No,----

7.4 How many household members in the respondents household belong to any organizations/groups/ associations? Total.....Adult Male.....Adult Female.....Children.....

7.5 Please, fill in the Specify information about the type of groups and main activities in table below

Name of the group /organization/ association (Multiple groups allowed)	Type of group (refer to codes in (Refer to codes A below)	Gender of HH member who belongs to this group	No. of years spent in this group	Main activity (refer to codes B below) Multiple options allowed)	Does the group participate in any banana related activities? 1= Yes, 2=No	If the group participates in banana related activities, what specifically does it do (refer to codes C below) (Multiple options allowed)

Codes A for type of organization/association/group: 1= Women only group 2= Men only 3= Youth only group 4= Mixed (men, women, youth) 5= Men and Women only
Codes B for main activity or purpose of the group: 1=Self-help activities such as labour mobilization, 2=Income generation, 3= Group access to inputs and extension, 4=Mobilizing savings and credit, 5=Group marketing of produce 6=Promotion of improved farming practices, 7=Access to credit, 8=others (specify) -----

Codes C for specific banana related activities: 1= Accessing technologies/free planting materials, 2=Sharing information on banana, 3= Training on banana, 4=Group marketing of banana 5=others (specify)

7.6 Has your HH membership to group/association/organsaition contributed to your HH use of HBVs? *Circle most appropriate*
 Scale: 5=strongly agree, 4=Agree 3=No comment/ neutral, 2=Disagree, 1=strongly disagree

8 Innovations and changes in household system

8.1 List the major changes and/or innovations that have occurred in *farming practices* (and/or generally in *household system*) due to introduction of HBVs

8.2 What is the overall most significant change that has occurred in this household as a result of the introduction and uptake of new banana hybrids? (Allow the farmer to freely mention as you rank the most important three)

Variable	Rank (1=most important, 3=less important)
1. Increased physical assets	
2. Increased food diversity	
3. Increased availability of food	
4. Increased stability of food supply	
5. Increased access to adequate food all the time	
6. Improved HH income	
7. Increased HH saving from banana production	
8. Increased number of banana products sold	
9. Increased production of bananas	
10. Hiring of labour	
11. Increase in livestock production	
12. Social networks	
13. Knowledge sharing	
14. Others(specify)	

9 Household Income

9.1 Please fill in the table below information about *Household income sources* in 20015 and rate according to importance)

Income source (refer to Codes below)	Rate the source on a scale of 1-3, where 1= Most important, 2=Important, and 3= Least important)
1)	
2)	
3)	

Codes: 1= Production and sale of crops, 2= Production and sale of livestock and livestock products, 3=Salary, 4= Casual labour wages, 5= Trading in agricultural produce, 6=Trading in non-agricultural products, 7= Remittances, 8= Fishing, 9= Boda-boda/taxi, 10= Brewing, 11=Brick Laying, 12=Other (specify).....

9.2 In the table below, give details of total annual income from **major crops** produced *besides banana* in the respondents HH?

Crop	Who mainly earns income from this crop in respondents HH 1=Male, 2=Female, 3=Both	Frequency of income from crop 1=Monthly, 2=seasonally, 3=Annually	Average amount per Month/seasonal/Annual	Total Annual Income (Computed by data collector)
1.				
2.				
3.				
4.				

9.3 In the table below, give details of total annual income from specific livestock type owned by in the respondents HH?

Livestock Type	Who mainly earns income from this Livestock in respondent's HH 1=Male, 2=Female, 3=Both	Frequency of income 1=Monthly, 2=seasonally, 3=Annually	Average amount per Month/seasonal/Annual	Total Annual Income (Computed by data collector)
1.				
2.				
3.				
4.				

9.4 In the table below, give details of total annual income from non-farm activities in the respondents HH?

Non-Farm activities	Who mainly earns income from this activity in respondent's HH 1=Male, 2=Female, 3=Both	Frequency of income 1=Daily, 2=Weekly, 3=Monthly, 4=Annually	Average amount per Day/Week/Month/Year	Total Annual Income (Computed by data collector)
1.				
2.				
3.				
4.				

9.5 What is your HH total annual earnings from remittances (If any)? -----

10 Livestock Ownership

10.1 In the table below, give details of *livestock* owned by the respondent's household

Livestock	For each of the following livestock, please tell me: How many does your HH own (If none, write zero and move to next animal)									
	Cows	Bulls	Calves	Goats Adult	Goats young	Sheep	Pig	Chicken local	Chicken improved	Rabbit
Number owned NOW										
Type of breed										
Livestock ownership 1=Male, 2=Female, 3=Both										
Total value in UGX										

11 Household Assets

11.1 In the table below, give details of **Agricultural equipment** owned by the respondent's household

Agricultural equipment	For each of the following agricultural equipment, please tell me: How many does your HH own (If none, write zero and move to next equipment)										
	Hand hoe	Panga	Knife	Sickle	Chemical sprayer	Weighing scale	Wheelbarrow	Oxcart/Plough sets	Treadle pump (irrigation)	Motorized pump	Watering can
Number currently owned											
Asset ownership 1=Male,, 2=Female, 3=Both											
Total Value (Shs)											

In the table below, give details of assets owned by the respondent's household

Household assets	For each of the following durable goods, please tell me how many does your HH own (If none, write zero)							
	Bicycle	Motorcycle	Vehicle	TV	Radios	Cellular phones	Solar panels	Water tank
Number owned								
Asset ownership 1=Male, 2=Female, 3=Both								
Total value in UGX								

General remarks: -----

Thank you very much for your time and responses

Appendix 5: Introduction letter from DEIS, Makerere University

MAKERERE

P.O. Box 7062 Kampala Uganda
Fax: 256 41 331641



UNIVERSITY

Phone: 256 41 332771 ext 411
Email: deis@caes.mak.ac.ug

COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF EXTENSION AND INNOVATION STUDIES

Your Ref:

Our Ref:

October 1, 2014

Introduction letter

Ms. Losira Nansirumbi is a PhD student of Agricultural and Rural Innovations at Makerere University. She will be conducting her dissertation study focusing on 'Social Dynamics in the Development and Uptake of Agricultural Technologies: The Case of Hybrid Banana Varieties in Central Uganda.' The overall aim of this study is to explore how social dynamics in the banana technology development process influence uptake of hybrid banana varieties among smallholder farmers in central Uganda for improved livelihood.

The purpose of this letter is to introduce her and her team to your office. Any information or other assistance you will provide to enable them accomplish the data collection phase of this study is highly appreciated.

Do not hesitate to contact the people mentioned below for further information about Losira's research:

Dr. Paul Kibwika,
Chair,
Department of Extension and Innovation
Studies,
College of Agricultural and Environmental
Sciences
Makerere University, Uganda
Tel: 256 710 506 952
Email: pkibwika@caes.mak.ac.ug

Dr. Haroon Sseguya
Coordinator for Graduate Programs
Department of Extension and Innovation
Studies,
College of Agricultural and Environmental
Sciences
Makerere University, Uganda
Tel: 256 701 2899 2810 / 2899 419
Email: hsseguya@caes.mak.ac.ug

Yours sincerely,

Haroon Sseguya, PhD
Coordinator for Graduate Programs

Appendix 6: Letter of Approval of the research study by the UNCST



Uganda National Council for Science and Technology

(Established by Act of Parliament of the Republic of Uganda)

Our Ref: A 504

2nd December 2015

Josira Nasirumbi
National Agricultural Research Organization
Mukono

Re: Research Approval: Social Dynamics in the Development and Uptake of
Agricultural Technologies: The Case of Hybrid Banana
Varieties in Central Uganda

I am pleased to inform you that on 23/11/2015, the Uganda National Council for Science and Technology (UNCST) approved the above referenced research project. This Approval of the research project is for the period 23/11/2015 to 23/11/2017.

Your research registration number with the UNCST is A 504. Please, cite this number in all your future correspondences with UNCST in respect of the above research project.

As Principal Investigator of the research project, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the research protocol or the consent form (where applicable) must be submitted to the designated Research Ethics Committee (REC) or Lead agency for review and approval prior to the activation of the changes. UNCST must be notified of the approved changes within five working days.
3. For clinical trials, all serious adverse events must be reported promptly to the designated local REC for review with copies to the National Drug Authority.
4. Unexpected events involving risks to research subjects/participants must be reported promptly to the UNCST. New information that becomes available which alters the risk/benefit ratio must be submitted promptly for UNCST review.
5. Only approved study procedures are to be implemented. The UNCST may conduct unannounced audits of a study records.
6. A progress report must be submitted electronically to UNCST within four weeks after every 12 months. Failure to do so may result in termination of the research project.

Below is a list of documents approved with this application:

	Document Title	Language	Version	Version Date
1.	Research proposal	English	N/A	August 2014
2.	Informed Consent Form	English	N/A	August 2014
3.	Interview Guide	English	N/A	August 2014
4.	Questionnaire	English	N/A	August 2014

Yours sincerely,


Helen N. Opolot
for Executive Secretary
UGANDA NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

LOCATION CORRESPONDENCE

Plot 6 Kinsera Road, Ntinda
P.O. Box 5831
KAMPALA, UGANDA

COMMUNICATION

TEL: (256) 414 208500
FAX: (256) 414 244879
EMAIL: info@uncst.go.ug
WEBSITE: <http://www.uncst.go.ug>

Appendix 7: Introduction and Informed Consent Form

Explanation of the study and the purpose

Hello, my name is **Losira Nasirumbi**, a Doctoral student of Agriculture and Rural Innovation in the Department of Extension and Innovation Studies, School of Agricultural Sciences, College of Agricultural and Environmental Sciences, Makerere University. This is a PhD research, approved by the Uganda National Council of Science and Technology (A 504) on **23rd November 2015**. This research that focus on the *Social Dynamics in the Development and Uptake of Agricultural technologies: The Case of Hybrid Banana varieties in Central Uganda* and covers six districts of Uganda: *Nakaseke, Luwero, Wakiso, Mukono, Mityana and Mubende*. The research aims to assess the contribution of social dynamics in technology development to uptake of hybrid banana cultivars by smallholder farmers for improved livelihoods in the Central Region of Uganda. Ultimately, the information generated will help document lessons and best practices as well as draw strategies for enhancing technology development and uptake that will contribute to development of appreciate technology and enhanced use of improved varieties for increased banana production on smallholder farms.

This research is funded by World Bank-ATAAS Project that is being implemented by National Agricultural Research Organization (NARO) where the researcher works as a Research Officer/Planning, Monitoring and Evaluation.

Procedures including confidentiality

To make sure that we do not forget or change what you are saying, I will write down the answers you give and record the conversation, with your permission. The information you give is highly confidential. During the report writing exercise and future publications, all responses shall be anonymised (not tagged to individual names) such that it is not possible to identify any participant. After PhD graduation, the notes and audio recordings shall be destroyed.

Risks, discomforts and right to withdraw

There are no risks or discomforts that shall result from your participation in the interview. You can refuse to answer any question or stop the interview whenever you wish.

Benefits

This study will not help you directly but the results will help to improve technology development processes. This will result into development of appreciate technology by research systems and enhanced use of improved varieties which will directly lead to increase in banana production thereby contributing to food and income security of smallholder farmers. If you do not want to participate, nobody will hold this against you.

Compensation for taking part in this study

There is no financial benefit for taking part in this research. However, facilitation in terms of a drink for instance a bottle of mineral water or soda will be provided alongside transport compensation of UGX 5,000 during Focus Group Discussion.

Sharing the results

After the study, I will share the results with the communities where the study is conducted and various stakeholders including line ministries, NARO and Makerere University. In addition, the results will be available in written form as PhD Dissertation and journal publications. If you would like to receive a copy of the report, please let me know and I will make this possible for you.

Duration of the interview/ Focus Group Discussion

The interview will take about 45 minutes – 2 hours.

Consent and contact

Do you have any questions that you would like to ask?

Are there any things you would like me to explain again or say more about?

Do you agree to participate in the interview?

1) Yes (Thank the person(s) and continue with the interview)

2) No (Thank the person and close the discussion)

Do you agree to audio recording of the interview?

1) Yes (Thank the person(s) and continue with the audio recording)

2) No (Thank the person and continue without audio recording)

Contact details:

If you have any other questions about this study later, you can contact:

Losira Nasirumbi

Department of Extension and Innovation Studies,

School of Agricultural Sciences, College of Agricultural and Environmental Sciences,

Makerere University,

P.O Box 7062, Kampala Uganda

Tel: 0772 594216/0703209677

Email: losirasfm@gmail.com

INFORMED CONSENT FORM**Note: Retain this copy after respondent (s) signing**

I (we) have read the foregoing information, or it has been read to me (us). I (we) have had the opportunity to ask questions and have been answered to my (our) satisfaction.

I (we) consent voluntarily to participate in this study under the conditions set in this consent document free from undue influence and coercion and understand that I (we) have the right to withdraw from the interview at any time.

I (we) do give permission for the anonymous results to be published and used in the public domain.

Name of participant:

Signature of participant:Date:/...../2015

The participant received a copy of this informed consent form

Initial of Interviewer Signature.....

Appendix 8: Hypothesized determinants of farmer's adoption and intensity decisions for new HBVs

Variables	Label (and measure)	H ₀ Sign	Rationale
Sex	Sex of farmer (1=Male, 0=Female)	+	Females often tend to have resource constraints (especially labor and land) and less access to information and as such they are less likely to adopt and intensify new technologies.
Age	Age of farmer (Years)	+/-	The age of a farmer can increase or decrease risk aversion. While it is assumed that older farmers have more experience and are knowledgeable, farmers are open to new technologies until a certain age after which they become less open until they reach old age
Educ	Formal schooling of the farmer (number of years)	+	Exposure to education may enhance the ability to receive and process information about new technologies and thereby facilitate adoption.
HHsize	Household size (Number of persons in a household)	+	Household size may be related to the availability of family labor. Family labor availability increases the willingness to adopt the new varieties. A large family size may also increase the food consumption requirement translating into increased likelihood to adopt new technologies that promise to increase yields.
LandCP	Total size of land allocated to other crops (Acres)	-	Farm households who have more land allocated to other crops are less likely to adopt and allocate more land to the new technologies
LandBP	Total size of land under banana crop (Acres)	+	Farm households who have more land allocated to bananas are more likely to adopt and allocate more land to the new technologies
Rec_info	If the household receives information about new HBVs (1=Yes, 0=No)	+	Farmers who receive information about the new technologies are more likely to use the new technologies
ExpHBVs	Number of years since the household first heard about new HBVs (Years)	+	Farmers with more experience (who have known HBVs for a long time) will tend to adopt and allocate more land to HBVs since

Variables	Label (and measure)	H ₀ Sign	Rationale
			they are aware of the benefits.
Times_ interact	Average number of times a HH interacts with other actors in a year	+	Farmer who interact with other actors have more information about the technologies, and are more likely to adopt. Frequent interactions may also wield considerable power over adoption and intensity decisions due to conformity pressures exerted on individuals' behavior by the contacts
No._ Group	Number of groups that a given household belongs to	+	Membership to groups is expected to positively influence adoption decisions given the social influence exerted by group values and norms. Social cohesion is also a key determinant of technology diffusion
NEIGHB	Neighborhood effects (the proportion of adopters in the parish excluding the household of interest)	+	Consonant with the social network theory, households located in a community that has greater experience with HBVs are more likely to adopt. Most farmers rely on earlier adopters as sources of influence on their choice decisions. Farmers are linked to their neighbors through a diversity of interactions that span beyond the sharing of information to risk sharing and credit, and exchange of planting materials which are likely to exert influence on technology choice.
fac1	Production biotic and abiotic related attributes index derived from factor analysis of attributes where biotic and abiotic attributes loaded heavily	+	Pests and diseases have been cited as important constraints to banana production. The prevalence of these constraints has been most severe in central Uganda. Most cooking banana hybrids were bred for tolerance to biotic and abiotic constraints which increases the expected likelihood of adoption among farming households
fac2	Consumption related attributes index derived	+	Farmers tend to prefer new varieties with better culinary attributes. New hybrids with

Variables	Label (and measure)	H ₀ Sign	Rationale
	from factor analysis of attributes where consumption related attributes loaded heavily		desirable consumption attributes are therefore expected to increase the expected likelihood of adoption.
fac3	Agronomic related attributes index derived from factor analysis of attributes where agronomic related attributes loaded heavily	+	Better agronomic attributes associated with hybrids are expected to motivate farmers to adopt