AN EVALUATION OF IMPACT AND CHALLENGES OF TISSUE CULTURE BANANA TECHNOLOGY IN KENYA

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DECLARATION AND RECOMMENDATION

I declare that this Thesis is my original work and has not been presented for any degree or any other award.

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DEDICATION

This work is dedicated to six great people:

My mother, Namukhosi

My wife, Annastacia

My late father, Justo

My children, Barbra, Florence, and Emily.

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The process of finishing the PhD work is tough and the experience is unforgettable. Many people have provided me with support, inspiration, encouragement, ideas, guidance, and patience to face the challenges in finishing this work. I am indebted to many people who have helped me in many ways to complete this work. After a long and successful career, it is but fitting to complete a thesis in a discipline, I have found exciting in my entire working life. I would like to acknowledge, my supervisors Profs. G.A. Obare, G. Owuor, and Dr. Lusike Wasilwa who helped me in complimentary ways and sourcing for funds to complete research work. Prof. Owuor George is responsible for instigating this study and supporting me in dealing with the obstacles. I am sure this has helped me. Prof. Obare has brought to my study his wealth of experience in supervising doctoral students and a guiding path to the completion of this type of academic venture. His background of knowledge and experience in tangential fields has been an inspiration for me to broaden the scope of my own research. Both supervisors have been invaluable resources providing me with superlative mentoring and practical help. It is impossible to overemphasize the contribution of my academic colleagues and friends in my career, spanning vocational education, training, lecturing, and consulting for industry. There have been too many acquaintances to name them individually, but it would be disheartening for me not to acknowledge the stakeholders who were instrumental in data collection that was a basis for this study. I thank them all the people whom I cannot mention here individually. This research required long periods of uninterrupted work, usually after official hours and always on weekends. My family my wife Anastasia and children, Emily, Florence and Barbra have all been wonderfully so supportive throughout this journey. My God bless you all.

ABSTRACT

Tissue culture technology was developed, and disseminated to farmers with active participation of actors along the value chain. However, the potential benefits of the technology are yet to be achieved. This is attributed to diverse challenges that have not been addressed. This study was designed to contribute to this information gap. Primary farm household and trader data were collected through a survey carried out in 2012. Multistage sampling approach was used to select counties, sub-counties, wards, markets, and finally survey units (households and banana traders). The survey targeted all banana farmers and traders in the study regions. After establishing a sample frame in villages (households) and markets (traders) semi-structured questionnaires were used to collect the data on personal characteristics, banana production, consumption and marketing. Double Hurdle model was utilized to analyse factors influencing farmers' uptake of TC banana technology; Nested logit model was used to assess factors influencing farmer knowledge, attitude and preferences to TC banana (TCB) technology; Propensity score matching was used to investigate the extent to which TCB technology has impacted on farmers' welfare and Tobit model was utilized to assess the determinants of banana traders' intensity of participation in the fruit markets. Descriptive statistics was used to describe the data sets. The results showed that though TCB technology adoption has increased over the years since initiation in late 1990s, the TCB adoption of TCB was about 30%. The highly adopted cultivar was TCB grand *naine* (18.9%) followed by TCB *ng'ombe* (11.7%) and the least adopted was *solio* (0.8%) and Gold finger (0.3%). The low adoption is due to limited access to planting material, lack of marketing, high transportation costs due its bulkiness and stakeholder perceptions. The PSM results showed that the impact of TCB technology on TCB adopters compared to non-adopters, was significant on banana production levels (Kernel $p \leq 0.05$; radius $p \leq 0.05$; NN $p \leq 0.05$, Stratified $p \leq 0.05$), income generation (Kernel $p \leq 0.05$; Radius $p \leq 0.05$, NN $p \leq 0.05$) and banana consumption (Stratified $p \leq 0.05$). The results suggest that institutional support structure like establishment of banana processing factory, opening up new TCB laboratories and developing local banana cultivars into tissue culture products, would lead to improved adoption of TCB. Therefore, intensification of the investment on TCB technology dissemination is a key policy instrument to raise incomes and reduce poverty among banana farming household, although complementary measures are needed.

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ACRONYMYS

APVC	-	Agricultural productivity value chain
CIMMYT	-	Centre for International maize and wheat
DD	-	Double Difference
DiD	-	Difference in Difference
ESM	-	Economic surplus model
FAO	-	Food and Agricultural Organization
GDP	-	Gross Domestic product
IDS	-	Institute of Development Studies
IDRC	-	International Development Research Centre
IFPRI	-	International Food Policy Research Institute
ISAAA	-	International Service for Acquisition of Agri-biotech Applications Afri-Centre
KACE	-	Kenya Agricultural commodity exchange
KARI	-	Kenya Agricultural Research Institute
KALRO	-	Kenya Agriculture & Livestock Research Organization
MDGs	-	Millennium Development Goals
NML	-	Nested multinomial logit
OLS	-	Ordinary Least Square
PMS	-	Propensity Score Matching
PS	-	Propensity scores
ROK	-	Republic of Kenya
SSA	-	Sub-Saharan African
SDGs	-	Sustainable Development Goals
SAFS	-	Sustainable Agriculture and Food Systems
TC	-	Tissue culture
TCB	-	Tissue culture banana
VC	-	Value Chain
WP	-	World Bank

CHAPTER ONE

1 INTRODUCTION

1.1 Background information

In tandem with Sustainable Development Goals (SDGs) (Osborn *et al.,* 2015), appropriate agricultural interventions are required to mitigate against hunger and poverty for the ever increasing human population not only in Kenya but also in other sub-Sahara Africa (SSA) (FAO./IFAD/WFP., 2012; IMF., 2014; Staatz & Dembele, 2007). It is estimated that about 370 million people live on less than 1$ per day, majority of whom (about 200 million) reside in SSA (IFAD., 2014; Nelson & van der Mensbrugghe, 2013). In Kenya, about 10 to 16 million people suffer from chronic food insecurity and poor nutrition annually. In addition, between two and four million people require emergency food assistance from well-wishers at any given time (RoK., 2011; Wambugu, 2004).

In Western Kenya about 1.8 million of people experience poverty incidences of over 60% with Rift valley region being estimated at 25.6% while in Nyanza region these figures are higher than the ones in Rift valley and Western (Place *et al.,* 2003; RoK., 2007; RoK., 2004; World Bank., 2008). Comparatively, at national level the proportion of people below the poverty line is estimated at 47% (IMF., 2014) ranging from a low of 21.8 per cent (two out of every ten people) in Nairobi to as high as 87.5 per cent (almost nine out of every 10 people) in Turkana counties (RoK., 2014). If the current trend of decline in per capita agricultural productivity continues, this percentage is likely to increase.

In order to arrest the food insecurity and poverty problems there is need look for alternative productivity enhancing innovations and intensification of agricultural production practices (ICSU./ISSC., 2015; RoK., 2013; RoK., 2007). As spelled out in Science, Technology and Innovation Policy Strategy of Kenya, this can be done through harvesting biotechnology in agriculture (RoK., 2008) The intervention can be done through investment in specific and targeted agricultural value chains if perceptible impact can be achieved (Powell *et al.,* 2013; RoK., 2013) like banana (*Musa spp*). The traditional perception of over-reliance on maize as a staple food crop may not be sustainable in the long run due to vagaries of weather, disease like maize lethal necrosis disease (MLN) and high production costs (Altieri *et al.,* 2014; Armbruster, 2001).

In Kenya, banana is an important staple crop as well as a source of income for smallholder farmers as indicated by the acreage, production levels and yield index (Dietz *et al.,* 2014; Qaim, 1999). The crop is likely to offer enhanced food security and income generation for the ever-increasing human population in the country. The crop provides more about 25% of the carbohydrates and 10% of the calorie intake for approximately 70% million people in the producing regions of the world. Banana enterprise has become a major source of revenue, as the crop is being traded among all economic actors along the value chain within and outside the country. Subsequently, the crop is increasingly becoming an important cash crop and food crop given the increasing acreage and production levels (AATF . 2009; Echezona *et al.*, 2011; FAO., 2012). Globally, the crop constitutes the fourth most important global food commodity, in terms of the gross value of production, after rice (*Oryza sativa*), wheat (*Triticum aestivum*) and maize (*Zea mays*) (Anyango *et al.*, 2010; Frison *et al.*, 2007). East Africa (most notably the Great Lakes region covering portions of Rwanda, Burundi, Tanzania, Kenya and Congo) is the largest banana producing and consuming region in Africa (Abele *et al.,* 2007; Shaibu *et al.,* 2012).

Estimate of banana consumption in sub-Saharan Africa, ranges from 70 to 312 grams per person per day. This is far below the WHO/FAO minimum recommendation of 400g per person per day or 146 kg per person per year (FAO., 2014). Subsequently, sustained increase in banana production could be achieved through investment in the development and dissemination of appropriate productivity enhancing innovations like biotechnology (ADB, 2010; Chataway & Smith, 2005; Kiome, 2003; Ozor & Igbokwe, 2007; Pender, 2008; Wedding *et al.*, 2013). Agricultural biotechnology is perceived as a promising option for increasing food security and poverty reduction in Kenya and other SSA countries because it can speedily increase agricultural production within a relatively short period compared to the conventional ones (CTA., 2005; Eicher *et al.,* 2005; Kiome, 2003; Ozor & Igbokwe, 2007; Tollens *et al.,* 2003; Wedding *et al.,* 2013). Other benefits attributed to biotechnology include improvement in quality and value of crops, increased rural incomes and employment creation to the rural population (GHI., 2013; Meyer, 2001; Rola, 2000; Staatz & Dembele, 2007; Wambugu, 2007). Biotechnology refers to the process of altering the biological process of microbes of plants or animals cells for the benefit of humans (CTA., 2005; Nyende, 2008). According to Nyende (2008), this process has the potential of increasing agricultural production, through increased yield or reduction in pest and disease losses. As documented by CTA (2005), there are three areas of biotechnology. They include genetic engineering, molecular marker, and micro-propagation (also known as tissue culture).

Tissue culture (TC) (a micro-propagation method) is a significant horticultural propagation method which was perceived to revolutionize the horticultural industry not only in Kenya but in other parts of the world where the technology is applied (RoK., 2013;

Wambugu, 2004). The *in-vitro* propagation of bananas provides excellent advantages over traditional propagation, which include a high multiplication rate, physiological uniformity, the availability of disease-free material all the year round, rapid dissemination of new plant materials that are high yielding throughout the world, uniformity of shoots, short harvest interval, and faster growth in the early growing stages compared to conventional materials.

Data from FAO indicates that the mean nutritional contribution of bananas in Kenya is about 12 calories per capita per day over the past 25 years (Smith, 2007), while Qaim (1999) observes that nearly every rural household has a couple of banana plants. It is perceived that banana consumption in the country is increasing. This is attributed to the changing eating habits and urbanization coupled with increased human population (FAO., 2011). Estimates revealed that about 49% of the farming households in Kenya produce banana as main crop with the share of the banana to other fruits decreasing from 63% to 49% (Echezona *et al.*, 2011). Due to its importance, the crop has attracted attention of farmers and other stakeholders along agricultural product value chain (APVC). Subsequently, more farmers are likely to adopt high-level management technologies aimed at intensify banana production in Kisii, Vihiga, Kakamega, Bungoma, and Nyamira are among the major producing counties in western Kenya (Table 1-1).

Table 1-1: Production statistics of banana in Kenya by selected administrative counties

County	Area (Ha)	Quantity (Ton)	Area (Ha)	Quantity (Ton)	Area (Ha)	Quantity (Ton)
	2010		2011		2012	
Kisii	4573	101540	3749	88652	4167	66889
Kakamega	944	13203	4987	74940	5133	76695
Bungoma	1679	26731	6141	91485	2165	51245
Nyamira	2112	42245	1719	33011	1795	33792
Migori	487	5925	675	8875	844	10507
Vihiga	903	16085	1926	28890	1911	28815
Busia	265	4875	2045	30675	407	5330
Siaya	669	9,817	752	9731.5	811	10628
Trans Nzoia	326	4443	239	5360	239	5594
Kisumu	198	6,374	247.5	12085	248	2634
Homa Bay	238	2,980	639	4605.5	505	4485
Uasin Gishu	49	630	49	747	74	2301
West Pokot	123	1268	100	1390	83	416
Turkana	10	55	30.1	185	44.1	226
National	61,345	1,253,494	64130	1290795	58175.3	1394412

Source: Extracted from RoK (2013).

Nyanza and Western provinces are among the key banana producing provinces in Kenya as shown in Figure 1-1, while in the North rift region of Kenya the banana crop production system is emerging in an originally maize and wheat production dominated environments (Kwambai *et al.*, 2006; USAID-KHCP., 2012). The crop complements other food (e.g. maize, cassava, sorghums, finger millets and potatoes) and income generation enterprises (tea, sugar cane, coffee, cotton and livestock) among smallholder households (Dietz *et al.*, 2014; Kristjanson *et al.*, 2004; RoK., 2013).

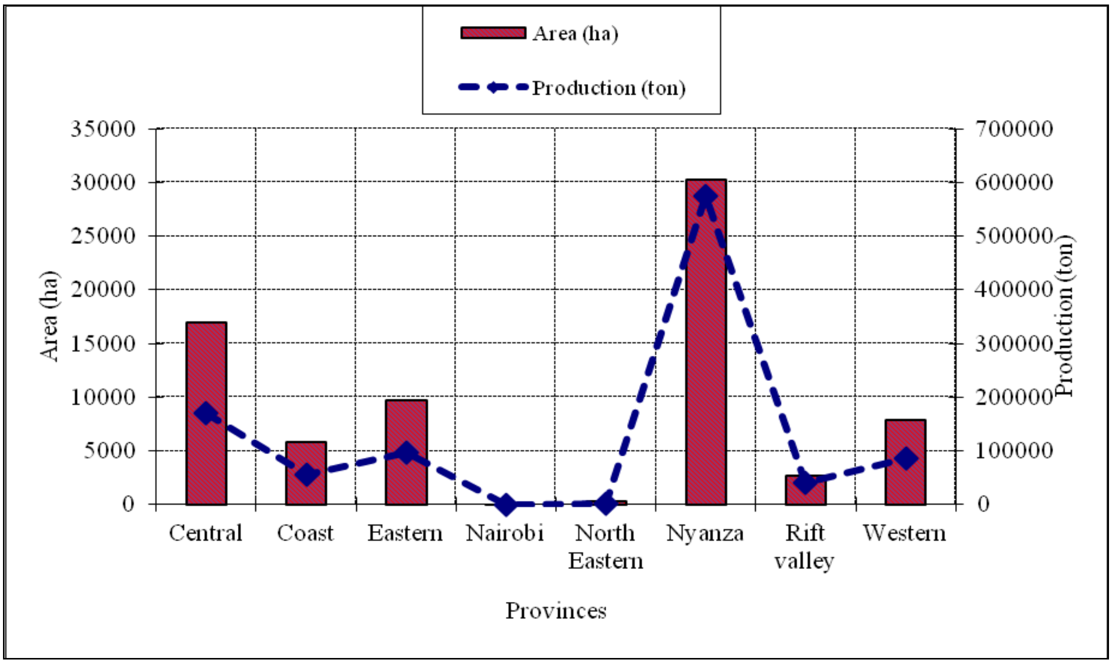

Figure 1-1: Production statistics of banana in Kenya by administrative provinces
Source: USAID-KHCP., 2012.

During the period 1961-to 1997, the growth rate of banana was about 6.56 % compared to 4.48 % from 2000 to 2012 (Figure 1-2). The number of banana growing households has also increased over years[1]. Most of the increase in production is due to area expansion. Over the years, intervention have been geared towards area expansion and increasing the yield per hectare. Evidence suggests that one of the major causes of low productivity of banana in Kenya is the continuous use of traditional, low yielding crop varieties coupled with poor agronomic management practices (RoK., 2013).

[1] See Appendix 6c for details

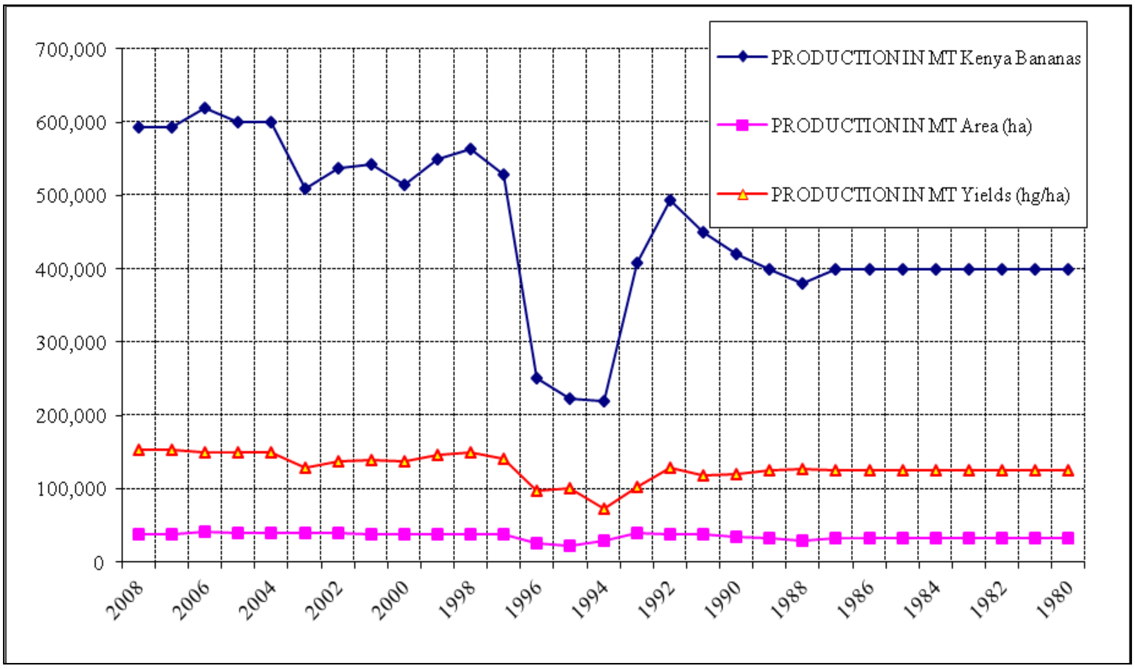

Figure 1-2: Production statistics of banana production in Kenya over years (RoK., 2013)
Source: FAO Survey data, 2012.

Further analysis shows that banana production in Kenya and the Eastern Africa region at large started declining substantially from 1980s (Bagamba *et al.*, 1998; ISAAA., 1997; RoK., 2013). This was attributed to both abiotic and biotic stresses including the crop management aspects (Atkinson, 2003; Frison & Sharrock, 1998; Frison & Sharrock, 1998) of which diseases and pests are addressed in tissue culture (TC) innovation. TC is the technique of propagation plant using part or single or group cell in a test tube under very controlled and hygienic conditions. As a result, there are many tissue culture banana (TCB) varieties and types whose yield potential, tastes and tolerance to diseases is variable (dela Cruz *et al.*, 2008; Kabunga *et al.*, 2011; Karamura *et al.*, 2012; Qaim 1999; Singh *et al.*, 2014; Wang *et al.*, 2009). Despite the attributes, it is not clear whether the new TCB varieties have significantly contributed to the welfare of the farmers in western Kenya

The major banana diseases attributed to yield decline fall into fungal, bacterial and viral groups whose infestation vary with banana cultivars (Lakshmanan *et al.*, 2007). The common farmer practice of using suckers increases the risk of banana diseases and pests infection causing yield loss of about 90% (Wambugu, 2004). Land degradation through decline in soil fertility (Lakshmanan *et al.*, 2007; Mbaka *et al.*, 2008) is another factor contributing to yield decline.

The production losses have negative socio-economic implications to the household, national, and regional economies in terms of deteriorating food insecurity, constrained poverty eradication, and biodiversity conservation. The affected actors along the banana productivity value chain (BPVC) include the farmers as producers, and traders particularly, the smallholder farmers in banana growing region like western Kenya. Tissue culture banana is one successful technologies that is pest-and-disease free (Andreu *et al.,* 2006; CTA., 2005; Melinda, 2004; Qaim, 1999). In addition, the crops mature early and uniformly thus creating good market opportunities (Wambugu, 2007).

1.2 Promotion of TCB technologies in western Kenya

Taking cognizance of the importance of the ailing banana industry due to yield decline, International Service for Acquisition of Agri-biotech Applications Afri-Centre (ISAAA.) in partnership with the then Kenya Agricultural Research Institute (KARI) now Kenya Agricultural and Livestock Research Organization (KALRO) as host, and Genetic Technology Laboratory (GTL), initiated TC-banana (TCB) technology project in Kenya in late 1990s (Hamide & Mustafa, 2004; Wambugu, 2004; Wambugu, 2007). The technical backstopping services were provided by Institute of Tropical and Sub-tropical Crops (ITSC) based in South Africa. The financial support for the project was obtained from the Rockefeller Foundation of the United States of America and the International Development Research Centre (IDRC) of Canada. The overall project outputs were to contribute to increased banana production through dissemination of pest and disease free and high yielding, TCB planting material to small holder farmers in banana growing regions for enhanced food security and income generation (ISAAA., 1997; Qaim, 1999).

Biological enhancement of TCB plantlets offers farmers clean planting material with extended protection against the crop's primary pest and disease constraints, which are common in the farming systems. One of the pre-requisites to enhanced farmer adoption of the TCB technology was ultimately the development of cost-effective delivery systems. This demanded involvement of key players (research, extension, policy makers) along the APVC with farmers as final beneficiaries playing a lead role. The increased yield is manifested in enhanced food security by consuming more banana and income generation through increased sales. It was observed that between 1989 and 2001 (at least) there was an overall neutral, fluctuating or downward trend in production of key crops (e.g. maize and beans) while at the same time population steadily increased (Haan *et al.,* 2001). Thus, the per capita food production and consumption declined during the same period and the trend is set to worsen in future if not arrested and reversed.

Up-scaling TCB in western region and other parts of Kenya was initiated by multiplying and distributing the clean (disease and pest free) plantlets using multiple dissemination pathways (Wambugu, 2007). This intervention aimed at reducing food insecurity (which affected about 9.8 million people in 2001 and 16 million people in 2011) and poverty (56% in 2001 and 47% 2011) (Fitzgibbon, 2012; Gitu, 2006). TCB cultivars that were up-scaled in these regions fall into three broad categories namely; i) cooking, ii) ripening and iii) dual purpose. The banana varieties vary in colour, size, shape, taste, and yield, which subsequently influence the consumer and farmer preferences. The purpose of this study is to evaluate the impact, and challenges including constraining factors to attainment of TCB benefits at various stages along the value chain. A number of banana varieties (with a spectrum of triploid hybrids) can be used for different purposes which include; processing, cooking and ripening (Karamura *et al.*, 2012. ; Mohamad, 2006) (Table 1-2). The yield levels of these cultivars are relatively high compared to the local ones (Muchui *et al.*, 2013).

Table 1-2: Selected Banana cultivars, yield levels, and uses

TCB cultivar	Yield potential (tons/ha)	Purpose
Grand Nain	49.28	Dessert
William	48.84	Desert
Dwarf Cavendish	30-40	Desert
Conventional banana	4.5-10	Dessert/ Cooking
Other varieties	20-30	Dessert/ Cooking

Source: Muchui *et al.* (2013); Karamura *et al.* (2012) and Qaim (1999).

1.3 Statement of the research problem

The production and yield of banana is low and demand outstrips supply. Banana production, among the sectors of horticultural production system, is a crucial issue in Kenya where banana and its products are important source of food and income yet not exploited and promoted in the country. Promotion of TCB technology along the agricultural product value was aimed at contributing to improving farmers' food security and income generation by about 10%. This was done through rapid micro-propagation and dissemination to smallholder farming community in Kenya. Despite the decrease in national poverty levels from 52% in

1997 to 46% in 2007, a significant proportion estimated at 20% of rural population is still food insecure and with high poverty levels. Data and literature on impact and challenges of TCB technology in Kenya are scanty because there are limited post-intervention studies carried out attributing economic benefits to TCB intervention. The emerging TCB technology impediments including the identification of weak segments along the banana value chain structure that constrains the attainment of set objectives demands further research. The banana production potential and marketing is yet to be fully analysed and documented in Kenya. Over years, there has been an increase in the number of banana value chain actors (e.g. input suppliers, farmers, processors, wholesalers, retailers, consumers, and change agents). However, their knowledge, attitude, and perceptions towards TCB innovation have not been investigated and documented. In addition, there is limited information on economic relationships among these banana actors that govern agri-business transactions along the value chain structure. This study is designed to address these information gaps for effective and efficient TCB up scaling for enhanced and perceptible impact on the target population.

1.4 Objectives of the study

The broad objective of this study is to contribute to a better understanding of the impacts and challenges of TCB technology in Kenya. The specific objectives of the study are to:

i. Analyse factors influencing farmers' uptake of TC banana technology
ii. Assess factors influencing farmer knowledge, attitude and preferences to TC banana technology value chain
iii. Investigate the extent to which TC banana technology has impacted on farmers' welfare
iv. Asses determinants of banana traders' intensity of participation in the fruit markets

1.5 Hypotheses

i. Technological, social, economic and institutional factors do not significantly influence the uptake of TCB.
ii. Technological, farm, farmer, social and institutional factors do not significantly influence farmer TCB cultivars preferences.
iii. TC banana technology has had no significant impact on farmers and other value chain participants' welfare.
iv. Traders' social, economic and institutional factors do not significantly influence banana trade.

1.6 Assumptions

1. The study assumes that there was adoption of TCB technologies along the APVC leading to welfare changes
2. Farmers' and other actors' along the BPVC access to TCB technology was non-random.
3. The declining trend in banana production can be reversed through TCB technology

1.7 Justification of the study

Impact assessment of new technologies, such as those used in agricultural biotechnology, is crucially important for researchers, policy-makers and donors (e.g. for TCB) (Bailey *et al.,* 2014; Smith, 2007). Banana research contributes to attainment of Kenya Vision 2030 and Millennium Development Goals (MDGs) in terms of eradicating extreme poverty and hunger (Abele *et al.,* 2007; RoK., 2007; RoK., 2005; RoK., 2014). Impact studies can help policy-makers identify the most effective and cost-effective strategy to tackle specific social and economic problems along the APVC as spelled out in KARI strategic plan (KARI., 2005; USAID., 2012). At the same time, impact assessments can help scientists as well as decision-makers in governments and international organizations set priorities and efficiently allocate limited resources for agricultural research and extension. In this manner, benefits in terms of poverty eradication, enhanced food security, and sustainability aspects are maximized. Impact studies are of particular importance in agricultural biotechnology like TCB, where choices have to be made regarding whether to produce or not, and how much, to invest in technology development and dissemination (UN., 2013) .

It is recognized that lack of impact information on project interventions on target beneficiaries along the APVC limits their replication and taking timely corrective action during and beyond project life (Farley *et al.,* 2012; Rajalahti *et al.,* 2005). In addition, limited information on the likelihood of sustained use of any technology also limits flow of project benefits beyond the project life. These factors shape decision making of farmers, traders, policy makers (governance) and project/programme managers in any project management like TCB in Kenya. According to Marther, and Oehmke (2003) and Mauyo *et al* (2011) conventional impact assessment methods have typically focused on productivity-enhancing benefits, which are estimated as yield difference between old and improved technologies as observed in experiments or cross-sectional farm surveys but with limited study on demand-pull factors like marketing.

It is important to take cognizance that an effective project intervention needs to be in line with government policy objectives as postulated in Kenya Vision 2030 (RoK., 2013;

RoK., 2007) and the global MDGs (RoK., 2013; RoK., 2005). Therefore, it is necessary to have an understanding of TCB impact assessment on the livelihoods of target community. This gives an opportunity to stakeholders in the industry to appreciate the efforts and funding in the past, now and in future. For example, the supporting institutions and other stakeholders in agricultural industry are not only interested in increased crop yield but also its effects on food security and income generation including natural resource conservation and use efficiency. Continued financial and technical support to the project like TCB depends on demonstrating the effects the technology on the intended beneficiaries. Knowledge on impact would provide information that would assist in making decisions to invest in the dissemination of the technology and its modification in tandem with farmer aspirations. It is against this background that this study documents economic benefits, challenges, opportunities and factors influencing the impact of TCB project on the target community.

1.8 Scope of the study

The study covered a wide spectrum of stakeholders, namely producers, input traders, banana fruits traders including super markets, and a few rudimentary processors but not exporters. In executing this assignment, the study team sought opinions on performance of TCB technology from a number of institutions/stakeholders: These included the ISAAA, extension services, Research (KARI/KALRO, JKUAT), and credit institutions.

1.9 Organization of the thesis

This thesis is organized in seven chapters. Chapter one, gives the background of the research problem addressed in this study and a detailed description of study sites. The second chapter reviews literature that deals with past studies and information pertinent to the study. Detailed and targeted analysis of literature is presented in Chapter two, which also describes the various aspects of TCB technology innovation as a biotechnology, the concept of innovation, adoption including farmers' preferences for the technologies, and impact in the study. The theoretical and conceptual framework of the study is presented in chapter two. The results from this study are presented in four separate chapters three, four, five, and six.

Chapter Three evaluates factors influencing adoption of TCB using a double hurdle model. The results showed that some factors positively while others negatively influenced the probability and intensity of TCB adoption. The adoption level of Tissue culture banana (TCB) was about 32%. The results also revealed that the likelihood of TCB adoption was significantly influenced by many factors (e.g. availability of TCB planting material, proportion of banana income to the total farm income, and per capita household expenditure). Those factors that significantly influenced the intensity of TCB adoption were occupation of farmers, family size, labour source, farm size, soil fertility, availability/access of TCB plantlets to farmers, distance to banana market, use of manure in planting banana, access to agricultural extension services and index of TCB/non-TCB banana cultivar attributes.

Chapter four reveals farmers' preferences of TCB technology using nested multinomial logit model. The results showed that farmer, farm, institutional factors including socio-cultural aspects significantly influenced farmer preferences of TCB adoption. It was revealed from the study that farmers as consumers and producers of banana use a bundle crop traits to choose cultivars to grow. The findings indicated that a number of factors played a significant role in TCB cultivar preferences.

Chapter five gives the impact of TCB on target community using PSM model. The results showed that there was significant impact (at a significance level of 5%) on income generation, levels of production and number of months that farmers depended on bananas for food. The banana production on TCB households increased to a maximum of 8636 kg annually. The TCB income effect ranged increased to maximum of KES 39,379 to 45,014 per household. The period of banana consumption per household also increased to 0.293. Therefore, increased TCB promotion and use would enhance food security and income generation.

Chapter six, gives banana trader participation in banana markets. The results showed that traders received market information from multiple sources probable to check on the reliability and accuracy. The results of the Tobit regression model showed that the age and sex of traders, distance to markets, types of banana and information sources significantly influence the volume of banana fruits handled by traders. Therefore, based on the study findings, some of the suggested policy recommendations include; the need to foster development of banana infrastructures and efforts should be geared towards improving market information sources among traders.

Chapter seven gives the general discussion, summary of main findings, implications for policy interventions and recommendations for further research. Traders both wholesaler and retailers play a significant role in banana markets. In Kenya the banana market is not fully developed. This demands targeted studies to assess their performance. The purpose of this chapter is to assess and characterize the actors involved in banana trade and give policy recommendations. The first section of the chapter deals with descriptive statistics about the actors of banana marketing followed by evaluating determinants of banana trade.

1.10 Limitation of the study

1. Limited time and financial resources constrained data collection in the four counties. Hence, results are largely applicable to those areas where similar conditions prevail.
2. The personal interview method of data collection was used and this required recall memory from the respondents on banana farm activities and impacts. This took time and demanded probing to get accurate information. Hence, some of the findings may be subject to memory lapses of the respondents.
3. The average price realized during the study year was calculated and used in converting production figures from quantities to monetary values, although the prices realized differ from farmer to farmer every year.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Technology advancement and technical change

Technical change, is defined as any shift in the production possibility frontier, which is attributed to technology advancement, like the TCB. The change occurs over time within any farming system. Technology advancement which is assumed to be exogenous (Heshmati *et al.*, 2010) influence farmers and other stakeholders along the APVC to embrace technical and social changes in the farming communities. The technical change may be manifested in adoption of improved agricultural production technologies like Tissue culture innovation which is one of the biotechnology innovations (Chaturvedi & Srinivas, 2014; Cooke & Downie, 2010).

The technological change can be in terms of advancement in innovations and may also imply adoption of improved agricultural production technologies (e.g. TCB innovation) which may lead to impacts on target groups through increased productivity (Busari & Alab, 2011). This implies that promotion of technical change through the generation of agricultural technologies by research and their dissemination to end users plays a critical role in boosting agricultural productivity target communities (Alene *et al.,* undated; Evenson & Westphal, 1994; Schneider & Gugerty, 2011). Schneider and Gugerty, (2011) revealed that there is evidence suggesting that there are multiple pathways through which increases in agricultural productivity can reduce poverty. The authors indicated that this is manifested through real income changes, employment generation, rural non-farm multiplier effects, and food prices effects. However, they indicated that initial asset endowments and constraints to market access inhibit the ability of the poorest to participate in the gains from agricultural productivity growth. This demands that when analysing the effects of TCB, fruit market analysis could also be done and this was covered in this study

There is an increasing debate about the potential contribution TCB technology can make to Kenya in terms of food security and income generation (Nyende, 2012). According to the author, there are those actors along the banana value chain who perceive that biotechnology innovation like TCB as a solution to many of the agricultural, economic, social, and environmental problems that developing countries are faced with. In addition, others actors indicate that the technology will bring more ills to the countries (Nyende, 2012). Available literature illustrates the rationale and benefits including challenges of developing and upgrading tissue culture innovations along value chains (Mbogoh *et al.,* 2003; Moreddu, 2013; Qaim, 1999; Qaim 2014; Smale *et al.,* 2006; Smale & Tushemereirwe, 2007). For example, Moreddu, (2013) indicated that tissue culture technology (e.g. TCB) has become central to the ability of farmers, and other agro-entrepreneurs like input suppliers, processors and traders and even policy makers to cope up with, exploit and compete in rapidly changing and evolving technical and economic environment.

The availability of TCB technology to the end users, and the capacities and abilities of end users to adopt and utilise these technology is critical for its adoption to realize perceptible outputs and impacts. In Kenya there is mixed reactions on adoption levels and perceived impact of TCB along the value chain (Langat *et al.,* 2013). It is perceived that the adoption levels are low and therefore the full impacts have not been realised. This calls for further studies to assess factors influencing adoption including the impacts.

2.2 Tissue culture technology in poverty reduction and food insecurity alleviation

In many parts of Africa, yield of major food crops including banana does not increase in tandem with the escalating human population (Cheke, 2006; Chopra, 2004; Eicher *et al.,* 2005; Pehu & Ragasa, 2008; Pellissier, 2008; Tittonell & Giller, 2013). All developments plans in Kenya since independence have given emphasis on food security and poverty reduction (Omiti *et al.,* 2002). Subsequently developments in agriculture over the last fifty years have targeted increasing crop yields sufficiently to provide on average more than enough food for every person in the country. Investments in agriculture including biotechnology through the use of tissue culture technology have been implemented to contribute to these policy objectives. Despite this investment, there is still food insecurity and high poverty level. It has been observed that the primary cause of food insecurity will continue to be poverty, rather than inadequate food production (Wichelns 2015). This implies that, policies and investments that increase the incomes of the poor will remain the best ways to extend food security to all. Subsequently, investments that promote growth in sustainable agriculture and provide non-farm employment opportunities in rural areas of lower income countries will be most helpful.

A number of studies have been undertaken and reviewers done relating food security and biotechnology and specifically on tissue culture technology (Desta, 2009; Gahakwa *et al.,* 2012; Izquierdo & de la Riva, 2000; Mugo *et al.,* 2011; Odame *et al.,* 2003; Ogero *et al.,* 2012; Ogero *et al.,* 2012; Panyika *et al.,* 2004). For example, Mugo *et al.,* (2011), conducted a study to establish whether income from tissue culture banana growers were significantly different from those growing conventional banana in Nyamira North. The study revealed that tissue culture banana growers had relatively higher incomes compared to conventional banana growers. However, there is need to look other impact indicators relating to food security at household level like duration households eat own produced banana fruits.

According to Ogero *et al.*, (2012a) farmers are encouraged to use of tissue culture to circumvented lack of cassava disease-free planting materials. In this study, it was observed that despite the TC technology being costly compared to conventional one, it outperformed the conventional ones in terms of growth rate and general performance. Therefore, TCB plantlets though costly, are superior to conventional practices using use banana suckers as planting material.

Gahakwa *et al.*, (2012), indicates that biotechnology has the potential to increase the world's food output and reduce food insecurity in Rwanda. He argues that agricultural biotechnology through tissue culture has contributed to increased productivity and food security through improve yield and quality levels. Such technological attributes entice the adoption of the technologies. However, the technology should, be simple, low cost and have little risk to humans and the environment. This is a case tissue culture technology like the TCB. However, in Kenya we have had mixed reaction the adoption and impacts of TCB.

Odame *et al.*, (2010), reviewed the key issues of modern biotechnology focusing on transgenic sweet potato and Bt maize to examine how governance issues influence household and national food security in the country. The authors argued that for biotechnology to engender food security in Kenya in the context of globalisation and international governance, the national biotechnology policies have to be facilitative. More specifically, there is need to synchronise biotechnology advancement agenda with national development policies taking into account structural limitations that could negate gains made through biotechnology activities. However, it should be recognized that in Kenya, there is the Biosafety Act of 2009, which stipulates on biosafety issues. The Act is consistent with the provisions and requirements of the Convention on Biological Diversity and the Cartagena Protocol on Biosafety (RoK., 2009; Secretariat of the Convention on Biological Diversity., 2000). The Act, also gives guidelines on how to manage and embrace modern biotechnology activities including GMOs human health and the environment. It should be noted that in Kenya there is no transgenic products from sweet potato or maize or banana. It should be clear that TCB is not Transgenic.

The Biotechnology debate which may lead to a misconception on TCB (Nyende, 2012; Qaim, 1999) and the Genetically Modified Organism banana type (Kikulwe *et al.,* 2008), demands seeking stakeholder (farmers) perception as regards its uptake. TCB as an agricultural biotechnology was perceived to contribute to poverty reduction and food security as shown through an *ex ante* socio-economic impact study by Qaim (1999) and Mbogo *et al.*, (2002) indicated the need to conduct follow-up on how benefits have trickled down to the targeted population (smallholder farmer) including the challenges and opportunities for the same.

Desta (2009), examined the role of Agricultural Biotechnology in alleviating food insecurity and its implications for smallholding farmers and biodiversity, as perceived by key stakeholders in Ethiopia in Ethiopia. The results revealed mixed reaction from different groups. The first and largest group expressed scepticism about the role of agricultural biotechnology in alleviating food insecurity. The second and smaller group of respondents held the middle ground and shared the opinion that if it is applied with proper caution under biosafety guidelines, it could be beneficial. The third and smallest group of respondents saw agricultural biotechnology as the only way to alleviate Ethiopian food insecurity. Delta (2009) concluded that the potential of agricultural biotechnology to address food insecurity is highly questionable and it may even intensify such problems. However, TCB is not GMO based but a micro propagation technique using plant tissues.

2.3 Factors influencing technology uptake

Effective technology development and transfer is important in achieving set goals of any interventions. TCB development and deployment along the value chain using multiple dissemination pathways was aimed at enhancing farmers' welfare. However, there are factors that may influence the adoption process. Subsequently, adequate understanding of technology adoption process is necessary for designing effective agricultural research and extension program like TCB.

Authors reviewing adoption studies have observed that that adoption decisions are influenced by a number of socioeconomic, psychological, demographic, biophysical and institutional factors including technological characteristics (Beshir & Wegary, 2014; Doss, 2006; Kaguongo *et al.*, 2010; Najaftorkaman *et al.*, 2014). Past studies of factors influencing farm households' modern agricultural production technology adoption decisions in Ghana (Akudugu *et al.*, 2012) and to evaluate that adoption of the found that farmers' literacy, family size, livestock wealth, access to output market and credit access for the new varieties farmer associations, distance to main markets and fertilizer credit influenced significantly influenced adoption. However, the sign (direction) of influence is debatable on some variables like age, education, and experience depending on circumstances under consideration.

Doss (2006), observed that some of the major reasons for not adopting farm-level technology in East Africa as farmers' lack of awareness of the improved technologies, lack of information regarding potential benefits accruing from innovation, the unavailability of improved and profitable technologies. In addition, given the farmer's agro-ecological conditions there are a complex of constraints faced by farmers in allocating factors of production (land, labour and capital resources) across farm and off-farm activities. Other authors have shown that farm incomes and availability of information influence technology adoption decisions by avoiding high risk farm activities particularly at smallholder levels (Domingo *et al.,* 2015; Kaguongo *et al.,* 2010; Mwangi & Kariuki, 2015).

Martey *et al.,* (2014) carried out a study to investigate factors influencing mineral fertilizer adoption and use intensity among smallholder farmers in Northern Ghana. They found out that the adoption of fertilizer technology was significantly influenced by age, nativity, farm size, access to credit, and distance to agricultural office. The result of the truncated regression estimates indicated that income of household head, membership of farmer association, distance to agricultural office, access to input shop, income earning household that do not participate in agricultural development project and income-earning male-headed household were the significant factors influencing fertilizer use intensity. Distance to agricultural office was a key positive determinant of fertilizer adoption and use intensity. The study recommends improvement in road infrastructure and technical training of agricultural extension agents. Farmer based organizations must be trained on regular basis to enhance their productive skills and technology uptake.

Risk aversion level of farmers is likely to be negatively associated with adoption of new technologies by farmers as they are less certain about the profitability (productivity) and other attributes (Hardaker & Ghodake, 1984; Juma *et al.,* 2009; Kaguongo *et al.,* 2010; Sulewski and Kłoczko-Gajewska, 2014; Vieider *et al*., 2015). Authors observe that farmer's level of risk aversion is a function of factors like poverty level, lack of information on the productivity of the technology, and stability of the impact of the technology are all important factors. To some farmers and Counties, TCB technology could be new and this may influence its uptake.

Several change agents like KALRO and ISAAA including Government departments have devised strategies to enhance dissemination of innovations like TCB. This is perceived to improve availability of relevant information for enhanced adoption and impact. Kaguongo *et al.* (2011), examine factors affecting the adoption of orange flesh sweet potatoes (OFSP), and intensity of adoption by a farmer in Busia and Rachuonyo districts of Kenya. The study also investigated whether participation in a value chain intervention programme increased farmers' likelihood of adopting OFSP technological components. The results suggest that the district where the farmer comes from, knowledge on value addition and nutritional benefits, and availability of vines were the key factors for adoption.

Farmers seek to maximize their utility from adoption of an innovation like the TCB. Factors that influence technology uptake and therefore the impact range from technological, farmer, farm and institutional including information sharing (Asante *et al.,* 2014; E.C., 2013; Mariano *et al.,* Undated). Technological issues that may influence innovation uptake may include complexity, profitability and risks associated with its adoption (CIMMYT, 1988; Couros & Kesten, 2003; Mtei *et al.,* 2013; Rogers, 2003). These factors need to be modelled in order to analyse how they influence farmers' TCB uptake.

For example, if the marginal cost (marginal factor cost) of the technology increases relative to marginal revenue its adoption may be affected (Asogwa & Abu, 2014). These factors for example may lead to low adoption of innovations like TCB. However, the factors that may influence the probability of technology adoption like TCB may not be the same factors influencing the intensity of its adoption (Beshir, 2014; Martey *et al.,* 2014; Martínez, 2004a). According to Mbaka *et al.,* (2008), these factors have not been fully studied and addressed for TCB technology.

2.8 Farmers' preferences for technologies-crop cultivars

Breeders develop different types of many crop varieties for farmers to choose. This implies that farmers are faced with the problem of choosing the crop cultivars to plant. These varieties have distich characteristics peculiar to others. A study undertaken by (Edmeades *et al.,* 2004; Ekesa *et al.,* 2014) in Uganda, showed that there motivating banana cultivar based traits and household factors that there economic association between household preferences for specific variety attributes (yield, disease and pest resistance, and taste), among other exogenous factors, and variety demand, or the extent of cultivation. The results showed that the determinants of banana cultivars are variety-specific and cannot be generalized across groups of cultivars; and 2) the determinants of absolute and relative demand are not the same in sign or significance. This implies that cultivar specific traits may be important for predicting the adoption of new technologies such as tissue culture technology, genetically transformed, or local varieties. This type of study on TCB cultivars is limited in Kenya more so in western Kenya. The adoption and non-adoption of specific TCB cultivars could be attributed to specific traits. No study has been done in Kenya to assess the banana cultivar preferences among farmers. This study contributes to these information gaps.

This information assists in identifying suitable local cultivars with preferred traits for improvement and identifies factors affecting their potential adoption. Banana is increasingly expanding in consumption levels in Kenya with desert type having higher demand especially in urban markets. Cooking bananas are also highly demanded but the supply is limited, and where available they are costly.

A recent survey in eastern and central Kenya showed that desert varieties are preferred due to market demand (Kasyoka *et al.,* 2011). The authors also revealed that the natural regeneration of these cultivars is a preferred by most farmers (>85%). However, they indicated that the cultivar is a source of pests and diseases to new plantations. This demands the need for enhanced application of tissue culture technology on these cultivars in order to improve adoption and production.

Studies have been carried out to analyse farmers' preferences for banana cultivars based on sensory evaluation (Adzaku *et al.*, 2009). Mugisha *et al.,* (2010), carried out research to determine consumer awareness of the introduced dessert bananas and the effect of introduced dessert banana attributes and consumer characteristics on willingness to pay for the introduced desert bananas. The study indicated that urban consumers had low awareness on the introduced dessert banana varieties. They also found out that some of the introduced dessert bananas were acceptable to consumers while others were not. This was based on sensory evaluation of the banana. In addition, based on hedonic pricing technique the authors suggested that taste, skin colour, and texture had significant effect on the consumer willingness to pay for new dessert banana varieties. These aspects of banana attributes are preferred for both desert banana and for cooking banana cultivars. This implies that the attribute need to be embraced by actors along banana value chain in order to enhance production of quality banana fruits to capture market potential.

The subjective preference ratings were used to rank sorghum varieties (*Pato, Wilu, Macia and Tegemeo*) by farmers in Igunga and Nzega districts of Tanzania (Bucheyeki *et al.,* 2010). In this study, farmers ranked Tegemeo sorghum variety at either the first or the second position across all three seasons. The study revealed that overall preference ranking of cultivars was based on eight criteria for crop cultivars was in the order of *Tegemeo* > *Pato* >

Wilu > *Macia*[2]. The preference rating based on the single criterion yield also revealed that farmers assigned a much higher preference to the landrace cultivar *Wilu* than was warranted based on the objective yield criterion. The authors observed that familiarity with the varieties by farmers seems to play a large role in subjective yield rankings. Furthermore, farmers prefer crop varieties/cultivars that has multiple traits and that meet multiple objectives (Dao *et al.,* 2015). This means that Tegemeo and newly improved sorghum cultivars could be introduced and incorporated in the farming systems based on multiple subjective preference criteria. The TCB traits/criteria were a key component in this study.

2.4 Impact of agricultural technologies

According to Kristjanson *et al.*, (2001), impact assessment is an evaluation that deals with the intended and unintended effects of the project output on the target beneficiaries. Impact assessment is classified into three broad categories namely; the direct outcome of the research activities, the institutional impact, and the people level impact. According to Morris *et al.* (2010), impact assessment can be done before an intervention (*ex-ante*) or after an intervention (*ex-post*). The former is aimed at assessing the impact of research that is underway or to be initiated while the latter aims to document and evaluate the impact of research that has already been conducted. The current study of TCB impact evaluation is an ex-post evaluation. As shown in Figure 2-1, development and dissemination of agricultural innovation to final beneficiaries involves collaboration with diverse actors (who include technology generators, input suppliers, farmers, and traders) along the value chain. All the actors play a significant role. However, farmers as producers and traders play key roles in upgrading the banana value chain. The current study focuses on these actors by looking at the roles and benefits as relates to TCB technology.

A number of indicators are used for impact assessment of project intervention. These indicators include; quantity of food produced, frequency of eating types of food, income generation and expenditure among others. A number of authors have used these indicators to measure technology intervention impacts. Nguezet *et al.*, (2011) and Asante *et al.*, (2014), examined impact of adoption of New Rice for Africa varieties (NERICAs) based on efficiency, income, and poverty indices among rice farming household in Nigeria. They used Instrumental variables to estimate the Local Average Treatment Effect (LATE) of NERICA adoption on income and poverty reduction among rice farmers. They revealed that there was

[2] The symbol > mean preference to

a robust positive and significant impact of NERICA variety adoption on farm household income and welfare as measured by per capita expenditure and poverty reduction. The empirical results suggest that adoption of NERICA varieties raises household per capita expenditure and income per cropping season, thereby reducing their probability of falling below the poverty line. Therefore, this suggested that intensification of the investment on NERICA variety dissemination is a reasonable policy instrument to raise incomes and reduce poverty among rice farming household, although complementary measures are needed. This aspect has not been done on TCB intervention in many parts of Kenya including western Kenya.

Period in terms months, days, and frequency per day of eating given types of foods is an impact indicator for measuring project success. When the food stocks are measured in terms of *grain* self-provisions, this indicator is calculated by counting the months between harvest and household stock depletion (Abdullahi *et al.,* 2011; Konda *et al.,* 2008; Patrick, 1999). However, in the case of continuously harvested fruits like banana including roots and tubers, the calculation is based on the number of months these products are harvested and eaten in the house.

Abdullahi *et al.*, (2011), carried a study on farming households' incidence of hunger based on duration after harvest. It was assumed that farmers experienced food shortage as period after harvest increases. This cycle of seasonal food shortage by farming households keeps occurring yearly. The result showed that more than 70 percent of households' experience severe food shortage as period of harvest increased. However, for fruits crops like banana the production is throughout the year and the number of months that households consume banana fruits would be a good measure of any intervention impact.

2.5 Agricultural value chain analysis

The country's ability to utilize its agricultural production potential depends on the innovativeness and creativity of actors in the agricultural sector, particularly farmers and marketers. The capacity of farmers and actors along the agricultural value chain to innovate in their production activities depends on the availability of technology.

The value chain approach in general has a long tradition especially in industrial production and organization, its application in international development and agriculture, has gained popularity only in the last decade (Anandajayasekeram & Gebremedhin, 2009; Anandajayasekeram *et al.*, 2009). The concept has continually evolved and more actor applying it in different fields (Kaplinsky, 2013; Ogidi & Abah, 2012; Parrilli *et al.*, 2013) more in agriculture and related fields (Orr *et al.*, 2013). The value chain concept has proven particularly useful for the identification and formulation of projects as well as in the development of strategies for improved agricultural and rural development (AFE., 2014). According to Anandajayasekeram and Berhanu (2009), there are four major basic stages in agricultural value chain. They include stages of production, vertical coordination, and business development services. Research has been devoted to TCB technology development but limited information on impacts and challenge in some regions of Kenya.

The banana value chain in Kenya is similar to any other fruits chain and may include many actors (e.g. TCB plantlet suppliers) of which the most important are producers, technology developers and disseminators (researchers and extension agents). In addition, input suppliers, banana producers, farm workers (including family labour), fruit merchants, fruit retailers, processors, commercial food preparation businesses (formal and informal), and consumers (FAO., Undated.; Kasina *et al.*, 2012; RSA., 2012). According to Trienekens, (2011), actors in the agricultural product (e.g. banana) value chain including retailers and wholesalers (Figure 2-1) may have limited resources to undertake the business activities. This is attributed to poorly developed banana markets. Producers (farmers) and informal vendors particularly cluster in lower income groups. Along the value chain, women have the greatest representation among processors, although the actual number of women involved in farming is undoubtedly larger than that involved in processing. Studies carried earlier have shown that about a quarter of the vendors of banana-based street encountered were female, and close to 25 percent of those interviewed derive their total household income from the processing activity. For these reasons, improving the profitability of banana vendors is likely to have a positive benefit on the poor, particularly poor women.

Tissue culture is an innovative horticultural propagation method which has revolutionized the horticultural industry and now there is mass propagation and the establishment of disease free stock material (FAO/IAAE., 2002). Further, it is indicated in the proceedings that this type of material is not seasonal as it can be produced throughout the year in the laboratory. This implies that there is great potential for enhanced adoption of TCB in major banana growing regions of Kenya other regions with similar environment (Wambugu, 2007). It was reported that there was an increasing demand for the technology with an estimated of about 50000 plantlets demanded annually (Wambugu, 2004). However, since the introduction of TCB in Kenya in 1997 there are successes and failures along its supply chain. This was perceived to increase in quality and quantity of banana. However, the actual situation on supply and demand for some TCB cultivars is not known.

Most studies analysing performance and impact of TCB have focused on a few segments along the VC with limited consideration on the whole value chain analysis. Qaim (1999), through an *ex ante* TCB economic impact analysis showed that the technology was likely to have a significant impact on farmers' welfare with relatively high returns. A follow-up survey by Mbogo *et al* (2002), confirmed that there was a significant TCB effect at plot and household level. A similar study by Nguthi (2007) showed that there is significant contribution to household livelihood assets.

Technology diffusion and adoption rate varies with type of technology. Mbaka *et al* (2008) showed that there was low TCB adoption (Mbaka *et al.,* 2008) in Kenya. The low adoption was attributed to a number of factors (Mbaka *et al.,* 2008; Mbogoh *et al.,* 2003; Nguthi, 2007; Rogers, 1983). The factors are broadly be grouped into farmer, farm, and institutional characteristics including the stakeholder perception. Besides this, there could be other controlling factors along the banana value chain that need identification and analysis. The evaluation may entail effects of technologies on beneficiaries. Banana input value chain spans from technology development and deployment to input material (plantlets) suppliers while output value chain spans from banana production, marketing, and consumption (Figure 2-1).

The value chain is characterized by provision of inputs to primary production, intermediary trade, to processing, marketing and up to final consumption/use. This study looked at the whole value chain but reported on issues related to farmers' production including preferences to banana innovation and traders conduct and participation in banana trade.

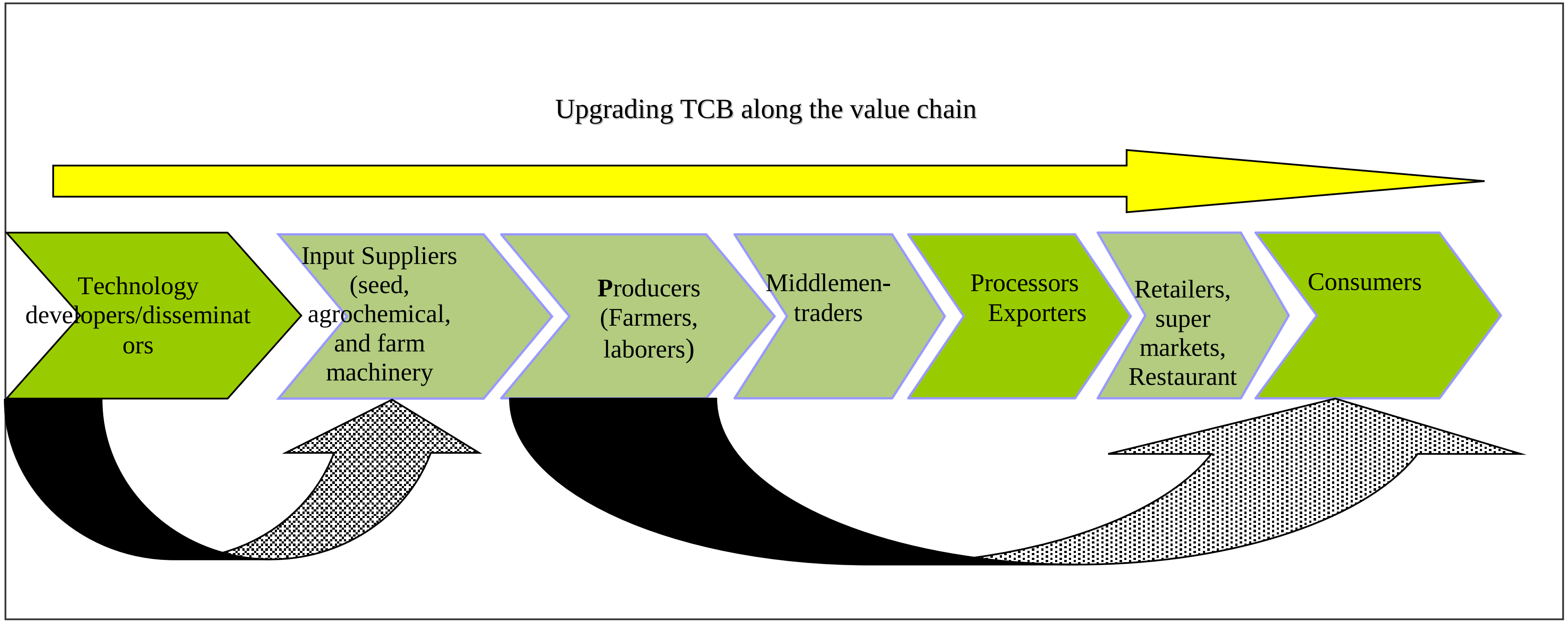

Figure 2-1: Banana value chain mapping
Source: Trienekens *et al* (2011) and Kaplensiky and Morris (2000).

2.6 Theoretical framework

2.6.1 Preference, Adoption and Impact Theory

Several theoretical contributions have been made for adoption (Ogada, 2013) and impact evaluation of technology interventions (Kristjanson *et al.,* 2001). These theories are of relevance to this study as they serve as a building block to this research work. From literature the theories discussed include; adoption theory (profit maximization, Chayanovian model, Recursive & non-recursive household model, and Risk aversion model) (Vieider *et al.,* 2015) and impact (instrumental variables, Propensity score matching) (Asante *et al.,* 2014; Bellù & Pansini, 2009; Kabunga *et al.,* 2014; Nguezet *et al.,* 2011; Qaim, 2014).

2.6.2 Adoption theory

A household is recognized as a basic unit of decision-making. Thus, it plays key a role in determining supply of factors of production and the demand for goods and services in order to maximize benefits (Becker, 1965; Grossbard-Shechtman, 1984; Grossbard, 1984) . There are three economic theories among others that explain decision-making procedures of farm households. The theories include; profit maximization or cost minimization, utility maximization and risk aversion (Ellis, 1993; Mendola, 2007; Rita *et al.,* 2014). The assumption of these theories is that farm households face a set of constraints (resources) as they maximise their objective functions for satisfaction. In this study, households are taken as basic unit in adoption of TCB. Farmers make a decision to adopt TCB. This a process, requires acquisition of TCB plantlets and other inputs that go with its proper agronomic management for enhanced productivity.

Profit maximization model

According to Ellis (1993), profit maximization theory recognizes peasant (or low resource base) households as profit maximizers in a perfectly competitive market environment. This implies that, despite having low resource base, households will allocate factors of production efficiently for profit maximization (Fafchamps, 1998). However, other studies have questioned the allocative efficiency of low resource base households based on empirical evidence. These households engage in trade-offs between profits and other equally important, but not necessarily economic, objectives which includes food security, social status and happiness (Bruni & Porter, 2007; Tan, 2013). This shows that households cannot be wholly profit maximizers because of other households’ food security and community social status objectives. Utility maximization theory treats households as both consumers and producers and are also referred to as non-separable households (Sadoulet & de Janry, 1995). Subsequently, it is important to analyse the two sides of their decision-making processes. Thus, households engaged in banana production may be profit and utility maximizers.

Chayanovian model

Chayanov's model of the peasant economy is based on autarkic nuclear family households. According to Chayanov (1966), assuming missing labour market and unlimited supply of land, the theory posits that farm household decisions would be more influenced by household size and structure (Bagchi, Undated; Hammel, 2005). A critical analysis of this has shown that the main weaknesses of this model is that the assumption of missing labour market and unlimited supply of land in its original form in Chayanov’s seminal work in the 1920s. The model was later modified by neoclassical economists during the 1960s. The modified version included perfect markets to explain the duality of farm household consumption and production decisions. The farm household, therefore, maximizes utility of consuming home-produced and market-purchased goods, and leisure time, subject to full income constraint (Bagchi, Undated; Bernstein, 2009).

Recursive and non-recursive household model

Farm households can make joint production and consumption decisions or not. If markets existed and functioned properly, production and consumption decisions would be recursive or separable (Omamo, 1998). Separability is based on the assumption that there is existence of perfectly competitive labour markets, perfect substitution of family and hired labour, perfect substitution of farm and off-farm labour and absence of specific disutility associated with working off the farm (Bedemo *et al.*, 2013; Sadoulet & de Janry, 1995).

However, in reality, labour markets in developing countries are imperfect and the household decisions cannot be separable. The household model is non-separable when the production decisions are affected by consumption preferences. Under this scenario, production and consumption decisions are linked because the decision maker is both a producer who is choosing the allocation of labour and other inputs to farm production, At the same time the household is a consumer, choosing the allocation of income from farm profits and labour sales to the consumption of commodities and services. In modelling TCB adoption, the production and consumption decisions are non-separable, thus the production and consumption decisions are non-separable.

Where markets are missing or highly imperfect, household decision becomes non-recursive because the household deliberately decides how much time to allocate to production, which affects consumption of leisure (Taylor & Adelman, 2003). In such cases, consumption and income affect each other. In less developed/developing countries, agricultural households face either missing or highly imperfect markets characterized by high transaction costs and constraints on marketed quantities (Ellis, 1993; Taylor & Adelman, 2003).

Like profit maximization theory, recursive, and non-recursive farm household models fail to recognize the role of risk and uncertainty in peasant household production decision-making. Farm households are not risk-neutral and assuming so leads to over-simplification of the objective function and the constraints (Taylor and Adelman, 2003). This is the gap that risk aversion theory, fills. The theory recognizes that smallholders produce under great risks and uncertainty arising from weather, pests and diseases, price volatility and social uncertainty (Ellis, 1993). As a result, they exercise a lot of caution in their decision-making. This restricts the applicability of profit maximization.

Risk aversion model

Households make multiple decisions to attain multiple objectives of food security, income generation and probably having social status in the community (Adewumi & Omoresho, 2002; Ellis, 1993; Korir, 2011). In the process of undertaking risks, the households get some outcomes. The risk aversion model approach in decision-making at peasant household is done from two main perspectives namely: expected utility approach and disaster-avoidance approach. In the expected utility approach, which is also called full optimality approach, a farm household chooses among risky alternatives based on its preference of the possible outcome and the probability of its occurrence. Farm households are viewed as utility maximizers constrained by risks. Other things being equal, households choose low risk–high utility productive activities. In the process of choosing to adopt/practice biotechnology options like TCB farmers undertake risks.

Disaster-avoidance model

As observed by Mendola, (2007), under the disaster-avoidance model, households facing risky income streams will first isolate safe alternatives and choose from them based on expected utility. The decision-maker's main concern is to avoid income falling below the subsistence level. This safety-first consideration could make a household prefer risky or less risky activities. Thus, at low levels of income, individuals may violate expected utility theory. Mendola, (2007) and Sadoulet *et al.* (1996) indicated that because markets are highly imperfect or, in some cases, missing in developing economies, this study is based on the non-separability of household production and consumption decisions. As indicated by Ellis (1993), the smallholder households are viewed as utility maximizers, constrained by market conditions, income, and stochastic production risks.

2.7 Preferences and utility theory

Utility concept can be used to analyse demand for goods and services (Reynolds, 2005) including specific technologies like TCB. This concept is subjective and unique to each individual. Economic theory states that utility is a measurement of the satisfaction derived from the consumption of alternative bundles of commodities (Dean, 2009). In recent years, the theory of consumer utility has gone beyond die traditional economic theory of consumer demand. According to Lancaster's model (also called characteristic model) of consumer behaviour, the theory on preferences states that goods are valued for the attributes they possess, and that differentiated products are merely different bundles of attributes (Wierenga, 1984). One can use scoring or rating for these attributes to reveal consumer preferences and tastes for a technology like TCB. Subsequently the importance for each factor/attribute is computed separately for each farmer.

2.8 Impact theory of technology

Improvements in technology, driven by application of scientific research to practical problems are important in economic growth and development of any system. However, the economic value of public investment in research may not be obvious unless evaluated. It is recognized that it is difficult to observe the impact of agricultural research/intervention, because the benefits may be diffused over many years and to millions of dispersed producers and consumers.

There are major technological advancements in Agriculture, which include biotechnology (e.g. TCB), mechanization, chemical fertilizers, and hybridization, which lead to increases in supply of products (e.g. banana fruits). Technologies among others are supply curve shifters because they allow farmers to produce more with a given level of inputs. It is recognized that this happens only when there is adoption of the technologies. Thus, after adoption of any technology like TCB there are expected changes (impact) on the target group. The introduction of a technology into any product value chain has a series of impacts on several segments of the chain. The attribution and distribution of these changes and benefits to the target groups is one of the major problems. There are diverse methods of impact evaluation.

Analytical Technique Economic impact assessment of research can be done through four approaches which include; indicator, econometric, programming and economic surplus (Ogunsumi *et al.,* 2007; WIPO., 2013). This study adopted a mix of these approaches Impact assessment of TCB intervention in this study is an *ex-post* assessment since the TCB varieties are already in the field, at varying levels of adoption by the farmers. The analyst follows a logical process, shown in Figure 2-3**,** which goes through the construction of a base scenario (with and without the project), According to Bellù, and Pansini, (2009), this type of Value Chain Analysis (VCA) is an accounting framework which refers to a sequence of economic activities vertically linked. It identifies, describes and assesses in economic terms relevant activities of all the factors (farmers, traders, consumers, authorities, and development organizations), which contribute to the production, transformation and distribution of a single commodity. Thus, a value chain analysis includes the description and evaluation of a sequence of operations (stages of the Value Chain) ranging from the primary production of raw materials, the assembly/processing of intermediate goods, the delivery and distribution of the commodity to retailers and the markets and finally, to the consumption of the final output.

Understanding utility theory is important in confirming the empirical analysis where the household is the principal agent in the utility framework. A household behaviour is central to the decision making process when goods and services are valued. Decision making, however, is complex and description of consumer theory helps in understanding these complexities.

The neoclassical theory of farm production indicates that the decision making process of what, how, when and how much to produce begins with an individual farmer who is the head of a household (Ellis, 1993). The traditional models that empirically assess agricultural household behaviour are based on the idea that agricultural households aim at maximizing a utility function given by consumption possibilities subject to availability of resources (e.g. farm size, technology, education, cash, socio-cultural values) or budget with which to satisfy consumption. In this study the households maximize utility (U_i) by choosing to produce TCB (U_{TCB}) in combination with other crop enterprises. Thus, a farmer rationally adopts TCB if utility from TCB is greater than non-TCB (U_{NTCB}) as shown in equations 2-1 and 2-2.

$$MaxU_i = F(U_{TCB}, U_{NTCB}) \qquad 2\text{-}1$$

Thus:

$$\Delta U = U_{TCB} - U_{NTCB} > 0 \qquad 2\text{-}2$$

where U_i is household utility function, U_{TCB} is utility from farmer *'i'* growing TCB and U_{WTCB} is utility derived from growing non-TCB. Utility derived by farmers and other project participants from adopting TCB intervention is manifested in the impacts and outcomes. Utility maximization from TCB can be influenced by household, farm, technological and institutional characteristics. These effects are manifested in measurable indicators through an Impact Assessment (IA) study.

2.9 Modelling impact of technologies

The concept of TCB intervention program leading to social, economic and productive impacts is built around the hypothesis that the development, dissemination (up-scaling) and adoption of the technology was perceived to increase food security and alleviate poverty (Mbogoh *et al.,* 2003; Qaim, 1999). According to these authors, the intervention had the potential to generate economic and productive impacts at the household level and to stimulate the income generation and food security attainment. Figure 2-2 shows the schematic framework for TCB impact evaluation.

In rural areas most beneficiaries depend on subsistence agriculture and/or rural labour markets and live in places where markets for financial services such as credit , labor, goods and inputs are lacking or do not function well (Asfaw *et al.,* 2012). In some rural household cash generation from agriculture often represent a significant share of their income (Carletto *et al.,* 2007; FAO., 2011), and can be expected to help households overcome financial obligations. According to Asfaw *et al.,* (2012) this, in turn, can increase productive and other income-generating investments, influence beneficiaries' role in social networks, increase access to markets and inject resources into local economies. Therefore, the impact of TCB programmes on the economic decision process can potentially manifested through changes in household behaviour and on the communities and local economies where the transfers operate.

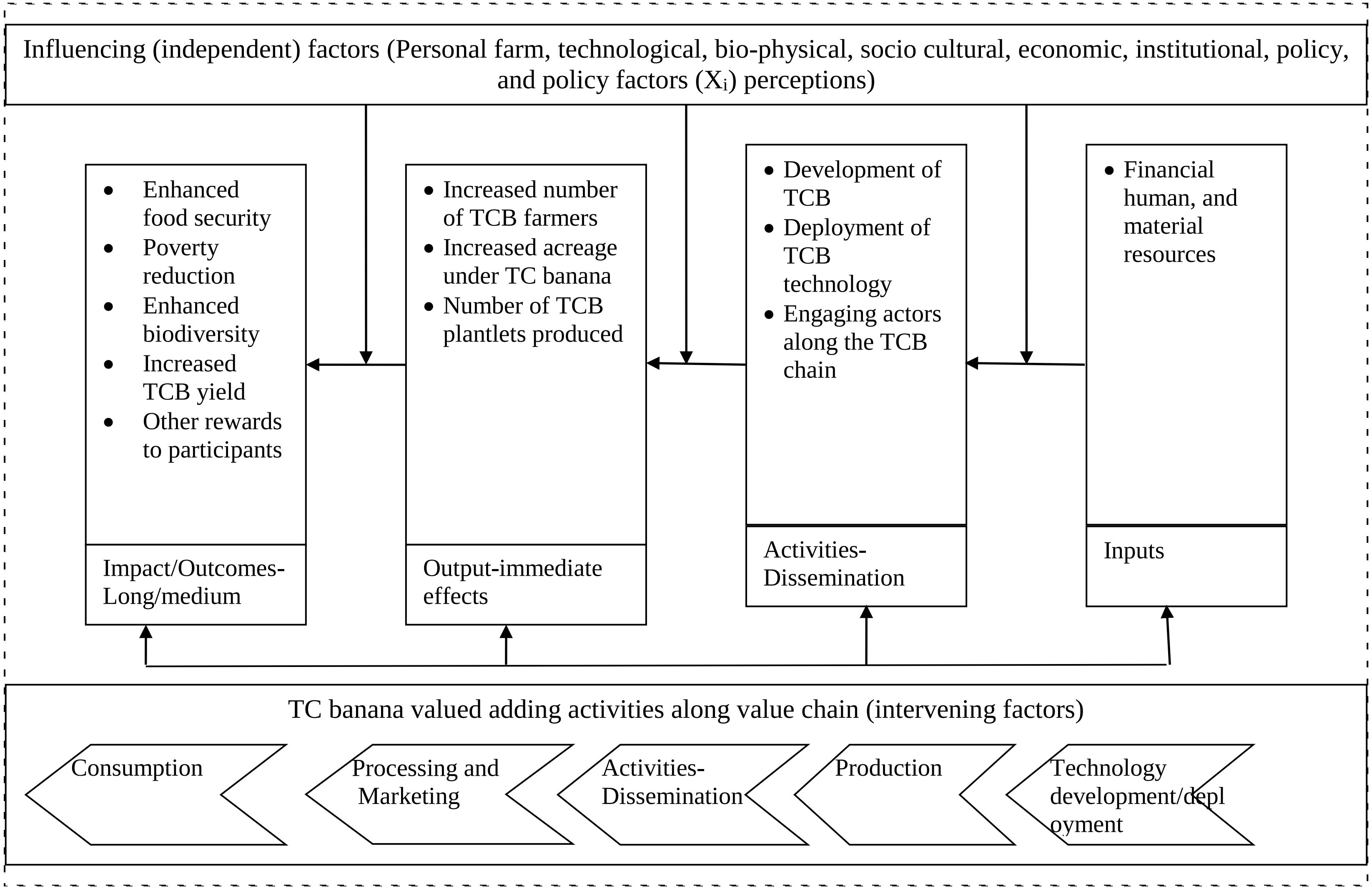

Figure 2-2: Conceptual framework for TCB impact and performance along the APVC

Impact evaluations can be classified into quantitative and qualitative approaches (Bamberger, 2013; Garbarino & Holland, 2009). Effective quantitative impact evaluation utilizes an explicit counterfactual analysis which isolates the welfare effect of a specific project/programme/strategy by comparing the actual observed outcomes of project participants with counterfactual outcomes (Asfaw *et al.,* 2012). Counterfactual are hypothetical outcomes that would have prevailed in the absence of the project (Muller–Praefcke *et al.,* 2010; Office of the Special Evaluator., 2013). Since people are either in or not in the project and cannot be both, these hypothetical counterfactual outcomes cannot be observed. The central objective of quantitative impact evaluation is to estimate these unobserved counterfactual outcomes (Asfaw *et al.,* 2012; Mawer, 2014).

Because of this counterfactual analysis, quantitative impact evaluation makes possible clear specification of the project impact being estimated (ADB., 2006; White, 2010). It is therefore generally regarded as more authoritative and is usually referred to as rigorous impact evaluation (Garbarino & Holland, 2009) and therefore analysis avoids biases in estimating project impacts. As indicated by several authors, one technique frequently used in evaluating development interventions is comparing "before" and "after" outcomes (Armstrong *et al.,* 2014; Menon *et al.,* 2014; Muller–Praefcke *et al.,* 2010). The problem of this comparison is that it uses the same group of individuals (i.e., project participants) and observes the temporal change in outcome of this group. This gives a potentially biased measure where the project is to be up-scaled because such a comparison fails to account for the changes in outcome that happen with the project participants without the project (Armstrong *et al.,* 2014; Office of the Special Evaluator., 2013). For example, changes of progress indicators of project intervention like TCB (income, yields) between two time periods (before intervention and after intervention may be due to partly to one's benefit from the project and partly to one's income change caused by secular changes in the economy in general, even if one did not participate in the project.

Analysts make efforts to make the "with" and "without" groups as similar as possible similar (Wanyama *et al.,* 2010). However, these two groups are only similar in a general sense and there is no guarantee that they are identical or close to identical. An obvious reason is that participating in the project self-selects participants and non-participants, making the two groups different. For example, in the TC banana project, participants and non-participants may differ in entrepreneurial capability or willingness to take risk, even if they seem similar in any other observable ways. Because of this failure to control for unobservable differences between the "with" and "without" groups, the estimated impact may be biased.

On the other side, qualitative impact evaluation does not use a counterfactual analysis but relies on understanding processes (Mawer, 2014; Office of the Special Evaluator., 2013) (i.e., if event A is done, then likely event B will occur, and then likely event C will occur, etc.); observing behaviours (e.g. consumption patterns); and condition changes (e.g., health, of household members). This type of evaluation usually draws inferences from studies like reviewing project implementation processes, interviewing project beneficiaries to get personal opinions, conducting focus group discussions, and analysing supportive secondary data (Catley *et al.,* 2013). An example of the qualitative approach is the techniques used in participatory impact assessments that reflect changes using participants' personal knowledge about the conditions in the project area. While qualitative evaluations build stories and provide contextual insights to what is happening within the project, they often are being criticized for lacking rigor and internal validity (Morton *et al.,* 2012). Major critics of this evaluation approach revolve around issues such as subjectivity in data, lack of a reliable comparison group, and lack of statistical robustness often due to small sample sizes (de Vet *et al.,* 2010).

It is against this background that quantitative impact evaluations using explicit counterfactual analyses of data from well-designed statistically representative samples are better suited for inferring causal relationships between the program and outcomes (Gertler *et al.,* 2011). However, there is increasing acceptance that qualitative methods can provide critical insights into the program context and in-depth explanations to the results observed in a quantitative analysis as indicated by Gertler *et al.,* (2011). For this reason, good impact evaluations often combine both quantitative and qualitative methods to the extent possible (Gramillano, 2012; Wanyama *et al.,* 2010).

2.10 Tissue culture technology description

Plant Tissue Culture is culturing of any part of the plant in a specially defined growth media under aseptic laboratory condition in Petri dishes, test tubes or in any other suitable glass containers (Lule *et al.,* 2013). The plant nutrient media consists of macro and micro salts, vitamins and desired levels of plant growth hormones (George & de Klerk, 2008). Banana plants produced from Tissue Culture are free from diseases at the time of supply and they give high yields since they are made from selected high yielding mother plants. If proper care is taken, as per instructions, they grow into strong healthy plants and give high yields of good quality fruits (JAIN., Undated.; Smith, 2007). Since they are produced under controlled laboratory conditions using selected nutrients, they usually give yields one or two months earlier than conventionally propagated plants as shown in Table 2-1. An adopter of TCB is one who had used TCB plantlets.

Table 2-1: Comparison of tissue culture plantation and traditional sucker plantation

TC banana plantation	Traditional banana sucker plantation
1. Plant are of same age	1. It is not sure that all the suckers are of the same age and therefore not uniform
2. Plants are disease free and healthy	2. Some suckers may be diseased
3. Plants carry same characters of mother plants	3. In case of suckers there is no possibility of assuring characteristics
4. As the suckers are selected from mother plant with high yields the tissue culture plants give high yields	4. M Low yields observed because suckers are from different mother plants having a range yield potential
5. Crop is ready for harvesting 11-12 months from plantation	5. Crop is ready for harvest in 15-16 months from the plantation
6. Crop growth is uniform	6. Crop growth is not uniform
7. Cost of inputs (irrigation, labour, and cultivation are less because crop period is less	7. Cost of inputs (irrigation, labour, and cultivation are more because crop period is long
8. In 28-30 months one main crop and two rations crop can be harvested	8. In 30-32 months one main crop and two rations crop can be harvested
9. More yield and profit	9. Less yield and less profit

Source: JAIN (undated); Smith, (2007); Lule *et al.*, (2013)

2.11 Description of study area

The study was conducted in five counties of Western Kenya and North rift region; Kisii, Bungoma, West Pokot, Uasin Gishu and Trans Nzoia (Figure 2-2) counties which was some of the counties where the TCB project was up-scaled TC banana technology. Multi-ethic groups with similarities and differences in production and consumption habits occupy these regions. The AEZs covered range from low potential areas to high potential zones covering relatively high potential zones of Kenya (Jaetzold *et al.*, 2005).

As shown in (Table 2-2), Bungoma County lie on between latitude 0°25'N and 0° 53´ N and Longitude 34°21´E and 35°04´E. Trans Nzoia County lies between latitudes 0°52´ and 1°18´N and longitude 34°38´E to 35°23´E. The West Pokot County lies from 0^0 10’N to 30^0

40’N and longitude 34^0 50’E to 35^0 50’E while Uasin Gishu County lies between latitude 0° 03′N and 0° 55N and longitude 34° 50′E to 35 ° 37′E. Kisii County is lies between latitude 0 30’ and 1 0’ South and longitude 34 38’ and 35 0’ East. The county covers a total area of 1,332.7 km square. The county’s total population is projected at 1,226,873 persons in 2012 (RoK., 2013).This represents 586,062 and 640,811 males and females respectively. By 2017, this population is expected to rise to 1,362,779 persons (650,982 males and 711,797 females) (RoK., 2009).. The county has a highland equatorial climate resulting into a bimodal rainfall pattern with two rainy seasons, the long rains occurring between February and June and the short rains occurring between September and early December. The adequate rainfall, coupled with moderate temperature is suitable for growing of crops like tea, coffee, maize, beans, and finger millet potatoes, bananas and groundnuts. The county is one of highest producer of banana in the country.

West Pokot County is one of the 18 counties that make up the Rift Valley region of Kenya. It borders Uganda to the west, Trans Nzoia and Elgeyo-Marakwet County to the south, Turkana County to the north and east and Baringo County to the southeast. Geographically, it lies between Latitudes 1^0 10’ and 30^0 40’N and Longitudes 34^0 50’and 35^0 50’E. The district has a total area of 9,100 square (RoK., 2013). Altitude ranges from 900m to about 3000. Rainfall is bimodal with the long rains falling between March and June and the short rains occurring between Septembers to November. The rainfall amounts range from 700 mm to 1600mm. Temperatures ranges from 9^0C to 30 ^{0}C. The County has a population of 512,690 people with a density of 37 persons per square. It is recognized that the county inhabitants are traditionally, nomadic pastoralists whose lifestyle is rapidly changing to sedentary mixed farmers, especially in areas where conditions permit. The greatest challenges are endemic poverty and food insecurity that renders the community dependent on food aid on annual basis. Agriculture has a huge potential for providing viable livelihood options to West Pokot people and thus alleviating the high poverty levels in the county. The potential also exists of transforming the pastoralist nomadic lifestyles to a sedentary one thereby affecting planning for social amenities. The county produces the following crops: bananas and other fruits trees, maize, beans, potatoes, sorghum, finger millet, dairy, and beef.

Table 2-2: Description of the counties where the TCB study was conducted in Kenya

District	District GPS coordinates	Temperatures	Elevation (meters above sea level)	Agro-ecological zone	Mean annual rainfall (mm)	Human Population 2009 census
Bungoma	0°25'-0° 53´ N, 34°21´ - 35°04´E	19.4: max: 25.5 min: 13.3	1500-2500	UM_1, UM_{2-3}, UM_4, LM_{2-3}	630-1600	1,630,934
Uasin Gishu	0°09′ -0° 20′N, 34°29′ - 34°33′E	17.9: max:26.0; min:9.7	1240 -1641	LH-$_{1-3}$	1600-2800	894,179
Trans Nzoia	0°52´-1°18´N, 34°38´- 35°23´E	10°C; max: 37°C min:10	1600-3800	UM_4, LH_3, UH	1,200	818,757
West Pokot	00 and 00 34’’N; $34^0$34’’-35^0 25E.	Min. 12°C; max. 23°C	1300-2500	LH_1, UH_{1-3}, LM, UM_1	1800-2000	512,690
Kisii	0°30′-0°58′ S, 34°38′-34° E	Min. 12°C; max. 23°C	1600-2000	LH_1, UH_1, LM, UM_1	1350-2100	1,152,282

Notes: UM=upper midland; LM=Lower midland; LH=Lower highland; UH=Upper highland. Max=maximum and min=minimum.
Source: Jaetzold *et al* 2005.

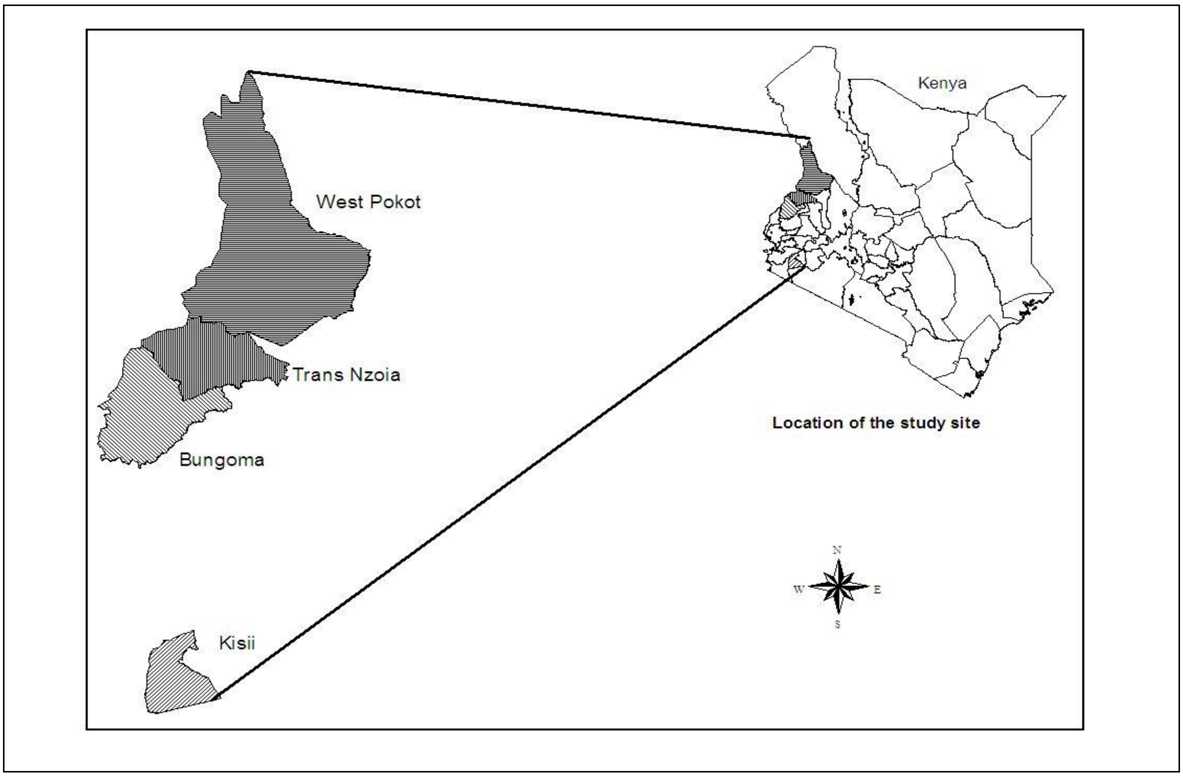

Figure 2-3: Map of Kenya showing the four study survey sites/counties**.**

2.12 General data sources and collection procedures used in the study

The Ministry of Agriculture extension officers identified the main banana growing areas in western, Nyanza and north rift regions. I addition, extensive literature review on the study region was done. The target areas for the study fall under the Upper midland zones 1 (mainly coffee), zone 3 (marginal coffee) and zone 4 (sunflower-maize) of West Kenya (Jaetzold *et al.*, 2005). The districts/regions covered included; Kisii, Bungoma, West Pokot and Trans Nzoia. A set of questionnaires (Household, trader and Input supplier) was developed and administered through personal and focus group interviews with the randomly selected farmers, traders, input suppliers to capture data on banana production practices and accrued benefits including emerging challenges.

The study utilized both primary and secondary data. Secondary data were sourced from literature and relevant research works in the area. Primary data was generated through a survey by conducting personal interviews using a designed and pre-tested semi-structured questionnaire mainly focusing on key impact indicator variables (yields, food security, and income generation as dependent variables). As indicated in the preceding section both TCB technology practicing and non-practicing (counterfactual) farmers were interviewed. Secondary data was be generated from various sources including Ministry of Agriculture, Ministry of Livestock Development and Central Bureau of statistics (CBS., 2005). Primary data was collected with the help of well-trained enumerators who were selected after an intensive interview. Templates were created in relevant data editor programmes (SPSS, Excel, and STATA) for immediate entry after checking for mistakes. Crosschecking was done immediately data was received from enumerators before being entered into the computer.

Primary data was collected using various instruments, which included four sets of questionnaires and two checklists.[3] The first questionnaire dealt with evaluation of the TCB producers and TCB preferences; the second targeted the TCB nursery managers and the third one was administered to traders. The two checklists were used in focus group discussion and key informant. A reconnaissance survey was carried out to facilitate in designing the questionnaires addressing key issues identified including identification of survey sites. The purpose of using the four sets of questionnaires was to provide a more holistic and complete understanding of the whole value chain structure. Extracting both qualitative and quantitative data on the TCB impact on target groups and the challenges faced will give a more realistic picture of the outcomes. Additional qualitative data was also collected in order to assess the

[3] See Appendices 1-4 for details

degree of strength (and weakness) of the relationships amongst TCB value chain actors (farmers, traders, input suppliers. Psychometric questions were asked on a numerical scale to get responses. The survey was done in three phases, targeting farmers, TCB input suppliers, banana fruit traders in respective markets, and super markets in each county where the study was undertaken.

2.12.1 Household survey

The target population for this study was made-up of banana growing farmers in Western Kenya. These included TCB and non-TCB adopters in the selected counties. Multistage random sampling technique was adapted. First, four counties were purposively selected from 47 counties. Two districts were randomly selected from each county. Five sub-locations were randomly selected from each of the districts, thus, giving 15 villages. Lastly, 331 farmers were randomly selected from each of the 15 villages using simple random sampling technique after listing all banana farmers in the sub location (Figure 2-4). The front-line agricultural extension officers of the Ministry of Agriculture Livestock Development and Fisheries facilitated this process.

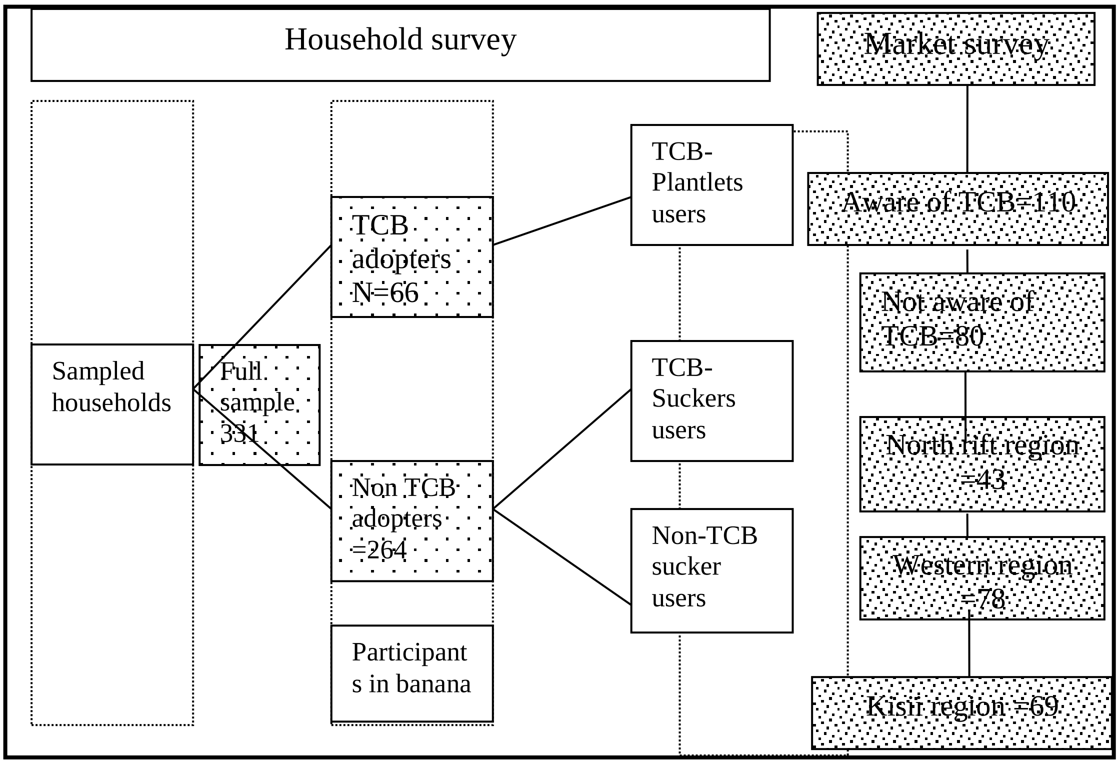

Figure 2-4: Distribution of the surveyed households according to the treatment received

2.12.2 Trader

We administered questionnaires to 190 traders determine role of banana trader in upgrading TCB technology along the value chain. The questionnaire contained four sections. The first section was on general socio-economic characteristics of traders including age, sex, highest education level attained, training, type of business, trading activities, sources of funds and banana market share. The second section included; questions to determine the pricing, profits, quantities of bananas traded and information sources on banana trade and policy aspects. The third section had questions on knowledge and perceptions of traders in TCB technology. The fourth section included questions to determine the trader attitudes on TCB and its impact on key impact variables namely, food security, income generation, health issues.

The respondents were required to indicate the degree of agreement or disagreement with each of the psychometric statements. We assigned a numerical score to each degree of agreement/disagreement. The scores from the statement were added-up to obtain the total score for each respondent. A five-point Likert scale was used to rank the responses with the ranking as follows: 5=strongly agree; 4=agree; 3=neutral; 2=disagree; 1=strongly disagree. Section 5 focused on constraints in banana trade. Other aspects that were given emphasis in the study included; banana traders' characteristics and employment, investment levels, banana prices, and volume of sales including income, as well as experience of traders in banana marketing. Others were; age and education, major and minor occupation, gender, farm sizes, labour, fixed inputs, value of credit, storage cost and value of losses during storage, membership of traders' association or cooperatives, income level, and transportation means.

2.12.3 Description of variables used for modelling for TCB impact assessment

The variables used in the analysis of the impact of TCB are shown in Table 2-3. The dependent variables are treated, and number of banana stools per arable land. Dummy variables are independent variables, which take the value of either '0' or '1'. They may be explanatory or outcome variables; however, in this study both dependent and explanatory variables were used as dummy variables.

Table 2-3: Description of variables used for modelling

Variable Name	Exp sign	Type	Description
Dependent			
Treated		Dummy	1=TCB growing; TCB; 0=otherwise
No TCB/ha		discrete	Number of TCB stools per unit area
Independent			
BanKind	+	Dummy	Kind of banana grown
STOOLSNO	+	discrete	Log of TCB stools
MONTHSBAN	+	continuous	Log of Household has banana
PriceTCB-Pl	+	continuous	Price of TCB planting material-plantlets
PriceTCB-Suck	-	continuous	Price of TCB planting material-suckers
DistTCB	-	continuous	Distance of TCB source
AGE	±	continuous	Head of Household Age
EDUCAT1	+	Dummy	HoH had no formal education
EDUCAT2	+	Dummy	HoH had Primary education
EDUCAT3	+	Dummy	HoH had secondary level
EDUCAT4	+	Dummy	HoH had post-secondary level
HoHOcup1	±	Dummy	HoH was a farmer as main occupation
HoHOcup2	±	discrete	HoH was a casual worker as main occupation
HoHOcup3	±	Dummy	HoH is a non-casual worker as main occupation
HoHOcup4	±	Dummy	HoH is Self-employed as main occupation
HoHOcup5	+	Dummy	HoH is a Farmers as main occupation
HoHOcup6	+	Dummy	HoH is an Agricultural Worker
HoHOcup7	±	Dummy	HoH is a teacher
HoHOcup8	±	Dummy	HoH is not economically active
MARST1	+	Dummy	HoH was married
MARST2	±	Dummy	HoH was single, widowed, divorced
FAMLY	+	discrete	Household family size
TCBPRD	+	continuous	Period of HoH growing TCB
EXP	+	continuous	Period of HoH involved in farming
BANPRD	+	continuous	Period of HoH involved in banana farming
FARMSZ	±	Continuous	Farm size in hectares
TENURE1OWT	+	Dummy	1=Owned with title; 0=otherwise
TENURE2ONT	+	Dummy	1=Owned without title; 0=otherwise
ARBLND	-	Continuous	Size of arable land acres
FERT1	-	Dummy	Perceived fertility status was low
FERT2	+	Dummy	Perceived fertility status was medium
FERT3	+	Dummy	Perceived fertility status was high
LABSOC	+	Dummy	Labour source 1=family; 0=hired
PlTCB	+	Dummy	Plant TCB 1=Plant TCB; 0=otherwise
PL-Mat	+	Dummy	Banana planting material 1=TCB; 0=0therwise
AvailPMat	+	Dummy	Planting material easily available 1=Yes;0=No
DistPMat	±	Continuous	Distance to planting material source
CashSc	±	Dummy	Source of cash for buying planting material
FarmInc	+	Continuous	Gross annual farm income
Non-FarmInc	±	Dummy	Non-farm income 1=Non-farm; 0=otherwise
InfSocMob	+	Dummy	Information source- 1=Other farmers;0=otherwise
InfSocMob	+	Dummy	Information source- 1=Mobile; 0=others

Notes: Exp.=expected and - means negative and +means positive.

2.12.4 Test for heteroscedasticity

Diverse test statistics for detecting heteroscedasticity exit. They include Park, Breusch-Pagan, Godfrey, White's testes, and Koenker-Bassett test of heteroscedasticity (Wooldridge, 2002). However, there is no single test statistics of heteroscedasticity that is better than the other. Against this background, Koenker-Bassett (KB) test of heteroscedasticity was employed in this study due to the ease of its applicability. Like other test statistics of heteroscedasticity, KB test is based on the squaring of residuals u_i. However, instead of being regressed on one or more regressors, the squared residuals are regressed on the squared estimated values of the regressand. The model is given in equations 2-3 to 2-5.

$$Y = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 ... + \beta_i X_i + \hat{u}_i \qquad 2\text{-}3$$

Then $\hat{u}_i$ is obtained from this model and then $\hat{u}_i^2$ estimated as shown in equation 2-4.

$$\hat{u}^2 = \gamma_1 + \gamma_2 Y_i + V \qquad 2\text{-}4$$

where $\hat{Y}_i$ is the estimated values from the model as in equation 2-5.

$$Y = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + K + \beta X + \upsilon \qquad 2\text{-}5$$

The null hypothesis is that $\gamma=0$. If this is not rejected, then, one can conclude that there is no heteroscedasticity. The null hypothesis is tested by the t-test or the F-test. In the presence of heteroscedasticity, ordinary least squares (OLS) estimates are unbiased. However, the usual tests of significance are generally inappropriate and their use can lead to incorrect inferences. Tests based on a heteroscedasticity consistent covariance matrix, however, are consistent even in the presence of the heteroscedasticity of an unknown form (Long & Ervin, 2000).

2.12.5 Test for multicollinearity

The variables in the models were selected using the Akaike information criterion (AIC), the variance inflation factor (VIF) and Contingency coefficients to avoid multicollinearity. Multicollinearity problem occurs when there exist linear dependencies among regression variables *(X_i.)* This limits separating out the effects of each independent variable on the dependent variable *(Y_i)*. Each independent variable may be redundant because it can be predicted well using the other variables in the model. This is the problem of multi-collinearity. This problem may negatively influence the regression model outputs and leads to improper conclusions drawn from incorrect parameter estimates and subsequently confidence intervals. Therefore, it is important to test for multi-collinearity and correct it prior to undertaking regression modelling. It is important to compute Variance Inflation Factor (VIF) test after running OLS regression to examine multicollinearity as shown in equation 2.6.

$$VIF = 1/(1 - R_j^2) \qquad 2\text{-}6$$

where, R_j^2 represents the multiple correlation coefficients between X_i and other explanatory variables, for each selected continuous variable were regressed on all other continuous explanatory variable i.e an auxiliary regression of each independent continuous variable X. Thus, the larger the value of R_j^2, the higher the value of VIF causing higher multicolinearity in the variable for continuous variables. As a rule of thumb, Gujarati (2003) stated that if the VIF value of a variable exceeds 10, which will happen if R_j^2 exceeds 0.90, then, that variable is said to be highly collinear. If the value of R_j^2 were '1', then it would result in cause perfect collinearity between variables. Therefore, for this study, Variance inflation factor (VIF) was used to detect multicollinearity problem for continuous variables. Contingency coefficients were also calculated to detect the degree of association among the dummy variables. Contingency coefficient is the Chi-square based measure of association. A value of 0.75 or more indicates a stronger relationship. The contingency coefficient was computed as shown in equation 2-7.

$$C = \sqrt{\frac{\chi^2}{(N + \chi^2)}} \qquad 2\text{-}7$$

where C represents Contingency Coefficient, $\chi 2$ represents Chi-square test, N stands for total sample number. If normality or homoskedasticity fail to hold, the Tobit model may be meaningless. In OLS estimates are consistent but not efficient when the disturbances are heteroscedastic. In the case of the limited dependent variable models also, if we ignore heteroscedasticity, the result estimates are not even consistent i.e. is the regression coefficient is upward biased (Maddala, 1983). In this study, heteroscedasticity was tested for some suspected variables by running the model.

CHAPTER THREE

3 ANALYSING FACTORS INFLUENCING ADOPTION OF TISSUE CULTURE BANANA

3.1 Introduction

In order to enhance and sustain the effects of TCB in Kenya, there is need to address factors influencing the adoption. The effects of TCB on products has been attributed to a myriad of factors ranging from socio-cultural, institutional, marketing and policy issues including farm and farmer (RoK., 2013).

In studies conducted by Fisher and Qaim (2011), Kabunga *et al* (2011a and 2011b), Langat et al (2013), showed that TCB adopters were observed to have relatively higher yields of up to 7% compared to non-adopters. This implies that desired increase of productivity attributed to TCB and subsequent impact on food security and income generation will not be fully achieved unless the TCBs are widely adopted by farmers.

Evidence from literature shows that TCB technology has not been fully adopted in Kenya due to a number of diverse factors. Some farmers plant TCB (adopters) while others do not (non-adopters). In addition, the level of adoption among adopters varies. This implies that farmers allocate different proportions of their farmland to TCBs. This raises key questions, first why are some TCB farmers adopting TCB, and how does the intensity or size of area allocated to TCB vary among farmers.

Studies that address the above questions are needed for future planning of up-scaling TCB are scanty. Therefore, the broad objective of this study is to assess the determinants of TCB in western Kenya. The specific objectives are to assess the influence of socio-economic factors on decision to adopt TCB in western Kenya. In contrast to most adoption studies in Kenya that have adopted logit, probit and Tobit, this study employs the Double hurdle model to take care of the two stages in decision making involved in planting TCBs. In order to achieve the set objective, it was hypothesized that the extent and determinants of TCB do not significantly depend on farmers' socio-economic, farm and institutional characteristics.

Understanding the importance of banana production in the country and keeping in mind paucity of banana research, this study aims to determine the factors that influence the TCB level of and intensity of adoption. Increased farm level adoption will increase farm production and hence profit. Ultimately, farmers will enjoy higher income and livelihood status. At the macro level, the impact will be less banana import and more favourable balance of payment

Several authors have summarized the critical factors influencing technology adoption in the developing and dissemination of agricultural innovations (Adesina & Baidu-Forson, 1995; Adesina & Zinnah, 1993; Baidu-Forson, 1999; CIMMYT., 1993; Doss, 2006; Feder & Slade, 1984; Rogers, 2003). These authors indicated that there are four primary classes: physical and natural characteristics- area of land under cultivation, acreage, and pre-adoption income/wealth and access to year around. Human assets include; quality and quantity of household labour, the age of household head and years of education of household head were proxies for the quality of labour and household size and the dependency ratio were proxies for quantity of labour. Social assets included farmer's membership in groups and the number of extension visits. Financial assets included farmer access to formal or informal credit, capital assets and the quality and ownership status of the home (Nowak & Korsching, 1983).

3.2 Methodology

3.2.1 Theoretical framework and analytical techniques

Technology adoption is perceived to be a mental process through which decision maker goes through a series of actions from first learning about an agricultural innovation to its final adoption/use (Dandedjrohoun *et al.,* 2012; Feder & Slade, 1984). Ultimately, the individual becomes a user of an innovation/technology. Rogers (1983) and Adesina & Zinnah (1993) present a conceptual model based for the farmers' adoption decisions. According to these authors, the decision is based on the assumption of utility maximization, which remains unobserved. The decision whether to adopt a new technology is based on a comparison of marginal/additional net benefits/utility of new technology against the old one. Let us define the old and new technologies by the symbols '*o'* and '*n'*. The preference of the i^{th} farmer (y_i) for the technology adoption is given by the difference between the marginal net benefits of adopting 'n' technology against that of adopting '*o*' technology which is unobserved. $y_i > 0$ corresponds to the net benefit of the technology (NB_{ne}) exceeding that of the *'o'* technology while NB_o refers to the net benefits of the '*o'* technology being smaller than that of the *'n'* technology. Formally, this can be summarized as specified in equation 3-1.

$$NB_{Net} = NB_n - NB_o \qquad 3\text{-}1$$

In modelling the farmers' utility or satisfaction levels that is derived from the use/adoption of TCB, the economic values or benefits associated with non-TCB cultivars and with the TCB are considered. A typical household seeks to maximize a multi-dimensional objective function, including food insecurity reduction, and increasing incomes. The additional benefits associated with TCB adoption was used as the basis for economic valuation process. A farmer receives additional benefits (NB_{Net}) from TCB adoption (NB_{TCB}) compared to non- TCB (NB_{NTCB}). Thus, the farmer moves from old technology (NB_{NTCB}) to new technology (NB_{TCB}). The indirect utility function U after the change is higher than the status quo. If the independent variable Y=1 then the farmer is an adopter of TCB. This implies that NB_{TCB} is higher than NB_{NTCB} as shown in equation 3-2**.**

$$NB_{TCB} > NB_{NTCB} \qquad 3\text{-}2$$

If the independent variable $Y=0$ then the farmer does not adopt the TCB and this implies that (equation 3-3);

$$NB_{TCB} \leq NB_{NTCB} \qquad 3\text{-}3$$

However, the farmer can be indifferent if the benefits from TCB and non-TCB are equal to (equation 3-4):

$$NB_{\mathrm{TCB}} = NB_{\mathrm{NTCB}} \qquad 3\text{-}4$$

The utility function can be assumed to be a function of farmer socioeconomic characteristics (Z_i), farm characteristics (C), Institutional characteristics (I), perceptions about the practice (P), and general farmer attitudes (E) including Technological characteristics (T). The utility function can be represented as specified in equations 3-5 to 3-7.

$$U_{TCB} = U_{TCB}\,(Z_i, X_i, C_{i,}, I_{i,}, P_{i,}, T_i, E_{i,}, \varepsilon_i) \qquad 3\text{-}5$$

$$U_{NTCB} = U_{NTCB}(Z_i, C_i, I_{i,}, P_{i,}, T_i, E_{i,}, \varepsilon_i) \qquad 3\text{-}6$$

$$U_{Net} = U_{TCB} - U_{NTCB} > 0 \qquad 3\text{-}7$$

where, U_{Net}, refers to the farmer's net utility associated with adoption of TCB, U_{TCB} utility associated with adoption of TCB, U_{NTCB} utility associated with adoption of non-TCB, Z_j is a vector of the farmer's socio-economic variables, Y_i is bio-physical factors and T_i are TCB technology attributes, and ε_i is the stochastic error term representing other unobserved utility components not in the model. Farmers opts to adopt TCB technology *if and only if* (*ioi*) the following condition holds) (equation 3-8).

$$U_{NET} = U_{TCB}(Z_i, C_i, I_{i,}, P_{i,}, T_i, E_{i,}, \varepsilon_i) > U_{NTCB}(Z_i, C_i, I_{i,}, P_{i,}, T_i, E_{i,}, \varepsilon_i) \quad 3\text{-}8$$

Since the random components of the preferences are not known with certainty, it is only possible to make probabilistic statements about expected outcomes. Thus, the decision by the farmer to adopt TCB is the probability that the farmer will be better off if this TCB variety is used. This is represented as given in equation 3-9.

$$\Pr ob(TCB) = \Pr ob(U_{TCB}(\int \text{Zi, Ci, I i, , P i, , Ti, E i, , } \varepsilon\iota > U_{NonTCB}(\text{Zi, Ci, I i, , P i, , Ti, E i, , } \varepsilon) \quad \forall i = 1, 2, 3 \ldots n \quad 3\text{-}9$$

These utility functions are generally expressed, therefore, the need to specify the utility function as additively separable in deterministic and stochastic preferences. Based on this argument, the function can be expressed as in equation 3-10.

$$U_{TCB}(Z_i, C_i, I_{i,}, P_{i,}, T_i, E_{i,}, \varepsilon_i) = U_{TCB}(Z_i, Y_i, T_i, E, \varepsilon_i) + \varepsilon_i \quad \forall i = 1, 2, 3 \ldots n \quad 3\text{-}10$$

It is assumed that the error term, ε_i, are independently and identically distributed with mean zero and unit standard deviations. The farmer maximizes the utility by growing/adopting TCB technology. The likelihood of the i^{th} farmer in adopting (Y_i) TCB or non-TCB can be influenced by a number of factors as given in the subsequent section can be modelled (equation 3-11).

$$Y_i = f(X_i, \varepsilon) \quad 3\text{-}11$$

This study employs the double-hurdle model with the assumption that, TCB adoption and intensity are two distinct or independent decisions. Cragg (1971) formulated double-hurdle model. The model assumes that farming household heads make two sequential decisions with regard to adoption and intensity of use of TCB technology. The decision and intensity of adoption of given technology can be made jointly or separately (Beshir, 2014; Gebremedhin & Swinton, 2003). The decision to adopt may precede the decision on the intensity of a technology, and the factors affecting each decision may be different. When the two decisions occur simultaneously and with the same explanatory variable, the double hurdle model is equivalent to a Tobit model (Humphreys, 2013; Young & Wilson, 1996). The Tobit model is used under the assumption that the two decisions are affected by the same set of factors (Greene, 2003).

However, it is hypothesized in this study that the decision to adopt TCB technology has to be made first because of the risk averse nature of smallholder farmers where they try the technology at small plots of land. The decision to adopt and intensify TCB technology may not be affected by the same variables. Thus, the use of the Tobit model cannot be justified under these assumptions.

An alternative modelling choice is the double-hurdle model which envisions a two-step process where a simple discrete ('adopt TCB or not TCB') decision is followed by a quantitative ('how many-TCB, which is the intensity') decision. In the double-hurdle model, both hurdles have equations associated with them, incorporating the effects of farmers' characteristics and circumstances. Such explanatory variables may appear in both equations or in either of one. A variable appearing in both equations may have opposite or same effects in the two equations.

Past literature shows that past studies have approached the farmers problem of choosing TCB technology or not using the univariate logistic or Tobit regression models (Nguthi, 2007). However, in this study we approach this by using a joint logit and Tobit (Double hurdle (DH) models because it has been hypothesized that factors that affect farmers' choice of an innovation like TCB are not necessarily be the same as those that affect the intensity of use.
The DH model, originally proposed by Cragg (1971) has been extensively applied in several studies (Akpan *et al.,* 2012; Martínez, 2004a; Moffatt, 2005; Odusina & Akinsulu, 2011; Ricker-Gilbert *et al.,* 2011). Pannell (1999) observes that if farmers were to adopt innovations like land conservation among others, they must first be aware that the technology exists and perceive as beneficial. Other papers have sought to separate the acquisition of the technology from the intensity of its use. The DH model has not been used in the area of adoption of TCB technologies. This gives information gap on TCB likelihood and intensity of adoption.

In analysing consumer spending on durable goods, Cragg (1971) devised the double hurdle model as an alternative to Tobin's model. This modelling approach involved a logit model to assess whether a consumer would purchase a certain good, followed by a regression model estimating level of expenditure on the good. Earlier models did not allow for differentiation in the parameters for a variable when its probability was 0 or not 0 (Fabiosa, 2005; Odusina & Akinsulu, 2011). In depth analysis of factors influencing farmers' decision making process/stage of likelihood of adoption and intensity may be different and estimating the whole process may be liable to error. The first stage of a double hurdle model is a probit/logit, while the second stage can be another probit/logit, an Ordinary least square regression (OLS), or any other form that fits the data.

Double hurdle models have proven useful in many types of microeconomic analysis since they were first adopted in 1971 (Jones, 1989; Legese *et al.,* 2009; Olwande *et al.,* 2009; Yen & Jones, 1997). In this model it is hypothesized that the decision of whether to adopt an innovation or not and how much to adopt may be joint or separate (Berhanu & Swinton, 2003; Olwande *et al.,* 2009; Teklewold *et al.,* 2006). When such decisions are associated with different equations, a double hurdle model becomes appropriate analytical tool/approach.

The double hurdle model generalizes the standard Tobit by introducing an additional hurdle, which must be passed for positive observations to be observed. Generalizations of the Tobit fall primarily under two categories depending upon their assumption of the source of zero observations. If it is expected that zero observations are due to misreporting or that the survey is too short to capture the expenditure, then an 'infrequency of purchase' model or 'p-Tobit' model should be employed. It has never been used for modelling in many studies (Ghadim *et al.,* 1999; Martey *et al.,* 2014; Minot *et al.,* 2000; Odusina & Akinsulu, 2011; Ricker-Gilbert *et al.,* 2011). Therefore, it was perceived that the double-hurdle approach captures the TCB adoption process best.

Technology adoption models assume that zero observations are either corner solutions or farmers who did not practice the technology (in our case, households that never planted TCB technology). In the double-hurdle model, coefficients in each hurdle are allowed to differ, and a change in a variable that is in both hurdles can affect the probability of adoption differently to the way it affects area allocated to the TCB technology. Following Cragg (1971 farmer i's adoption equation in growing of TCB can be expressed as shown in equations 3-12 and 3-12:

$d_i^* = \boldsymbol{z_i \alpha} + v_i$ 3-12

with d_i= 1 for adoption or 0 otherwise. Farmer *i's* adoption intensity equation can be expressed as given in equation 3-13.

$y_i^* = \boldsymbol{x_i \beta} + u_i$ 3-13

where y_i* represents the latent participation decision, and d_i* is a latent variable describing participation. $\boldsymbol{z_i}$ and $\boldsymbol{x_i}$ are vectors of exogenous variables, and $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are parameter vectors. The random errors u_i and v_i are normally distributed as N(0, 1) and N(0, σ^2), respectively. It also is assumed that u_i and v_i are independent.

In the standard Tobit model, a latent variable y_{i2}^* is assumed to represent a household's utility associated with consumption. It is assumed that observed technology adoption of technology equals desired adoption for positive values of y_{i2}^*, but equals zero if otherwise. In the double hurdle model a second latent variable, y_{i1}^* or hurdle, associated with the decision to adopt is added. Positive levels of adoption are only observed if both hurdles are positive. Formally, the model is as given in equations 3-14 to 3-17.

$y_{i1}^* = \alpha w_i' + v_i$ 3-14

$y_{i2}^* = \beta x_i' + u_i$ 3-15

$y_i = \beta x_i' + u_i$ If $y_{i1}^* > 0$ and $y_{i2}^* > 0$ 3-16

$y_i = 0$ Otherwise

$v_i \sim N(0, 1)$ and $u_i \sim N(0, \sigma^2)$ 3-17

where y_{i1}^* is the latent variable describing the household's decision to adopt TCB, y_{i2}^* is the latent variable describing the level of adoption, y_i is actual level of TCB adoption, w_i is a vector of variables explaining whether a household adopts TCB, x_i is a vector of variables explaining how much land the household allocates to TCB, and v_i and u_i are the error terms. The model was specified as given in equations 3-18 (Logit component) and 3-19. (Truncated Tobit component) which give rise to the DHM;

$$Y_{i1}^{*}=\beta_0+\beta_1 lnq10bprc\_a+\beta_2 lnhhage2+\beta_3 q1hhsex+\beta_4 q1hheduc+\beta_5 occ\_off+\beta_6 q1hhhmar+\beta_7 q1faml+\beta_8 Lnhec+\beta_9 q2labhr+\beta_{10} q8tcavl+\beta_{11} q2labfam+\beta_{12} Manuredm+\beta_{13} Fertbdum+\beta_{14} q33fdsht+\beta_{15} Lnbanprop+\beta_{16} Lnpcdy+\beta_{17} Dismeext+\beta_{13} Trandumm+\beta_{14} Bundumy+\beta_{15} Kisidumy \qquad 3\text{-}18$$

$$y_{12}^{*}=\beta_1+\beta lnq10bprc\_a+\beta_2 lnq1hhage+\beta_3 occ\_off+\beta_4 ocup\_far+\beta_5 q1faml+\beta_6 Lnhect+\beta_7 q2fert+\beta_8 q2labhr+\beta_9 q8tcavl+\beta_{10} lnq9dist2+\beta_{11} Manuredm+\beta_{12} Fertbdum+\beta_{13} Lnbanprop+\beta_{14} Dismeext+\beta_{15} Dismefam+\beta_{16} Aveindex+\beta_{17} Overinde+\beta_{18} Trandumm+\beta_{19} Bundumy+\beta_{20} Kisidumy \qquad 3\text{-}19$$

The model assumes that both participation and intensity equations are linear in their parameters. Consistent estimates of the Double-Hurdle model can be obtained by estimating (or maximizing) the likelihood equation given in equation 3.5 (Blundell & Meghir, 1987). This means that for farmers to plant at least a TCB banana, they have to overcome two hurdles namely: to decide to plant TCB or not (i.e. to be a potential TCB household), and then to decide how many stools to plant. As shown in equations 3.12 and 3.13, the estimation of the double-hurdle model requires specification of the error term structure. One of the key assumptions about the structure is that the errors ε and u are independently and normally distributed equation 3.15 (Moffatt, 2005; Reynold, 1990). Besides the normality assumption, the error term u_i has been assumed to be homoscedastic in nauture. It is recognized that, if these assumptions are not met it will lead to inconsistent and biased parameter estimation (Blundell & Meghir, 1987; Yen & Jones, 1997). In addition, and as observed by Blundell and Meghir (1987) among other authors, Independence assumption was assumed in Cragg's original model. Subsequently, the log-likelihood function (Blundell & Meghir, 1987) is written as given in equation 3-20.

$$L(\alpha,\beta,h,\gamma)=\prod_0\left[1-\Phi(w_i^{'}\alpha)\Phi\left(\frac{x_i^{'}\beta}{\sigma_i}\right)\right]\prod_1\left[(1+\gamma^2 y_i^2)^{-1/2}\Phi(w_i^{'}\alpha)\sigma_i^{-1}\phi\left(\frac{I(y_i)-x_i^{'}\beta}{\sigma_i}\right)\right] \qquad 3\text{-}20$$

where Φ and ϕ symbols are the probability density functions and cumulative distribution function for a standard normal random variable respectively. This model can be modified to allow for heteroscedasticity by specifying the variance of the errors as a function of a set of continuous variables as indicated by Aristei and Pieroni, (2008) as given in equation 3-21.

$$\sigma_i = \exp(z_i h) \tag{3-21}$$

where *zi* represents the continuous variables in x_i, which are the set of variables explaining the technology adoption decision. In addition, the exponential specification (*exp*) is chosen because it imposes the desirable property of the function that the standard deviation σ_i be strictly positive (Yen *et al.,* 1995). As indicated by Crowly *et al* (2012) to assess the impact of the regressors on the dependent variable, marginal effects (ME) can be calculated using the maximum likelihood results obtained from the double hurdle model. The ME assists in the interpretation of results. It has been shown that three different marginal effects can be calculated based on three different definitions of the expected value of the dependent variable y_i. There is the overall effect on the dependent variable, which is, the expected value of y_i (the dependent variable) for values of the explanatory variables, x_i (the independent variable). In the Tobit model and it is various generalisations. This is more commonly known as the unconditional expectation (or unconditional mean) of y_i. Mathematically it is written as; E $[y_i|x]$. The unconditional expectation function can be simplified, and decomposed into two parts; the conditional expectation, $E[y_i|x, yi > 0]$ which is the expected value of y_i for values of the explanatory variables, x, conditional of $y_i > 0$ and the probability of a positive value of y_i for values of the explanatory variables, x, $P[y_i > 0|x]$. Subsequently, after estimation of the DHM, one can also estimate the expected effect of explanatory variables on the probability and intensity of adopting TCB technology. First, we estimate the probability of TCB adoption as in equations 3-22.

$$\Pr(d^* > 0 \mid x_i) = \phi(x_i \alpha) \tag{3-22}$$

Then the conditional expected intensity of TCB adoption can then be estimated as in equation 3-23:

$$E(y_i \mid y_i > 0, z_i) = z\beta + \sigma\_X\_\lambda(z\beta / \sigma) \tag{3-23}$$

Finally, the unconditional expected quantity of TCB adoption can be estimated as:

$$E(y_i \mid x_i, z_i > 0, z_i) = \phi(x,\alpha\} z\beta + \sigma \_ X \_ \lambda(z\beta / \sigma) \qquad 3\text{-}24$$

The term $\lambda(z\beta/\sigma)$ in equations 3.24 and 3.25 is the inverse Mills ratio expressed as given in equation 3-25.

$$\lambda(z\beta / \sigma = \phi(\lambda(z\beta / \sigma) / \varphi(\lambda(z\beta / \sigma\left(\lambda(z\beta / \sigma\right) \qquad 3\text{-}25$$

The marginal effect of each independent variable can then be estimated following procedures outlined in Burke (2009). For a given observation, the marginal effect of an independent variable, x_j, around the probability that $y > 0$ is given in equation 3-26.

$$\partial(y > 0 \mid x) / \partial x = \phi(x\alpha) \qquad 3\text{-}26$$

The marginal effect of the same independent variable, x_j, on the expected value of y, given that $y > 0$ (conditional average partial effect – CAPE) is shown in equation 3-27.

$$\partial(y \mid > 0 \mid x) / \partial x = \phi(x\alpha) \qquad 3\text{-}27$$

The marginal effect of the independent variables on the unconditional expected value, (which we used in this study) of *y* (unconditional average partial effect [UAPE]) is shown in equation 3-28.

$$\lambda(z\beta / \sigma) = \phi(\lambda(z\beta / \sigma) / \varphi(\lambda(z\beta) / \sigma\left(\lambda(z\beta / \sigma\right) \qquad 3\text{-}28$$

If x_j is only determining the probability in the equation, then $\beta j = 0$, and the second term in equation drops out. Alternatively, if x_j is only in the second stage model, then $\alpha_j = 0$ and the first term drops out. Either way, the marginal effect will still be a function of parameters and explanatory variables in both stages of the regression (Burke, 2009). The standard errors for the elasticities may be derived using mathematical approximation (Crowley, 2012).

Unlike variable selection for the Tobit model, when all variables that are assumed to influence the intensity of TCB adoption, the choice of explanatory/independent variables for the participation and intensity of TCB adoption for the double-hurdle models is relatively complex. There is no clear theoretical guidance regarding equation specification and one option proposed is to include non-economic variables in the sample selection equation (Jones, 1989; Legese *et al.*, 2009; Olwande *et al.*, 2009; Yen & Jones, 1997).

In this study, the choice of variables for the first and second stage equations was done through a lengthy selection procedure. It involved trying out many different combinations of variables from the list of explanatory variables identified to be relevant in explaining the two-step decisions. Accordingly, a set of non-economic variables (i.e., demographic, household and location variables) were included in the selection equations of the Heckman and double-hurdle models as determinants of the decision to participate in TCB production. For the second-stage decision equations, economic and some of the non-economic variables are identified as determinants of the actual TCB acreage/quantities produced. This was followed by an empirical method of excluding those that are found to be insignificant. Therefore, the estimation was based on the final set of explanatory variables obtained after a series of estimations, starting from a specification that uses all the explanatory variables in both hurdles and gradually dropping the insignificant ones based on the LR tests. Some of these explanatory variables included; farmer characteristics (age, sex, education, family size, preferences, employment, occupation, agricultural training), farm characteristics (farm size, fertility levels, tenure system), institutional of input and output markets (input/output market access, price of plantlets, prices of banana fruits/bunches, credit, extension access), and technological characteristics (taste, storability, yield, cost).

In limited dependent variable models (like DHM), the effects of explanatory variables must be evaluated at the mean of the dependent variables. For the standard (homoscedastic and truncated normal) Tobit model, McDonald and Moffitt (1980) suggest decomposition of the unconditional mean of the dependent variable into the probability (of a positive observation) and the conditional mean. The effects of explanatory variables on these components can then be assessed (Yen & Jen, 1995).

The estimated coefficients in the double-hurdle model cannot be interpreted in the same way as in a linear regression model. To assess the impact of the regressors on the dependent variable y, it was necessary to analyse their marginal effects. This involved decomposing the unconditional mean into the effect on the probability of TCB adoption and the effect on the conditional level of number of TCB bananas weighted on arable land and differentiating these components with respect to each explanatory variable. The computation of unconditional mean of each variable is given in equation 3-29.

$$E[y \mid x_i] = P(y > 0)E(y_i \mid y_i > 0) \qquad 3\text{-}29$$

In the double hurdle model, the probability of adoption and the intensity of adoption conditional on participation (Martey *et al.,* 2014; Yen & Jones, 1997) is computed as given in equations 3-30 and 3-31.

$$P(y_i > 0) = \phi(w_i^{'} \alpha)\phi\left({x_i \beta}/{\sigma} \right) \qquad 3\text{-}30$$

$$E(y_i \mid y_i. > 0) = \phi\left({x_i \beta}/{\sigma} \right)^{-1} \int_0^{\infty} \left[{y_t}/{\sigma\sqrt{1+\theta^2 y_t^{\,2}}} \, \phi\left[{T(\theta y_t - x_i^{'} \beta}/{\sigma_t} \right] \right] dt$$

3-31

For the continuous explanatory variables, these marginal effects are used to calculate elasticities at the sample means. For the discrete or categorical variables, the marginal effects are used to calculate percentage changes in the dependent variable when the variable shifts from zero to one, *ceteris paribus*. The elasticities of the double-hurdle model are given by the derivation of the unconditional mean with respect to the explanatory variables. The unconditional mean of *y* consists of the probability of *y* being uncensored and the conditional mean of *y*. Average partial effect of x_i is given in Equation 3-32.

$$\frac{\beta_i}{N} \sum_{j=1}^{N} F(x_i \beta) \qquad 3\text{-}32$$

If x_i is continuous or is a discrete variable, then the average partial effect is the average of the discrete differences in the predicted probabilities. An average marginal effect is an estimate of a population averaged marginal effect, which is the mean marginal effect for a population. The distribution of the covariates must be representative to consistently estimate the population-averaged marginal effect. Mean partial effects and marginal effects at the mean are different quantities and can produce different estimates. The standard errors for the two marginal effects are estimated following the bootstrap procedures with 100 replications as recommended by Burke (2009).

Linear dependencies among regression variables bring the problem of separating out the effects of each independent variable on the dependent variable. Each independent variable may be nearly redundant in the sense that it can be predicted well using the others. This is the problem of multicollinearity. This problem may negatively affect the usefulness of a regression model. This leads to inappropriate conclusions drawn from incorrect parameter estimates and confidence intervals, particularly, small changes in the data values may lead to large changes in the estimates of the coefficients. The more the problem is more likely to arise the more independent variables there are in the model. It is thus important to test for multicollinearity and remedy it prior to regression modelling.

The use of the Double Hurdle model was based on the assumption that the TCB technology adoption decision and the intensity use were determined independently. In order to justify the use of the Double Hurdle model, a restriction test was carried out where the log likelihood values were obtained from a separate estimation of Tobit, logit and truncated regression models. Based on the values obtained, the following likelihood ratio statistic was computed using the formula given in equations 3-33 and 3-34.

$$LL = -2(LL_{Logit} + LL_{Truccatedr\ egresion} - LL_{Tobit}) \approx \chi_p^{2} \qquad 3\text{-}33$$

$$LL = -2(LL_{DHM} - LL_{Tobit}) \approx \chi_p^{2} \qquad 3\text{-}34$$

The test statistic has a chi-square (χ^2) distribution with degrees of freedom equal to the number of independent variables (including the intercept). The Tobit model is rejected in favour of the Double Hurdle model if *LL* exceeds the appropriate chi-square critical value (Burke, 2009). The Likelihood ratio test (Manyika *et al.*, 2012) showed that the double hurdle model statistically outperforms the Tobit model (equation 3- 35).

$$\Gamma = -2(\ln\_\ L_T - \ln\_\ L_{TR}) \approx \chi_k^{2} \qquad 3\text{-}35$$

The test hypothesis is written as (equation 3-36):

$$H_o = \lambda = \frac{\beta}{\sigma} \text{ and } H_o : \lambda \neq \frac{\beta}{\sigma} \qquad 3\text{-}36$$

Cragg's Model reduces to a Tobit Model if Z_i=X_i and $\gamma = \beta/\sigma$. Given the first condition, the second condition is a testable restriction (equation 3-34). Therefore, the Tobit Model was tested against Cragg's Model by estimating a logit, a Truncated Regression, and a Tobit Model with the same variable X_i and computing the following likelihood ratio statistic (equation 3-37).

$$\lambda = 2(Ln_{\log it} + Ln_{tobit\_truncated} - Ln_{tobit}) \qquad 3\text{-}37$$

where λ is a chi-square distribution with R degrees of freedom (R is the number of independent variables including a constant). The Tobit model was rejected in favour of Cragg's model if λ exceeds the appropriate chi-square critical value.

3.2.2 Definition of Variables and Working Hypothesis

From the theoretical and conceptual model above, several hypotheses can be derived that merit empirical examination. These hypotheses can be divided between factors that affect adoption and those that affect the degree and intensity of TCB adoption. It is important to first define what is meant by TCB adoption. For logit estimation, a household was regarded as an adopter of TCB if and only if he/she was found to have planted at least one TCB cultivar using original TCB plantlets. Those who used TCB suckers were treated as non-adopters. The dependent variable in this model was a binary choice variable, which was '1' if a household planted TCB and '0' if otherwise.

For the second hurdle, TCB adoption became continuous and the dependent variable was the number of TCB stools weighted on the arable land per household. It is recognized that there is no firm economic theory that dictates the choice of which explanatory variables to include in the double-hurdle model to explain technology adoption behaviour of farmers. A number of interrelated factors within the decision-making environment influence farmers to adopt agricultural technologies. For instance, Feder *et al.* (1984) and Adesina (1995) identified lack of credit, limited access to information, aversion to risk, inadequate farm size, insufficient human capital, tenure arrangements, inappropriate and inadequate farm equipment, supply of complimentary inputs and inappropriate transportation infrastructure as key constraints to rapid adoption of innovations in less developed countries. However, not all factors are equally important in different areas and for farmers with different socio-economic situations. The household characteristics deemed to influence TCB adoption in this study include household heads characteristics (age, gender, and education) and household size.

The dependent variable for the DHM analysis is dichotomous in nature in the first hurdle representing farmer's adoption of TCB and in the second hurdle the level of adoption, which in this case was the number of TCB stools planted weighted on the arable land under each household. This was to distinguish or discriminate between those who had adopted TCB and those who had not in the study area. The dependent variable took a value of “1” for adopters and “0” for non-adopters of TCB while in the second hurdle it was the number of TCB planted by each household.

Review of literatures on factors influencing farmers’ access to technologies, and adopting past research findings and the author's knowledge of the adoption studies area were used to establish working hypotheses of this study. It is recognized that, the observed adoption choice of an agricultural technology like TCB was hypothesized to be the end result of socio-economic characteristics of farmers and a complex set of inter-technology preference comparisons made by farmers. Several hypotheses were proposed on the decision factors that affected the probability and intensity of adoption of TCB varieties (Table 3-1). In this study, the following hypotheses are used with a priori sign expectations. Among number of factors, which have been related to farmers’ access to TCB, in this study, the following demographic, socio-economic, and institutional factors were hypothesized (working hypotheses) to a function of the dependent variable.

Age of the farm household head: The age of the household head was a continuous variable, defined as the farm household heads’ age at the time of interview measured in years. Farmer's age may negatively influence both the decision to adopt and extent of adoption of improved TCB cultivars. It was hypothesized that older farmers are more risk averse and less likely to be flexible than younger farmer counterparts and thus have a lesser likelihood of adopting new technologies like TCB.

Sex of Household head: Gender consideration in technology development and dissemination is critical. This variable was a dummy variable that assumed a value of “1” if the head of the household was male and “0” female. From earlier studies, there were two major factors, which restricted women’s access to new technologies more than men. These were related to women’s lack of control over production resources and social capital (e.g. land, attending meetings for new knowledge). With this background including the existing gender differences; male-headed households have mobility, participate in different meetings and had more exposure to information related to TCB; therefore, it was hypothesized that male-headed households had more access to use TCB than women.

Education level: This was expected to have both positive and negative effects. It was argued that increasing educational levels among the farmers (youths), reduces the probability of the them participating in agriculture (Agwu *et al.,* 2012). On the other side more education augments farmer's ability to receive, decode and understand information relevant to making innovative decisions. Thus, it is hypothesized that farmers with more education are more likely to adopt TCB or exit from TCB farming than farmers with less education. It was assumed that educated people were able to read and write. The four levels of education were 0=none, 1=primary, 2=secondary and 3=post-secondary. Of the four variables, only two entered the model to avoid the dummy variable trap. Farmers with higher education were assumed to read and write and were expected to have more exposure to the external information and therefore accumulate new knowledge on agricultural innovations like TCB. For example, the educated people had the ability to analyse costs and benefits of innovations. The more educated a household head was, the more likely to adopt a new technologies like TCB.

Family labour: Family size, a proxy to labour availability, may influence the adoption of new technologies positively as its availability reduces the labour constraints faced in banana production. The family size referred to the total number of family members/persons of the household who could work on the farm. This was measured in measured in family size. The larger the number of family labour, the more the labour force available for agricultural production purpose. In addition, the more the family labour force available, the lower was the demand for hired labour. This meant that no or low cost for hired labour for households with large family sizes. If demand for hired labour decreased due to availability of family labour the need for TCB decreased. Therefore, family labour was hypothesized to have negative impact on access to TCB.

Hired labour: Hired labour use, may influence the adoption of new technologies positively as its availability reduces the labour constraints faced in banana production. This variable was a dummy variable that assumed a value of ‘1’ if the household hired labour and ‘0’ if not hired Adoption of TCB was hypothesized to demand additional labour in planting, weeding, and harvesting including packaging for sale.

Marriage status of HoH: Marriage was hypothesized to influence the adoption of TCB positively or negatively.

Soil Fertility (Tolerance to poor soil): Fertility conditions of soils are hypothesized to be positively related to the probability and use intensity of TCB varieties. If farmers perceived that improved TCBs have larger bunch and finger and are as good as and palatable as the local varieties, rate and intensity of adoption are expected to be higher.

Off-farm income: The availability of off-farm income can affect the probability of adoption positively since it can increase the farmer's financial capacity to pay for costly inputs like buying TCB plantlets, fertilizer, manure and hiring labour.

Plantlet price: Since they are improved banana planting material, TCB are more expensive relative to banana suckers, cost of planting material was hypothesized to negatively influence the adoption of TCB technology. The price of TCB plantlets was perceived to enhance the likelihood and extend of adoption of TCB. The lower the price the higher the adoption and vice-versa.

TCB plantlet availability: In order to make use of technologies, farmers should be able to get planting material either in the formal or informal distribution systems. Thus, planting material availability is hypothesized to positively influence the adoption of TCB technology.

Extension contact: Agricultural extension may also enhance the efficiency of making adoption decisions. Based on the innovation-diffusion literature (Adesina and Forson 1995), it was hypothesized that extension visit is positively related to adoption by exposing farmers to new information and technical skills. In this study, this referred to the number of extension contacts with the respondent in a year. Farmers who had frequent contacts with extension agents were expected to have more information on TCB and therefore they would influence farm household's demand for new technologies like TCB.

Participation of households in TCB production: This was a dummy variable, which took a value '1' and '0'. Thus, '1' was for TCB participants and 0=otherwise (control group). If a household participated in TCB project, then it is expected to have good knowledge on the benefits of TCB. Therefore, it was expected that, this variable positively influenced farmers to expand the area under TCB.

Membership in farmer groups: This is a dummy variable, which took a value "1" for membership and "0" otherwise. Some of the households were members of merry-go-round group, which could provide multipurpose services. Therefore, it was hypothesized that farmers who are members of groups had more access to new technologies like TCB.

Experience in banana farming: This refers to the number of years the household head had been involved in banana farming. A farmer having more experience in banana farming had higher tendency towards using the new technologies and vice versa. Hence, this variable was assumed to have positive influence on the dependent variables.

Experience in farming: This referred to the number of years the household head had been involved in farming. A farmer who had more experience in farming had higher tendency towards using the TCB technology and vice versa. Hence, this variable was assumed to have positive influence on the dependent variables.

Farm size: This is the total land size owned by the household head. It was a continuous variable. The larger the farm sizes the more the likelihood of allocating more land and accompanying resources to TCB. The main hypothesis was that the farmer who cultivates larger size of land can utilize more capital and will demand for TCB and therefore he/she will be more accessed to TCB.

Livestock units: This referred to the total number of animals possessed by the household measured in tropical livestock unit (TLU). Livestock is considered as another asset, which could be liquidated as security against emergency. In addition, livestock manure could be used add nutrient to the banana fields. As the total number of animals in the household increases, the household would be less likely to go for new technology. This could be attributed to increased wealth and income base of farm households, which makes more money available in the households. Subsequently, this variable will have a negative influence on the dependent variable.

Attitudes towards TCB index: The other factor, which was perceived to influence the household's access to TCB, was their attitude on TCB pests and diseases tolerance. Many farmers, as can be expected, had perception of TCB being tolerant to pests and diseases. This is because TCB was assumed to be without any infections pest and insect damage. It was measured based on the farmer's positive or negative perception. This was rated on scale of 1-5. Therefore, it was expected that farmers who rated TCB as tolerant were likely to adopt TCB. The total score for a respondent was obtained by summing up the score obtained on each factor

Price of banana fruits: Price in the banana fruits in the market may also have a direct impact on the adoption behaviour of farmers. If farmers perceive that there will be attractive price for the banana fruits, the probability of adoption and proportion of banana area under the TCB cultivars would increase.

An index on TCB characteristics (Tolerance): If farmers perceive that a certain banana variety has better diseases, pests, and lodging tolerance, Better yield potential (finger size, bunch size) and storability, early maturity there will be higher probability for adoption of such banana varieties. This was a summation of all the attributes of TCB and since they were eight attributes the maximum score was 56.

Farmers access to credit (CREDIT): Smallholder farmers are expected to form a group (that can serve as collateral) to take credit from different credit sources. However, farmers perceived that it was difficult to access credit from these sources. It is a dummy variable, which takes a value "1" for those who received credit and "0" otherwise. Therefore, it was expected that farmers who are unable to get credit were not able to use formal credit.

Table 3-1: Variable description used in modelling

Variable	Definition
TREAT	Dummy farm type 1=Treated; 0=otherwise
LnINTENSITY	Log of number of stools per arable land in ha.
LNBANAREA	Log of banana area in ha.
Q1RESEX	Head of household sex 1=female
LnHHAGE^2	Log of age of head of household in year squared
Q1HHEDUC	Head of household education level
OCC_OFF	Occupation of HoH –off-farm income-dummy
OCC_PTY	Occupation of HoH-farming dummy
Q1HHHMAR	Marital status of HoH 1=married; 0=otherwise
Q1FAML	Family size-number
PEROD	Period grown banana in years
LnPERIODV2	Log of Period grown banana in years
LnHECT	Log of farm size in ha.
Owtitle	Land tenure 1=own with title;0=otherwise
Q2FERT	Fertility level of the farm
Q2LABHR	HH hired casual labour-dummy
Q2LABFAM	HH only uses family labour dummy
Q8TCAVL	Availability of TCB plantlets dummy
LnQ9DIST2	Distance to TCB plant source-km
LnQ10BPRC_A	Price of banana plantlets-KES
CREDIT	Used credit access to buy TCB dummy
MANUREDM	Used manure to plant dummy
FERTBDUM	Used inorganic fertilizer to plant dummy
LnBANPROP	Log of Proportion of banana revenue to total farm revenue (%)
AVEINDEX	TCB banana technology attributes index
Overinde	Overall perception index of banana benefits
lnPCDy	Per capita consumption expenditure in KES
trandumm	Trans Nzoia county dummy
bundumy	Bungoma county dummy
kisidumy	Kisii county dummy
wpokdumy	West Pokot county dummy
dismeext	Access to government extension dummy
dismefam	Farmer-to-farmer extension dummy
Dismeres	Inform. Source Research dummy

Source: Survey data 2012

Farmers' perception of TCB (FPPERF): Farmers were expected to have good knowledge on benefits of TCB. Therefore, it was expected that farmers who had positive information on TCB rated it high.

Physical distance of farmers from TCB sources (DINST): Farmers near the TCB plantlet materials had the advantage of reducing cost of transportation and were likely to acquire it cheaply than those who lived distant locations. Therefore, location in some regions was expected to increase access to use TCB.

Distance to markets: Access to good infrastructure can form a backbone for rural household commercialization. Farmers will grow perishable crops for markets only when they are assured that they can market them easily. "Distance to fertilizer shop" in the last cropping season was used to proxy access to market. Distance to the nearest road is as a proxy for the cost of taking the produce to the market. The hypothesis is that good infrastructure has a positive impact on the decision to engage in commercial horticulture production or a shift from subsistence TCB to a more commercial TCB orientation.

Off-farm employment: Rain-fed agriculture is highly seasonal, carries some inherent risk, and is characterized by lumpy cash flows. In the absence of well-developed markets coupled with lack of formal farm insurance, farmers will tend to self-insure. One form of self-insurance is engaging in off farm employment. In poor countries where agriculture marketing is in the initial stages of development, other sources of income like salaries and transfer payments are very significant. However, the way they affect agricultural commercialization is very ambiguous. The extra income could be used as an important source of income when it comes to investment in farm enterprises. In other cases, where the investment is labour intensive with close management required then they will be negatively correlated with commercial crops. Then non-farm income could play an important role in enterprises choices and investments decisions.

3.3 Results and discussions

3.3.1 General socio-economic characteristics of respondents

Shown in

Table 3-2 are the general socio-economic characteristics of the respondents. The average household size for TCB practicing farmers was 6.9, while that of non-practicing was 7.2, with an overall mean of 7.0 members. The average age of those farmers who had adopted of TCB technology was 51.2 years, while that of non-adopters was 51.6 years with an overall mean age of 51.4. The distance to the banana selling markets was significantly different ($p \leq 0.05$). It was 38km for those farmers who planted TCB, while for those who did not was 14.3 km with a pooled mean of 37.1 km. The period of planting banana for TCB adopters was 17.5 years, while that for non-adopters was 13.8 years with an overall mean of 23 years. The average number of years of farmers in planting TCB banana was about seven years.

Table 3-2: Descriptive statistics for sampled farmers and farm characteristics by participating and non-participating groups in TCB growing in Kenya

Variable		Full sample (n=330)		Adopters (n-65)		Non-participating (n=149)		Statistic sign.	
		Mean	SD	Mean	SD	Mean	SD	t-Stat	χ^2
Family size		7.0	2.6	6.9	2.4	7.2	2.8		…
Age of HoH-years		51.4	13.3	51.2	13.3	51.6	13.4		…
Distance source –km		37.1	9.2	38.3	9.8	14.3	20	***	…
Period planted bananas-yrs		23.0	13.9	17.5	14.3	13.8	12.4		…
Period planted TCB-yrs				6.5	5.2				…
Period in farming-yrs		20.9	13.3	20.3	14	21.6	12.3		…
Livestock ownership (TLU)		6.1	12.2	7.5	16	4.4	3.9		…
Farm size in ha		8.8	55.3	10.7	65.5	6.7	40.8		…
Arable area in ha.		7.1	4.6	8.7	59	5.3	3.6		…
No. of banana stools		84.1	34.1	126.7	45.5	35.5	52	**	…
No. of TCB banana stools		54.0	37.8	131.3	58.9	…	…		…
TCB performance index		24.1	16.4	26.9	18.2	20.8	13.3	***	…
Proportion Banana revenue-farm		49.3	42.8	54.4	41.7	43.0	39.53	**	…
Main occupation HoH %	Farming		73.1		73.6		72.7	…	
	Petty trade		8.6		5.2		12.7	…	**
	Off- farm		1.5		17.2		12.7	…	
Gender of HoH %	Male		8.5		45.2		37.2	…	
	Female		7.5		16		19.3	…	
Education HoH %	None		4.9		3.4		6.7	…	***
	Primary		47.4		44.6		50.7	…	
	Secondary		28.6		26.9		30.7	…	***
	Post-secondary		19.1		25.1		12	…	***
Land tenure %	1=with title		56.1		52.1		61.3	…	
	0=without		37.1		47.9		38.7	…	
Soil fertility %	low dummy		9.0		10.4		7.3	…	***
	medium dummy		68.7		67.6		70	…	***
	High dummy		22.3		22		27.7	…	***
Labour source %	Family		83.7		83.9		83.5	…	
	Hired		73.8		78.6		65.5	…	**

***≤0.01; **≤0.05; and *≤0.10 denote significance at the 1%, 5% and 10% levels respectively

Source: Survey data 2012.

The number of years in farming for head of household was 22.0 years for non-TCB adopters, while that for non-TCB adopters was 20.0 years. The overall mean of period in years of farming for respondents was 20.0 years. The average number of livestock for TCB adopters was 7.5, while that for non-adopters was 4.4. The average farm size was about 10.6 acres for TCB adopters, while that for non-adopters was 6.7 acres with an overall mean of about 8.8 acres. On the other hand, the average arable land for adopters was 8.7 acres, while that of non-adopters was 5.2 with an overall mean of 7.1 acres. The main occupation for adopters was 73.1% (farming) and 17.2% (off-farm), while for non-adopters was 72.2% (farming) and 12.7% (off-farm). The proportion of male headed respondents for adopters was 45%, while for non-adopters was 37%. Across all the groups majority of farmers had attained at least primary level of education. Most of the respondents (52% for adopters and 61% for non-adopters) had land title deeds. Most of the farmers perceived fertility level of farmers to be at least from medium to high (89% for adopters and 98% for non-adopters). The proportion of households using family labour was about 84% for both groups and those using hired labour was higher in TCB practicing farmers (79%) compared to those who were not planting TCB (66%).

3.3.2 Awareness and Adoption TCB Technology

Exposure or awareness can be defined as the degree at which the users know technologies. The rate of exposure is a critical variable explaining adoption. It is the proportion of farmers who have been exposed to the technology. Technology awareness among farmers is an essential step toward their adoption. There were several TCB information sources for awareness creation among farmers as shown in Figure 3-1. They included extension (35%), other farmers, radio/television (12%), Agricultural Society of Kenya (ASK) shows and research each 11% (Figure 3-10. Among the print media, the leaflets were reported by 4% of the respondents while the brochure was 1%. Universities, Non-Governmental Organizations (NGOs) and churches formed 5%. The low adoption rate of TCB low adoption is attributed to asymmetric information to farmers which leads to heterogeneous knowledge exposure (Kabunga *et al.*, 2011). From these results, the use of multiple dissemination pathways is key to effective dissemination of TCB technology among farmers and other stakeholders in the banana industry.

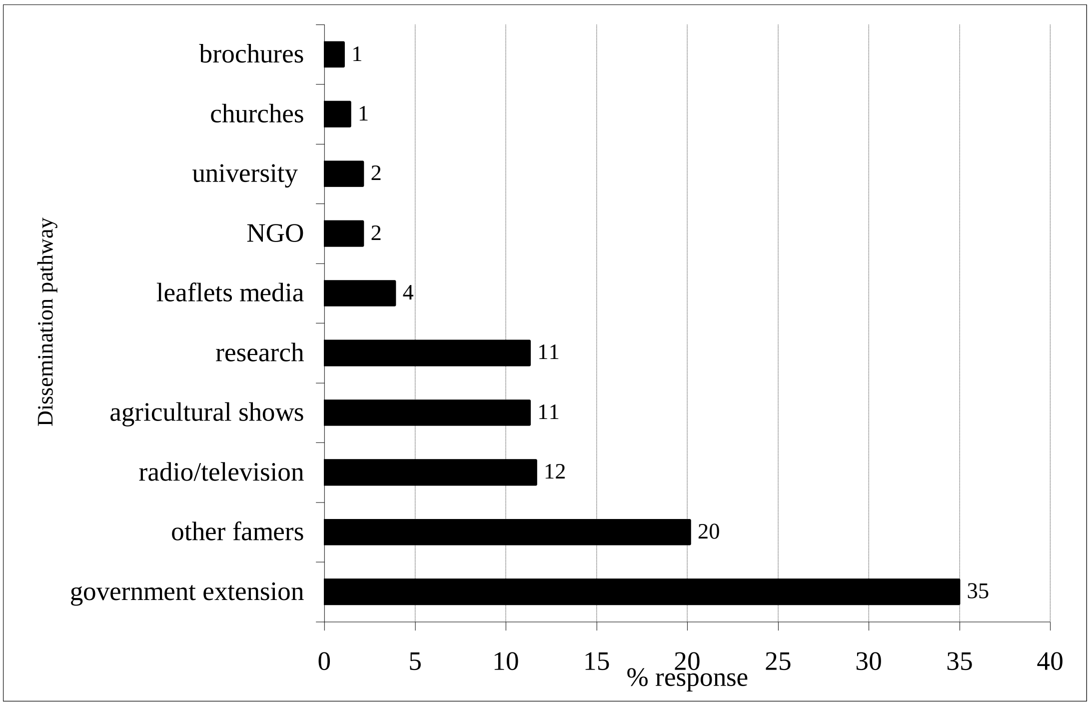

Figure 3-1: Dissemination pathways for TCB technology (n=243)

Source: Survey data 2012.

3.3.3 Adoption levels of banana agronomic practices

The adoption is defined as the degree of use of a new technology this case TCB cultivars. The rate of adoption is a critical variable in estimating the returns to research and development investments. It is the relative speed with which an innovation is accepted and utilized by members of a social system (Rogers, 1983). It is defined as the proportion of the area planted with modern varieties over the total area planted to the crop. There are a number of technological components in TCB, which include agronomic components, varieties/cultivars and post-harvest aspects.

Agronomic performance influence the performance of crop varieties (Kamira *et al.*, 2013; Tushemerehe *et al.*, 2001). Farmers were asked the agronomic management of banana orchards as shown in Table 3-3. Out of 330 respondents, 19.9% adopted the TCB technology by using plantlets and 79.1% did not (Table 3-3). The adoption of issue culture (TC) banana technology that was introduced in Kenya more than 10 years ago is relatively low. Similar observations were made by other authors (Kabunga *et al.*, 2011). Besides, 45.3% of the respondents indicated that TCB planting materials were easily available despite the distance and transportation costs that were relatively high. The sources of cash to buy TCB plantlets was 16.1%, 37.5% and 46.4% for credit, own savings and farm sales respectively. Additional finance from micro-credit to purchase complementary banana inputs was reported by Ouma *et al* (2013).

The proportion of farmers with banana spacing ranging from nine to sixteen square meters was 32.7% while 67.3% were outside this range as shown in Table 3-3. The plant density was variable in the study region and this could have significant effect on optimal banana yield. Similar results on variability in banana spacing (stool density) has been reported by several authors (Jassogne *et al.,* 2013.; Mpiira *et al.,* 2013.). The average mean banana spacing was 10 square meters. The proportion of farmers using basal and top-dress inorganic fertilizers was 15.7% and 8.3% respectively. About 29.2% of respondents were practicing earthing-up banana stools. The majority (60.1%) were propping bananas while 39.1% were not. About 44.1% of the farmers practiced disease control in their banana orchards. Despite that manure is becoming scarce and expensive a large proportion of farmers were using probably due to its long-term effect on banana yields. Mpira *et al* (2013) also reported similar results on enhanced use of manure in banana orchards in Uganda despite the limitations.

Table 3-3: Levels of adoption of banana agronomic technological components (n=330)

Technological component	%response
Planting material-use of TCB plantlets (yes=1)	19.9
Planting materials-use of Suckers (yes=1)	79.1
Availability of planting material (yes=1)	45.3
Sources of cash for purchase of plant materials-credit (yes=1)	16.1
Sources of cash for purchase of plant materials-own savings	37.5
Sources of cash for purchase of plant materials-farm sales	46.4
% farmers with Spacing 9-16m^2 (yes=3 to 4 by 3 to 4m^2)	32.7
Mean banana spacing meters square	10.1
% farmers using manure (yes=1)	88.3
% farmers using Inorganic basal fertilizer (yes=1)	15.7
% farmers using Inorganic top-dress fertilizer (yes=1)	8.3
% practicing earthing-up and making basins	29.2
Pruning of bananas –number of plants per stool	6.3
% response Earthling up of bananas (yes=1)	29.2
Propping of bananas (yes=1)	60.1
Pest control (yes=1)	33.9
% response with disease control (yes=1)	44.1

Source: Survey data 2012.

3.3.4 Adoption TCB cultivars

The rate of adoption is major impact indicator of any technology in applied research and extension agenda. It shows the degree of acceptance, diffusion, or rejection of new research outputs. The rate of adoption is defined as the share of farm area utilizing the new varieties (Bowman & Zilberman, 2013; Feder *et al.*, 1985; Gedikoglu *et al.*, 2011).

Farmers were asked the type of banana cultivars they were aware of and which ones they grew as shown in Table 3-4.

Table 3-4: Adoption levels of TCB cultivars in Western Kenya-2012

TCB cultivar	Type	% response n=66
TCB grand naine	Ripening	18.9
TCB *ng'ombe*	Cooking	11.7
TCB Chinese Cavendish	Ripening	11.4
TCB Uganda green	Cooking	10.6
TCB Williams hybrid	Ripening	10.4
TCB giant Cavendish	Ripening	9.3
TCB dwarf Cavendish	Ripening	6.7
TCB *nusu ng'ombe*	Cooking	6.7
TCB *sukari*	Ripening	4.1
TCB unknown	Ripening	4.1
TCB vallery	Ripening	1.8
TCB Kampala	Ripening	1.8
TCB Nigeria	Ripening	1.3
TCB solio	Cooking	0.8
TCB gold finger	Dual	0.3
Chi-square		230.5^{***}

***p≤0.01 denote significance at the 1%.

Source: Farm survey 2012.

There was a significant difference ($p \leq 0.001$) in the proportions of farmers growing different TCB cultivars. Out of 1000 banana cultivars developed and up-graded (CTA., 2013) a total fifteen TCB cultivars were identified and grown by farmers in western Kenya with proportion of farmers growing them ranging from less than 1% to 19% (Table 3-4). Out of about 15 TCB cultivars grown by farmers, 13 (86%) were ripening; one (7%) was dual and one (7%) was cooking. This implies that there was more demand for ripening banana than cooking. The highly adopted TCB variety was the *Grand naine* followed by *Ngombe* (12%) and Chinese Cavendish. The least adopted TCB cultivar was Gold finger followed by *solio* (<1%). In addition, it was observed that farmers grew several banana cultivars on the same piece of land probably due to disease epidemic. Farmers indicated that some varieties were more prone to some diseases than others. For example, they indicated that *Sukari* cultivars were more prone to diseases. It was indicated that diseases had wiped out some cultivars like the *sukari* from some farms in the western region. Further analysis showed that farmers also grew different cultivars for different uses; some were for beer or dessert and others for cooking. Therefore, the number of cultivars grown can be determined by the different uses/types and as a risk insurance against pests and diseases including uses. This demands that different banana types and cultivars through TC technology can be expanded to cater for this eventuality.

3.3.5 DHM Model Results

The first step of the analysis in estimating determinants of participation in TCB and their intensity of TCB adoption consisted of testing the Tobit model against the two-stage Cragg Tobit alternative model. As the Tobit model was nested in the double hurdle model formulation we can test the use of the double hurdle model against the Tobit using a Likelihood Ratio (Manyika *et al.*, 2012) test as (Humphreys, 2010). The results of the formal log-likelihood ratio test between the Tobit and the Cragg (1971) two-stage model confirm the superiority of the Cragg model and the rejection of the Tobit model; that is, the test statistic Γ=1138.01 exceeds the critical value of the $\chi 2$ distribution (p-value < 0.01) (Table 3-5). This suggested that the decision to participate in TCB and the intensity of TCB adoption might be governed by different processes. Tobit models show a limited power to tackle zeros generation and interpretation.

Table 3-5: Test statistics of double-hurdle model

Type of statistics	Logit	Truncated, Y(Y>0)
$\chi 2$	94	126
p-value	0.00***	0.00***
Log-L	-46	-177
AIC((-LOG-L+k)/N)	0.25	
$\chi 2$-Test Double Hurdle versus Tobit	$\Gamma = 64 > \chi 2 = 32$	

***≤0.01 denote significance at the 1%.

Source: Author's computation 2012.

Accordingly, explanatory variables were checked for problems of multicollinearity, endogeneity, and heteroscedasticity. Following Gujarati (1995), the problem of multicollinearity for continuous explanatory variables was investigated using variance inflation factor (VIF) and tolerance level, where each continuous explanatory variable was regressed on all the other continuous explanatory variables. The larger the value of VIF, the more likelihood of multicollinearity or collinear is the variable (X_j). As a rule of thumb, if the VIF of a variable exceeds 10 and R^2 exceeds 0.80 the variable was said to be highly collinear. The values of VIF were less than ten and hence no signals of multicollinearity problems.

To observe the degree of association between dummy explanatory variables contingency coefficients were computed. Contingency coefficient is a chi-square based measure of association where a value 0.75 or above indicates a stronger relationship between explanatory variables. This was also checked and less than 0.7.in order to take care of endogeneity an attempt was made to exclude dependent variable as explanatory variable. To avoid heteroscedasticity problem, robust standard error was estimated.

Presented in (Table 3-6), are results of the DHM of household participation in TCB. Tiers 1 and 2 are maximum likelihood coefficients of the determinants of adoption as shown in (Table 3-6). The log-likelihood of 95.24, (significant at 1% level), implies that the overall model is fitted and the explanatory variables used in the model were collectively able to explain the farmers' decision regarding the adoption of improved TCB in Kenya. Coefficients in the first hurdle indicate how a given decision variable affects the likelihood (probability) to adopt TCB. Those in the second hurdle indicate how decision variables influence the intensity of TCB adoption. Equally, the marginal effects (ME) of the logit and truncated Tobit components of the DH model show changes in the probability/intensity of adoption of TCB for additional unit increase in the independent or decision variables. Thus, the logit model proposed for the first stage of the double hurdle model to predict farmer's likelihood of adopting TCB Banana technology. Out of the 20 variables in the model, four were significant at $p \leq 0.10$ levels. The analysis showed that the variables that significantly influenced the probability of TCB adoption were; availability of TCB planting material (q8tcavl), proportion of banana income to the total farm income (lnbanprop), per capita household expenditure (Lnpcdy), and the location of the farmer in Kisii County (Kisidumy).

Accessibility of TCB plantlets to farmers was hypothesized to positively influence the likelihood and intensity of TCB adoption. The project was designed such that the planting material was to be availed to farmers either through formal or informal distribution systems (Mbogoh *et al.*, 2003; Njuguna *et al.*, 2010). The study findings revealed that this variable positively, and significantly ($p \leq 0.01$) influenced farmers to plant TCB. This implies that enhanced accessibility of TCB banana plantlets increases the likelihood and intensity of farmers adopting TCB technology. Households who were accessible to TCB plantlets tend to have 34% higher probability of adopting TCB technology compared to those who were not accessible. This implies that, as the family size of farming household head increases, the probability of adopting TCB increases too. This implies that the number of household members would enhance the adoption of TCB and this could be due to probably the manure effect on banana production. Akpinar *et al.*, (2012), have also reported positive effects of family size on technology use.

Table 3-6: Parameter estimates of the generalized double hurdle model of TCB adoption in Kenya

Variable	First Tier			Second Tier		
	Coef	ME	SE	Coef	ME	SE
lnq10bprc_a	-0.039	-0.004	0.0094	0.035	0.0341	0.0850
lnq1hhage	…	…	…	-0.190	-0.187	0.691
Lnhhage2	0.180	0.012	0.037	…	…	…
q1hhsex	0.580	0.056	0.045	…	…	…
q1hheduc	0.343	0.038	0.024	…	…	…
occ_off	0.064	0.007	0.056	2.235***	2.022	0.552
Ocup_far	…	…	…	1.625***	1.577	0.613
q1hhhmar	-0.244	-0.029	0.068	…	…	…
q1faml	-0.108	-0.012	0.008	0.180***	0.177	0.067
Lnhect	-0.030	-0.003	0.016	-0.314***	-0.309	0.113
q8tcavl	2.015***	0.336	0.088	0.717***	0.705	0.311
lnq9dist2	…	…	…	-0.183***	-0.180	0.097
q2labfam	-0.602	-0.078	0.096	-0.087	-0.085	0.378
Manuredm	0.930	0.079	0.042	2.141***	1.984	0.634
Fertbdum	0.349	0.042	0.072	0.651	0.635	0.569
q33fdsht	-0.139	-0.016	0.04	…	…	…
Lnbanprop	0.159**	0.018	0.009	0.017	0.017	0.092
Lnpcdy	0.197*	0.022	0.012			
Dismeext	0.065	0.007	0.037	1.018***	0.997	0.316
Dismefam	…	…	…	0.783	0.761	0.497
Aveindex	…	…	…	-0.016**	-0.016	0.008
Overinde	…	…	…	0.004	0.004	0.018
Trandumm	0.411	0.046	0.047	0.248	0.244	0.437
Bundumy	0.111	0.013	0.081	1.534**	1.435	0.649
Kisidumy	1.862*	0.132	0.044	-1.047	-1.021	1.565
Cons	-5.003			0.045		
Sigma				1.066		
Number of obs				66		
Prob > chi2				0.000		
Truncated regression						
Wald chi2				67.800		
Log likelihood				95.244		
No. of iterations				5		

Notes: Coef. means Coefficient; SE is standard error; and ME is the marginal effect.

***p ≤ 0.01; and **p ≤ 0.05 denote significance at the 1%, and 5% levels respectively;

Source: Survey data 2012.

The hypothesis was that the proportion of income received from banana (lnbanprop) significantly influence adoption of TCB. Revenue generated from banana (LnBANPROP) positively and significantly influenced likelihood and intensity of TCB adoption. One percentage increase the proportion of revenue generated from would increase the adoption of TCB by about 1.8%. This implied that income from banana encouraged farmers to grow and to adopt innovations like planting TCB. Thus, the higher the proportion of banana revenue at household level, the higher the adoption of TCB innovation. This could be because farmers were interested in income generating farm enterprises in order to meet household financial obligations. Similar studies have shown positive effect of income both on and off-farm on technology adoption (Abdoulaye *et al.,* 2014; Pandit *et al.,* 2014). Therefore, any efforts to enhance household income either from farm and off-farm activities including credit would enhance technology adoption like TCB.

Per capita household expenditure was positive and significant ($p \leq 0.10$) on the effect of likelihood to adopt TCB. One percentage increase in per capita household expenditure would increase the adoption of TCB technology by about 2.2%. This indicated that the higher the per capita household expenditure the higher the likelihood of farmers adopting TCB technology. This could be because income from TCB technology could be used in meeting household expenditure. Awotide *et al.,* (2012) showed adoption of improved varieties had a significant positive impact on total households' expenditure. This suggests that adoption of improved crop varieties significantly generate an improvement in farming household living standard. Hence, efforts should be intensified to ensure farmers have access to adequate quality improved TCB plantlets at the right time. All programs, strategies and policies that could lead to increase in improved rice adoption should be intensified in order to achieve the much desired poverty reduction and generate an improvement in rural farming households' welfare in western Kenya.

Furthermore, the variable on location of farmer in Kisii County (proxy for ecological location) was positive and significant ($p \leq 0.10$). Households in Kisii County tend to have 13.2% higher probability of adopting TCB innovation compared to those in Trans Nzoia County. This implies that farmers' location in Kisii County were more likely to participate in TCB technology production than those located in other areas. This is consistent with the fact that that these region (Kisii County) and its environment have a favourable banana production zone and also it is one the main banana growing regions in Kenya with relatively small-scale farms compared to west Pokot, Bungoma and Trans Nzoia counties. Farmers in Kisii region sell relatively large quantities of bananas in other regions of Kenya like Nairobi and Kisumu. Similar results have been reported by study undertaken in Uganda on determinants of farm-level adoption of cultural practices for banana Xanthomonas Wilt Control (Jogo *et al.*, 2013). In addition, agro-ecological zone has been shown to influence the performance of banana varieties (Kamira *et al.*, 2013). This trade orientation significantly contributes to farm revenue and probably the likelihood in TCB participation.

A number of factors hypothesized to influence TCB adoption as shown by other studies were not significant. This is contrary to expectations hypothesized to influence the likelihood of TCB adoption but were not significantly different from zero. The non-significant variables negatively related to the likelihood of TCB adoption were: use of family labour (q2labfam), hiring of labour (q2labhr), marital status (q1hhhmar), food security (q33fdsht), family size (q1faml), Bungoma county dummy (Bundumy), TCB plantlet price (lnq10bprc_a), and farm size (Lnhect). Those variables that were not significantly different from zero and positive related to the likelihood of TCB adoption were: age of HHH (lnhhage2), sex of HHH (q1hhsex), education level of HHH (q1hheduc), off-farm occupation of HHH (occ_off) use of manure (manuredm) and inorganic fertilizer use (Fertbdum). These results suggest that all these variables did not significantly change the likelihood of TCB adoption as compared to non-adopters. Surprisingly, the plantlets prices, which ranged from KES 70 to KES 180 per plantlet was negative and non-significant. The statistical insignificance of these variables leads one to conclude that probably price is not an issue in TCB adoption and the problem could be distribution and access of the planting materials.

This second stage model explored TCB intensification among farmers (Table 3-6). Because this analysis considers only TCB adopters, this model is conditional on the first stage model. This second stage model uses truncated Tobit regression method. The second dependent variable was the number of TCB stools weighted on the acreage under arable land per farmer. The number of stools was weighted on the arable land planted because some farmers did not have specific banana plots. For example, there was intercropping of banana stools with other crops. In some instances, there was single rows of banana planted with varying intra- and inter-plant spacing along the terraces. Subsequently, in this second model the farmers were pruned from 330 to 66 the TCB adopters only.

The adopters were those farmers who planted TCB banana using TCB plantlets. Those farmers who were non-adopters used TCB suckers in establishing banana orchards. The variables involved in this intensity adoption model were as shown in Table 3-6. The results showed that out of the 20 variables considered in this model, only 11 were significant ($p \leq 0.10$).

The variable off-farm employment as main occupation of farmers (occ_off), was positive and significant ($p \leq 0.01$). Farmers who had off-farm employment tend to have higher probability of intensifying adoption of TCB innovation compared to those who do not. Probably this implies that those farmers who were engaged in off-farm occupation were likely to intensify TCB production by expanding banana acreage using the superior TCB plantlets for enhanced production. This is in line with the working hypothesis. Thus, farmers are likely to have additional income, which enhances their purchasing power to buy TCB plantlets. This result concurs with studies undertaken on banana adoption in Kenya and other similar environments that off-farm income has a significant effect on TCB adoption (Langat *et al.*, 2013). This is also in line with economic theory that more income means higher purchasing power for consumers and producers.

The variable farming as main occupation of household heads (ocup_far) was positive and significant ($p \leq 0.05$). Farmers whose main occupation was farming tend to have higher probability of intensifying adoption TCB innovation compared to those whose main occupation was non-farming. This implies that those farmers, who were fully engaged in farming as the main occupation, intensified TCB banana adoption. Farmers inclined to farm-income generation activities, are likely to adopt he productivity enhancing TCB technology.

The variable family size (q1faml) was positive and significant ($p \leq 0.01$). The ME shows that the probability of TCB adoption increases by 17.7% for every member increase in the farming household head's family. This implies that, as the family size of farming household head increases, the probability of adopting TCB increases. This may also imply that banana producers in the study area primarily depended on family labour probably with limited hired labourers for farm activities.

Intensity of agricultural technology use in farming can be influenced by amount and availability labour as indicated by Beshir (2014) on technology intensification. The use of family members as main labour source on the farm (q1faml) was positive and significant, ($p \leq 0.01$). Households who use family members as main labour source tend to have 18% higher probability of intensifying adoption of TCB innovation compared to those who do not. This implies that, as the family size of farming household head increases, the intensity of adopting TCB increases. This may also imply that banana producers in the study area primarily depended on family labour probably with limited hired labourers for farm activities. Labour use is crucial in enhanced investment in TCB intensification and subsequently commercialisation. Langat *et al* (2014) also reported similar results that labour has a significant and positive effect on banana technology adoption.

The variable farm size (lnhect) was negative and significant ($p \leq 0.01$). One percentage increase in the farm size would decrease the adoption of TCB by about 30.9%. The higher the farm size the lower the TCB technology intensification. Farmers with smaller farm sizes were likely to intensify TCB technology, which is a source food and surplus for sell to meet household financial obligations. This in line with project and country's objectives in alleviating food security among the smallholder farmers in the region as documented by Mbogo *et al* (2002) and Wambugu (2004a).

The variable farm fertility level (q2fert) was negative and significant, ($p \leq 0.05$). Households whose farm fertility is low had about 51% lower probability of intensifying adoption of TCB innovation compared to those who whose farms had higher fertility. This implies that the lower the perceived fertility level the higher the TCB intensification and vice versa. Since banana generally require relatively high fertility levels, if the farms are relatively low in fertility levels then expansion of TCB is likely to be high but probably with relatively enhanced use of manure. This could be due to low yield of TCB technology under low fertility regimes. Reversing this trend requires optimal application of organic and inorganic fertilizers.

The variable availability of TCB plantlets to farmers (q8tcavl) was positive and significant, ($p \leq 0.05$). Farmers who are easily accessible to TCB plantlets have about 71% higher probability of intensifying adoption of TCB innovation compared to those who are not accessible. Enhanced access of farmers to TCB technology increased the intensification of TCB. This is in line with the a *priori* working hypothesis that availability of TCB plantlets increases the intensity of adoption because the demand for TCB planting material is progressively increasing against the low supply.

Market accessibility is important in technology adoption through input acquisition and product sales. The variable distance to banana market (lnq9dist2), was negative and significant, ($p \leq 0.10$). One percentage increase in distance to markets of TCB would decrease the probability of intensifying adoption of TCB by about 18.0%. The more the distances to the product market the less likelihood of TCB intensification or putting more land under the TCB. The longer the distance the more the transaction costs and the less the profit that accrue to the farmers. This could act as a disincentive to expand the TCB technology. This demanded the opening up of more banana markets and value addition technologies including packaging to increase farmers' profit margins. Similar observations have been made by other others and was attributed to high transaction costs (Adeoti *et al.,* 2014; Martey *et al.,* 2014).

Manure and mulch are considered the traditional techniques for maintaining banana plot productivity (Mpiira *et al.,* 2013.), The variable, use of manure in planting banana (manuredm), was positive and significant, ($p \leq 0.01$). Households who use manure to plant banana tend to have higher probability of intensifying adoption of TCB innovation compared to those who do not. This implies that farmers who applied manure were likely to intensify TCB banana technology. This is because manure was easily available and not expensive among farmers in the study region. The farmers were also aware that use of manure was part of the agronomic package of TCB technology for one to realize full benefits of the technology. Mugo *et al.* (2013) reported that farmers applied manure in banana orchards with majority of them applying at least two 20-kg tins per stool. The results also showed a significant effect of manure on banana production. This contributes to the enhanced use of manure among farmers who were expanding TCB technology.

Farmers' contact with extension agents is expected to have a positive effect on adoption based on innovation-diffusion theory (Sani *et al.,* 2014). Therefore, such contacts, which expose farmers to availability of information can be expected to stimulate adoption. Subsequently, a positive relationship is hypothesized between extension visits and the probability of adoption of a new technology. The variable contact with agricultural extension services (dismeext) was positive and significant, ($p \leq 0.05$). Households who are in contact with extension services tend to have higher probability of intensifying adoption of TCB innovation compared to those who are not in contact. Contacts with Government extension agents enhanced the intensification of the TCB technology. This is true given that government extension agents are represented upto sub-locational level. They also play a lead role in promoting the TCB technology in partnership with other agents along the banana value chain. Sani *et al* (2014) have reported similar results of positive impact of extension contact with farmers growing cowpea varieties. However, it is recognized that despite the mobile telephony not being significant it has been shown that perceived ease of its use, usefulness, relative advantage, compatibility, and attitude were found to be direct predictors of agricultural technology adoption behaviour (Okuboyejo & Adejo, 2012). The study provides evidence for the potential of mobile technology in agriculture

The variable average index technology attributes (aveindex) was negative and significant, ($p \leq 0.05$). One percentage increase in the average index of TCB technology increases the probability of intensifying adoption of TCB by about 1.6 %. This index measured the technological attributes of TCB technology. The likert scale rating ranged from one (1) to four (4) (1=very poor; 2=Poor; 3=Good; 4=Excellent). The technological attributes considered were; disease-tolerant, pest–tolerant, yield potential, sweetness, cookability, lodging, suckering ability, finger size, finger length, bunch size, feed for livestock, drought- tolerant, maturity period, ripening and storability. The index was computed by summing up the farmers' scores against each of the attributes. Similar results by Kalinda *et al* (2014) showed that farmers also seek specific varietal attributes, such as early maturity, yield potential, tolerance to water stress, pest/disease tolerance, better processing quality, and cob/grain size in adoption of maize varieties. According to Rogers's Diffusion of Innovations technological (DIT), attributes in terms of relative advantage, compatibility, complexity, triability, observability and possibly (Couros & Kesten, 2003; Kalinda *et al.,* 2014; Komolafe *et al.,* 2014; Rogers, 1995) including the cost implication may significantly influence adoption

The variable Bungoma county dummy (bundumy) was positive and significant ($p \leq 0.05$). Households in Bungoma County tend to have higher probability of intensifying adoption of TCB technology compared to those in Trans Nzoia County. This implied that being a farmer in Bungoma enhanced the TCB technology intensification. This could be due to low levels of banana acreage in the region against the competing crops like sugarcane.

3.3.6 Challenges of growing TCB and management of orchards

Tushemerehe *et al* (2001) spelled out step-by-step agronomic management of banana orchards. Farmers who were growing TCB experienced challenges in management of TCB orchards. There were several challenges expressed by TCB practitioners in western Kenya as shown in

Figure 3-2. They included; banana vulnerability to drought stress (28%), high inputs costs required, susceptible to pest/diseases (12%), lack banana planting material (12%), lack of enough information, lack of markets (6%), low yields (5%), susceptible to lodging (4.%), no banana intercropping (2%), short economic life (2%), poor suckering ability1%) and low fruit shelf life (1%).

Vulnerability of TCB to drought (TCB required a lot of water), high input costs (buying of TCB plantlets, fertilizers/manure), lack of planting materials, low yields, susceptibility to lodging, no intercropping with other crops, short economic life, poor suckering ability and low shelf life of the fruits. These challenges are a disincentive to expand TCB banana orchards.

TCB vulnerability to drought was one of the challenges experienced by farmers. TCB cultivars like any other improved high yielding crop cultivars require more water in order to realize potential yields. Increased and sustained banana yield demands provision of enough water for growth. Out of 331 respondents, none of the farmers reported any watering of the banana orchards. Therefore, there is need to encourage farmers to irrigate the banana orchards when there is signs of water stress. Water stress leads to low yields.

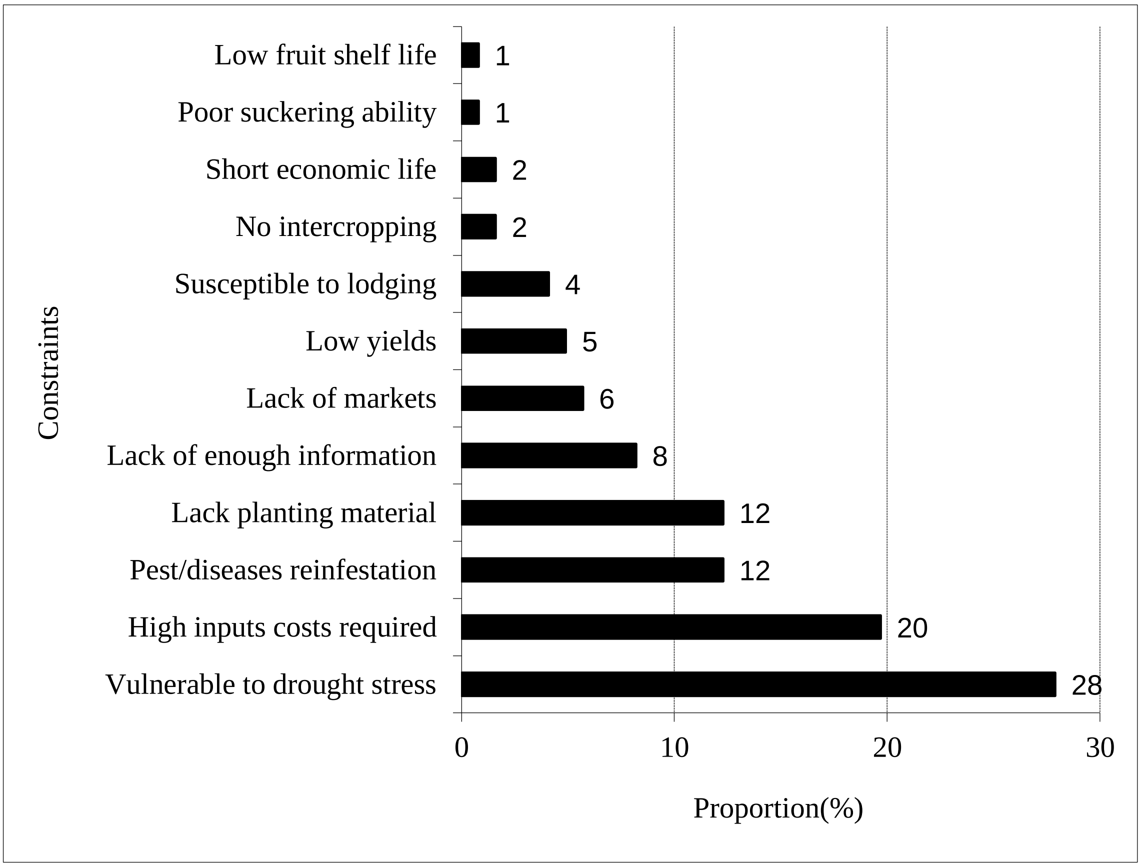

Figure 3-2: Constraints / challenges of growing and managing TCB.
Source: Survey data, 2012.

High inputs required are some of the limiting factor revealed by farmers. This is due to purchase of TCB plantlets, purchase of fertilizer/manures, probably labour digging holes, and orchard maintenance. Though it is recommended to intercrop banana with other crops in areas where rainfall is high without much loss in banana production there are limitations. Some farmers indicated that they faced challenges when intercropping banana with other crops. The negative intercropping effects were; crop shading and low crop yields. This could be attributed poor spacing of each crop and low fertilization/manuring. It is recommended that intercropping can be done in newly planted orchards fields, has some advantage in that the land gives a return before the banana crop is ready for harvest. It is best not to inter-crop green manures such as tephrosia, mucuna, and canavalia in banana. Green manures and other inappropriate intercrops compete with banana for nutrients and water, which may lead to soil exhaustion and plant health problems.

3.4 Conclusions

The objective in this chapter was to assess adoption and intensity of adoption of inorganic fertilizer in selected counties of West Kenya. The research question was 'what were determinants of TCB adoption?' In order to conduct this, a double hurdle model was adapted. The first stage is adoption of TCB technology and the second stage of the model is a measure intensity of adoption. There were 20 variables used in the logit model, four of which were significant at the 10% level. The significant variables were availability of TCB planting material (q8tcavl), proportion of banana income to the total farm income (lnbanprop), per capita household expenditure (Lnpcdy), and the location of the farmer in Kisii County (Kisidumy). These variables are important in terms of targeting technologies.

The second stage model considered only TCB adopters, and the model is conditional on the first stage model. This second stage model uses Truncated Tobit model. The number of TCB weighted on arable land was used as the dependent variable. Findings from the second stage regression model estimating the intensity of TCB adoption revealed that 11 variables that significantly ($p \leq 0.10$) influences TCB adoption intensity. They included while those that significantly influenced the intensity of TCB adoption were; occupation of farmers, occupation of farmers, family size, labour source, farm acreage, farm fertility status, availability/access of TCB plantlets to farmers, distance to banana market, use of manure in planting bananas, agricultural extension services, average index technology attributes, Bungoma county (bundumy) was positive (sugarcane zone). Technology developers and disseminators need to utilize these factors to further fine tune the targeting of intervention strategies for enhanced adoption and impact.

Therefore, the results of the study suggest that adoption and intensity of use of TCB can be enhanced by taking cognizance of these variables in order to meet the priority needs of farmers who were final beneficiaries of the technology. The key benefits include alleviation of food shortage problem and low farm incomes in the country. Opening up more TCB multiplication centres and widening the technology to other banana cultivars would enhance the impact of the technology.

CHAPTER FOUR

4 FARMER ATTITUDES AND PREFERENCES FOR TISSUE CULTURE BANANA CULTIVARS

4.1 Introduction

Banana plays a significant role in Kenyan as food security and income generating crop. Banana fruits are an important component of healthy human diet. A healthy diet consists of eating a variety of foods from five food groups but in the correct proportions. These include; foods containing starch, fruit and vegetables, milk and dairy food, foods containing protein, and that containing fats and sugars. Bananas fall in the fruit and vegetable group as well as the food group, which mostly contain starch. Banana provides more than 25% of the carbohydrates and 10% of the calorie intake for approximately 80% people in the producing regions. Banana has become a key source of revenue as they are not only traded within countries but also exported. In spite of the enormous benefits of Banana, studies have shown that production, consumption of banana in Kenya is low though progressively increasing compared to the recommended daily intake (Hall *et al*, 2009).

Banana enterprise is a potential food and poverty alleviation for smallholder farmers in not only in Kenya but also in other sub-Saharan Africa countries and the Latin America due to its low productivity and low input applications. In addition, apart from being a food security crop, banana is a highly sustainable crop, with a relatively long plantation life and stable yields. The banana crop requires low external input and therefore, the cost of production is low. In addition, the crop does not require any storage arrangement as it yields throughout the year. In addition, the annual crops like cereals require storage facilities in order to enhance their longevity.

Many banana cultivars have been released along the banana value chain (Abodi *et al.*, 2007; Edmeades *et al.*, 2004). However, not all these TCB cultivars have been taken up by farmers in the country. According to Abodi *et al.*, (2007), the demand for specific innovations could be attributed to specific banana cultivar traits. Therefore, the choice of banana cultivars for planting material could have an implication on adoption and consumption. The adoption and non-adoption of specific TCB cultivars could be attributed to specific traits of each cultivar. No study has been done in Kenya to assess the banana cultivar preferences among farmers. This study contributes to filling this information gap. This information will assist in identifying suitable local host cultivars with preferred traits for improvement for enhanced adoption.

In Kenya and in most other East African Countries, the annual per capita consumption of banana is ranges from 28-155 kg, which is one of the highest in the world (IITA., undated.,). Despite its food security role throughout the year, the national average yield of banana is about 4.5-14.6t/ha (Muchui *et al.,* 2013; Muendo & Tschirley, 2004) with a potential of increasing to over 20-40 t/ha through increased use of improved varieties like TCB and good management practices (FAO., 2012).

Consequently, stakeholders along the banana value chains have focused on the development and diffusion of TCB cultivars through multiple dissemination pathways. The TCB cultivars are characterised by cultivar-specific traits such as early maturity, high yielding, pest and diseases free, sweetness and nutritional contents. The TCB cultivar traits or attributes are the performance characteristics for both the production (agronomic) capacity of the crop and the consumption attributes of the product (fruits).

According to Edmeades *et al.,* (2004), despite these efforts, limited adoption of the improved banana variety with specific traits persists. Although banana varieties are high yielding, they may not be attractive to farmers unless they possess some other banana-specific traits that farmers consider important. Studies on farmers' crop variety choices consider crop as a bundle of multiple characteristics (Acheampong, 2015). Specifically for TCB, such bundle of traits may include production characteristics such as disease and pest resistance, high yielding, early maturity and adaptability to harsh environments (Muchui *et al.,* 2013); consumption characteristics such as taste and colour and subjective importance farmers place on planting material.

Smale *et al.* (2004) revealed that farmers choose crop varieties based on a set of attributes that best responds to production constraints, assures consumption preferences, and satisfies specific market requirements. These crop-specific attributes hypothesis have been highlighted in some adoption studies (Acheampong, 2015; Ghimire *et al.,* 2015; Longley *et al.,* 2012; Smale *et al.,* 1998; Wanyonyi *et al.,* 2008). Farmers' adoption decisions are therefore not only driven by profit maximisation but rather on complex processes that are affected by several socio-economic and psychological variables (Borges *et al.,* 2015). Farmers grow crops that satisfy their concerns and that once there is harmony between these concerns and variety attributes, the result is varietal preference and land allocation decision (Wale and Mburu, 2006). Although some studies have explored the determinants of adoption of banana varieties by farmers in Kenya (Langat *et al.,* 2013; Mwangi & Kariuki, 2015) and other developing countries (Jogo *et al.,* 2013; Pedersen, 2012) the preferences of farmers for TCB variety traits have not received much attention.

Consumer, knowledge, attitudes tastes and preferences towards banana are important for effective development, and dissemination of innovations among target communities (Mugisha *et al.,* 2010; Sporledera *et al.,* 2014). Past research on banana gave emphasis on agronomic aspects with limited consideration on consumer and producer tastes and preferences including other marketing components (Muendo *et al.*, 2004). In Kenya, there is limited information on consumer and producer preferences of improved banana cultivars. In this study a household is treated as a consuming and producing unit (non-separable) given that the production and consumption decision may not be separable (Sadoulet & de Janry, 1995). Household decisions are said to be non-separable if the household's consumption decisions and production decisions are interdependent and non-recursive (Aragie & McDonald, 2014).

It was hypothesized that household's banana preferences as a producing and consuming unit may be influenced by technological, personal, farm, and institutional characteristics. These would subsequently influence marketability, and consumption patterns of the products. Preferences are symbolized by the perceptions, taste, and attitudes that beneficiaries hold toward banana. As markets emerge, producers and consumers are faced with more choices of what to produce and how to produce and what to consume. For successful technology adoption, a new banana crop or cultivar should offer a combination of good fruits and market demand by meeting the consumer needs. This is because consumer preferences could orientate the production, distribution, and commercialization of banana fruits.

Although some studies have explored the determinants of adoption of improved banana varieties by farmers in Kenya (Langat *et al.,* 2013; Nguthi, 2007) and other developing countries (Conley and Udry, 2002; Mather *et al*., 2003; Faturoti *et al*., 2006; Badal *et al*., 2007) the preferences of farmers for banana variety traits have not received much attention. Subsequently, limited information exists on these aspects in western Kenya, which are critical in adoption, production, and marketing of banana products. This research was designed to bridge this information gap. The purpose of this study was to examine empirically farmers' knowledge, perceptions, and preferences of TC banana. The objective of this study was to analyse farmers' preferences to TCB cultivars; investigate aspects of TCB banana cultivar attributes that are used in evaluating and differentiating between cultivars; and assess the potential challenges for production and consumption of the product. Therefore, this study expands the literature on crop variety traits in Africa by employing choice experiment to elicit farmers' preferences for TCB traits. The present study contributes to the empirical literature on farmer tastes and preferences by assuming a non-random fixed-cost coefficient whilst other attributes are allowed to vary. This study contributes to the development and up-scaling desirable banana cultivars including TCB in Kenya.

4.2 Methodology

5.2.1 Theoretical framework

In order to assess the factors influencing farmer preferences of tissue culture banana cultivars, two complementary methods were utilized in this section. They included descriptive statistics, and the econometric analytical frameworks. The descriptive included mean, variance, standard deviation, standard error, and proportions while the econometric method included the multinomial nested logit model (MNN). The nested logit model was used in order to reduce the problem of independence of irrelevant alternatives (IIA) that results from estimating a non-nested multinomial logit model. An example of IIA in this application is that the log odds of using cooking TCB verses TCB ripening would not be affected by the presence of non-TCB banana cultivars.

A number of researchers have explored various factors affecting farmers' and consumers' acceptance and their attitudes towards types of food products and services using different analytical models (Dhamotharan & Selvaraj, 2013; Ekesa *et al.,* 2012; Kikulwe *et al.,* 2010; Kim, 2010; Matteazzi *et al.*, 2013; Onyango, 2004; Wanyonyi *et al.,* 2008). The models utilized by these authors were; nested logit, nested probit, multinomial logit, multinomial probit, ordinary least regression model, conjoint, multinomial nested and nested multinomial probit models (Louviere *et al.*, 2000; Merino-Castelló, 2003). For instance, Onyango *et al*, measured consumer preferences for genetically modified foods, not yet available in the marketplace, using stated preference techniques while Wanyonyi *et al* (2008) analysed farmer preferences of newly released maize varieties based on a five-scale likert rating using descriptive statistics in North West Kenya.

The probability of a household choosing different types, kinds, and cultivars of banana is a polychotomous choice between a series of alternatives (dependent variable). In this study, farmers were assumed to first choose which type of banana to grow (i.e. whether TCB and non-TCB), after which they decide whether to plant cooking or ripening types. Lastly, they pick on which type of banana varieties to plant (Figure 4-1).

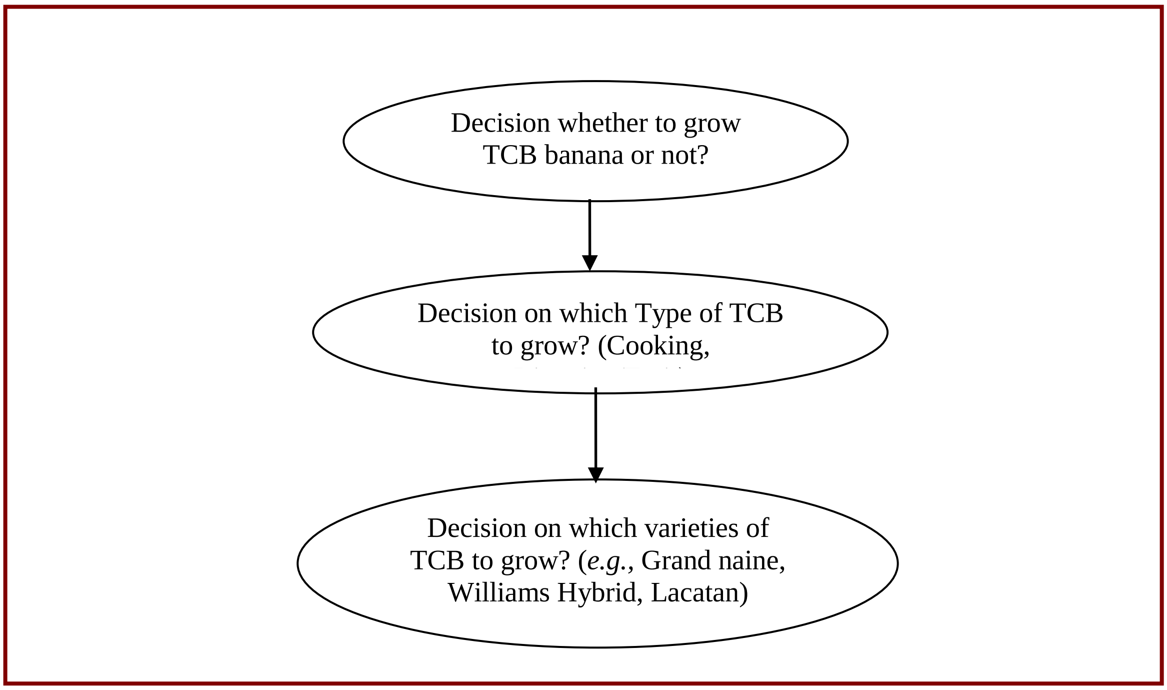

Figure 4-1: Decision Tree for Analysing TCB and NTCB variety preferences

We assume that each producer or household has a utility function *U*, that depends on the banana technology option selected. A complete model of households' technology decision posits that the utility a household derives from a series of successful choices banana technology can be at three levels. We visualize a household who selected an alternative that maximizes utility. Choice of a given banana cultivar gives the farmer a certain level of utility. The choice behaviour can be modelled using random model, which treats utility as a random variable, which has two components: the measurable component and the error component. The utility function is written as shown in Equations 4-1 to 4-4:

$$U_{ki} = V_{ki} + \varepsilon_{ki} \qquad 4\text{-}1$$

$$U_{TYPE} = V_{TYPE} + \varepsilon_{ai} \qquad 4\text{-}2$$

$$U_{KIND} = V_{TYP} + V_{KIND} + \varepsilon_{TYP} + \varepsilon_{KIND} \qquad 4\text{-}3$$

$$U_{VAR} = V_{VAR} + V_{TYP} + V_{KIND} + \varepsilon_{TYP} + \varepsilon_{KIND} + \varepsilon_{VAR} \qquad 4\text{-}4$$

where *Vi* is the systematic (observed) component and ε is the error (unobserved component) component. A three-level nested multinomial logit was obtained by partitioning the choice set into nests and then the nests into sub-nests as shown in (Figure 4-2).

Figure 4-2, shows that total 330 individuals in the whole sample. They are nested within two clusters (Level-1), the TCB growers, and non-TCB growers. These clusters are nested into two groups of cooking, and ripening bananas - defined as Level-2. Finally, the cooking and ripening are aggregated into 13 banana cultivars, which constitute Level-3. The information in the lower levels is aggregated in the upper level giving the hierarchical structure model.

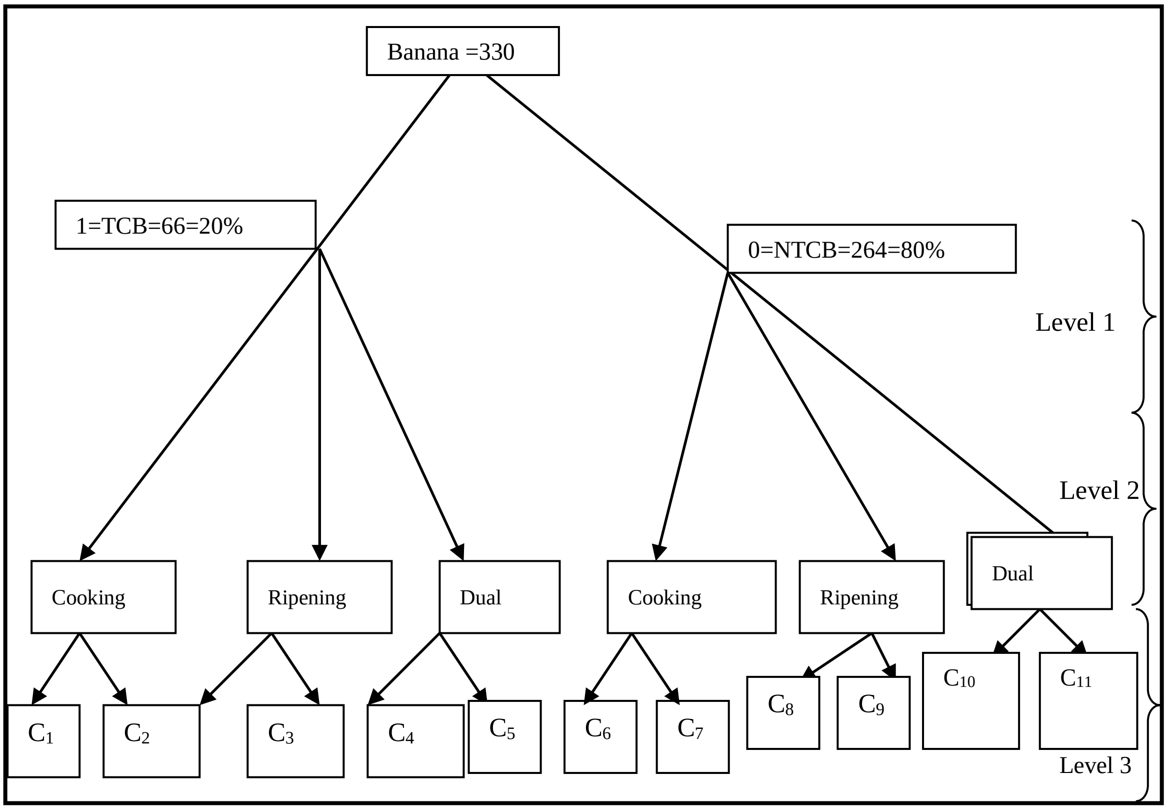

Figure 4-2: Three Tiered Choice (tree) structure of TC decision-making process for NML model

Suppose that there are *k* alternatives from which to choose and can be divided into M sub-groups such that the choice set can be written as $n_1 \ldots n_m$; $m_1 \ldots m_i$; m = 1…, *M* and $\sum_m n_m = N$. This choice-set partitioning produces a nested structure and logically, one may think of the choice process as that of choosing among M choice sets and then making the specific choice with the chosen set. The determinants of TCB cultivar preferences are the primary goal in this study. The model assumes that if farmer *'i'* decides to choose alternatives from TCB cultivar n_i from TCB types m_i then the utility of this farmer is given as given in equations 4.5 to 4.11.

$$U_i(TCB.Type...m = \beta_{zi}X + \varepsilon_{type\_i} \ \forall \ m = 1...., m. \quad 4\text{-}5$$

$$U_i(TCB.Kind\_cok\_rip...n = \alpha X_i + \varepsilon_{kindype\_i} \ \forall \ m = 1....., m \quad 4\text{-}6$$

$$U_i(TCB.KVAR...n = \gamma X_i + \varepsilon_{KIND\_TYPE\_i} \ \forall \ n = 1....., n. \quad 4\text{-}7$$

$$P_{nkm} = P_{n|m}P_m \quad 4\text{-}8$$

$$P_{n|m} = \frac{\exp(\beta X_j \mid m)}{\sum_{n_m} \exp(\beta X_j \mid m)} \quad 4\text{-}9$$

$$P_m = \frac{\exp(\gamma z_m + \tau_m I)}{\sum_m \exp(\gamma z_m + \tau_m I_m)} \quad 4\text{-}10$$

$$I_n = I_n \sum_{n_m} \exp(\beta X_j \mid m) \quad 4\text{-}11$$

where, utility U_i is derived by farmer '*i*', P_n is the unconditional (marginal choice) probability of choice *n*; $P_{n|m}$ is the conditional probability of choosing alterative *n* given that a household selected the choice-set *m*, P_m is the probability of selecting the choice-set *m*, $X_{n|m}$ are attributes of the TCB cultivar choices and other personal, economic and institutional factors, $\mathbf{z}_m$ are attributes of the TCB type choice sets, I_m is an inclusive value (log sum= $\sum_{m=1}^{3} \exp \beta z_{nm}$) of utility derived from utility of having all the choice-sets *m*, β and γ are vectors of coefficients to be estimated, and τ_m is the coefficient of the inclusive value of choice-set *m*. If we restrict value parameters to be one, then the nested logit model will be similar to multinomial logit model. The nested logit model is consistent with random utility maximization if the conditions' inclusive value parameter (τ) is bounded between zero and one. The model has been found to be extremely flexible and is widely used for modelling individual choice.

Explanatory factors are expected to determine the alternatives chosen by farmers/consumers at various nests. The explanatory variables that were entered into the model included farmer characteristics (age, sex, education, family size, employment, occupation, agricultural training), farm characteristics (farm size, fertility levels, land tenure system), institutional of input & output markets (input/output market access, price of plantlets, prices of banana fruits, credit, and extension access). Other variables included: total Livestock units (TLU) and technological characteristics or performance (insect pest tolerance, disease tolerance, yield potential, sweetness, cook-ability, lodging, suckering ability, finger size, finger length, bunch size, feed potential, drought tolerance, maturity period, ripening quality, Storability, and profits/benefits). These factors were rated likert scale rating of one to five). Summative likert scale (which was a proxy measurement for TCB performance index) was derived by adding up all the ratings/scores for specific attributes.

The dependent variables for nested multinomial logit model were cooking TCB (Gold finger, Solio, Uganda green, *Nusu Ng'ombe*, and *Ng'ombe*), ripening TCB (Grand naine, Williams hybrid, Giant Cavendish, Dwarf Cavendish, Chinese Cavendish, Lacatan, Vallery, and dual purpose (Gold finger). In tier two, there were cooking, ripening, and dual purpose option. However, the dual-purpose type was grouped together with cooking types for this study because it was only one cultivar. In the first tier, there were two alternatives namely TCB and non-TCB option. The TCB cultivars for tier one were in repeated net structures as shown in Figure 4-2.

4.3 Results and discussions

4.3.1 Farmer TCB cultivar awareness

Out of 331 farmers sampled, 57% preferred local cultivars while about 43% preferred TCB banana. The preference to TCB cultivars was due to early maturity and free of diseases and pests. As shown in Figure 4-3, among the TCB cultivars, *grand naine* was widely preferred by farmers followed by TCB *ng'ombe*, TCB Chinese Cavendish and TCB giant Cavendish. The least preferred cultivars were Gold finger and *solio*, which is a dual cultivar. Probably, the later cultivars were least preferred because of specific technological attributes like yield, taste, and cookability. Other studies that support these findings on banana cultivar preferences were by Dimelu *et al* (2012) who revealed that some of the reasons for banana cultivar preference were technological attributes (like early maturity, free of pests and diseases, taste and yield) and plethora of other factors which include social value and market demand by consumers. These may demand to conduct sensory evaluation of these cultivars to ascertain detailed consumer preferences.

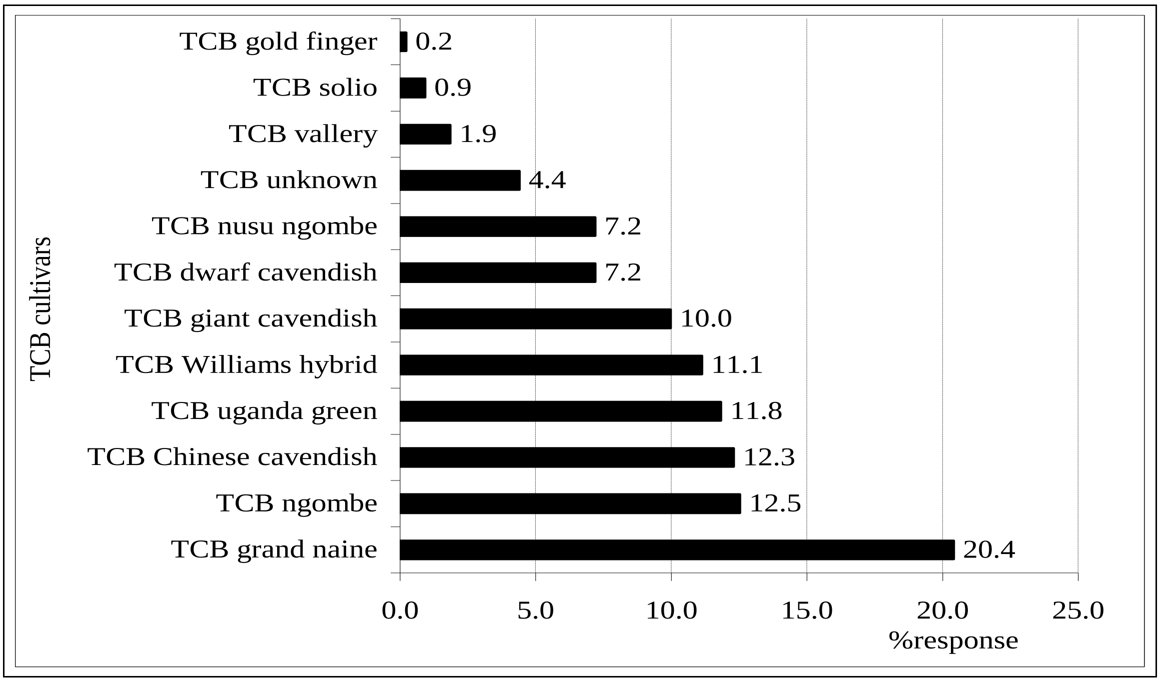

Figure 4-3: Percentage response TCB variety preferences by farmers in western Kenya-2012
Source: Survey data 2012.

4.3.2 Farmer Likert scale rating of TCB cultivar attributes

Banana cultivar utilization and adoption is a function of technological specific attributes. Therefore, identifying these factors are important in development and up scaling of banana cultivars in the region. Farmers who are producers and consumers of different banana identified and rated cultivars. They scored the banana cultivar attributes on a likert scale of one to four (1=very poor, 2=poor, 3=good and 4=excellent) (Table 4-1).

The proportion of farmers who preferred various attributes between TCB and non-TCB were significantly different ($p \leq 0.01$) across all the attributes. The attributes rated as good and excellent among the non-TCB were suckering ability, finger size, finger length, and bunch size. Most farmers (>80% of sample size) rated TCB cultivars as good or excellent in the following factors: pest tolerance, disease tolerance, yield potential, sweetness, suckering ability, finger size, finger length, bunch size, feed potential, drought tolerance, maturity period, ripening quality, and storability) than the non-TCB. Some of the cultivar preference factors are related. For example, farmers equally scored finger size, finger length, bunch size, and yield. Other studies have reported similar variety technological preferences. For example, Dhamotharan and Selvaraj, (2013) indicated that consumers and producers preferred specific banana cultivars because of their fruit perishability, taste and medicinal value while Sangudom *et al.* (2014) showed that there was nutritional advantage of harvesting fruit at the more mature stage.

Table 4-1: Farmer preferences of TC and non-TC banana quality parameters in Kenya

Quality parameter	Percent response by banana								chi-square
	TCB n=66				NTCB n=265				
	Very poor	Poor	Good	Excellent	Very poor	Poor	Good	Excellent	
Pest tolerance	0	6.3	56.9	36.8	1.5	5.3	75.0	18.2	26.459***
Disease tolerance	0	7.1	57.7	35.2	5.9	20.6	55.9	17.4	68.46****
Yield potential	0	2.2	47.4	49.6	0	21.2	49.3	29.5	85.484***
Sweetness	1.8	5.1	47.7	45.4	0	8.4	61.5	30.1	15.554***
Cook-ability	20.8	10.8	43.8	24.6	7.0	5.8	61.6	25.6	13.847***
Lodging	3.6	22.4	50.3	23.7	7.5	27.1	54.9	10.5	14.19***
Suckering ability	2.8	11.3	55.7	30.2	0.7	9.3	61.7	28.4	3.37
Finger size	0	3.2	54.5	42.2	0	28.0	46.9	23.1	1.15***
Finger length	0	3.9	58.2	37.9	0	30.7	44.5	24.8	1.00***
Bunch size	0	4.0	56.2	39.5	0	31.5	43.4	25.2	1.07***
Feed potential	0	15.7	46.4	37.2	0	11.54	63.4	25.2	12.80**
Drought tolerance	1.8	27.5	42.6	28.0	0	12.1	65.2	22.7	25.77***
Maturity period	0.2	10.7	66.7	26.1	0	7.2	37.0	37.0	8.07**
Ripening quality	0.2	11.9	49.5	38.5	0	8.1	71.1	20.7	20.79***
Storability	0.4	15.5	71.3	24.0	0	4.7	39.9	44.2	42.47***

***p ≤ 0.01 and **p ≤ 0.05 denote significance at the 1%, 5% and 10% levels respectively.
Source: Survey data 2012.

Presented in Table 4-2, are farmers' ratings of TCB technological attributes on a likert scale of one (1) (lowest) to four (4) (highest). Different studies have shown diverse banana cultivar preferences. For example, Ekesa *et al.*, (2012) found out that preferred banana varieties qualities which were valued for their cooking qualities, which included; large bunches and suitability for production of banana beer. Farmers in western Kenya identified fifteen banana attributes, which they considered as key issues (Table 4-2). The study revealed that there were significant differences in the banana attributes (disease tolerance, pest tolerance, yields, sweetness, cookability, lodging, finger length, bunch size, drought tolerant, maturity period, ripening, and storability at p≤0.01) except for the suckering ability and storability. Probably the suckering ability was not a key attribute in cultivar considered by the farmers. The pooled summative likert scale (positive summation of ratings) for all the variables also showed significant differences between the TCB and non-TCB cultivars. This implies that if these attributes are considered in banana technology development and transfer, then technology adoption may be enhanced. Based on these results more banana cultivars can be subjected to tissue culture technology and up-scaled for enhanced impact as indicated by Dhamotharan and Selvaraj, (2013), Kikulwe *et al* (2010), Ayinde *et al.*, (2010) and Dzomeku & Asigri (2012).

Kamira *et al* (2013) also found out that a major impediment to the wider technology uptake included lack of consumer acceptability among other technological attributes.

Table 4-2: Likert scale rating of farmer TCB verses NTCB quality parameters in Kenya

Preference indicator	TCB		NTCB		t-value
	Mean	SD	Mean	SD	
Disease tolerance	3.281	0.587	2.853	0.775	7.234***
Pest tolerance	3.305	0.582	3.099	0.537	3.746***
Yields	3.561	1.080	3.082	0.710	5.107***
Sweetness	3.366	0.666	3.217	0.583	2.470**
Cookability	2.723	1.054	3.058	0.772	-2.787**
Lodging	2.941	0.776	2.684	0.762	3.463***
Suckering	3.134	0.713	3.177	0.613	-.665
Finger size	3.390	0.551	3.350	2.832	.325
Finger length	3.340	0.550	2.942	0.745	7.152***
Bunch size	3.486	2.358	2.937	2.358	2.749**
Feed	3.349	1.720	3.137	0.592	1.390
Drought tolerant	2.968	0.793	3.106	0.592	-1.886
Maturity period	3.259	3.189	0.6471	0.548	1.065
Ripening	3.262	0.666	3.126	0.524	2.209**
Storability	3.279	0.732	3.194	0.501	1.253ns
Pooled (summative scale)	43.301	9.397	41.685	7.552	1.943*

***p≤0.01; **p≤0.05; and *p≤0.10 denote significance at the 1%, 5% and 10% levels respectively.

Source: Survey data 2012.

4.3.3 Determinants of TCB variety preferences

To identify determinants of TCB varieties, a nested multinomial logit model procedure was employed (Greene, 2003). Before fitting this model, the problem of multicollinearity among explanatory variables was checked using variance inflation factor (VIF) for continuous variable), condition index (CI) and contingency coefficient for dummy variables). The variables with multicolinnearity problems were dropped. Those variables used in the generation of these results showed that multi-collinearity was not a serious problem between discrete variables. Similarly, the problem of multi-collinearity was not serious among continuous variables after dropping some variables because VIF value was less than 10 and CI value was less than 30. The results of the NMLM estimates are presented in Table 4-3, Table 4-4 and Table 4-5. In all the decision levels the log-likelihood ratio test of goodness-of-fit of the estimated model was statistically significant ($p \leq 0.01$) indicating that the data fitted the model well.

Table 4-3: Nested multinomial logit parameter estimates of level 1: TCB and NTCB in Kenya.

Variable	Coef.	Std. Err.	z	P>z	ME
Banana price (KES)	0.003	0.008	0.42		0.0000
age of HHH	-0.074	0.145	-0.51		0.0000
Age squared of HHH	0.001	0.001	0.06		0.0000
sex of HHH	1.126	0.479	2.35	**	0.0002
Family size	0.024	0.093	0.25		0.0000
Years growing banana	-3.304	0.819	-4.04	***	-0.0003
Years growing banana squared	0.304	0.073	4.14	***	0.0000
Farm size	0.147	0.138	1.07		0.0000
Land ownership (1=With title;0=otherwise)	0.824	0.605	1.36		0.0001
Constant	27.086	886.766	0.03		
Number of obs	1779				
LR chi2(12)	69.12				
Prob > chi2	0.0000				
Pseudo R2	0.2399				
Log likelihood	-109.465***				

Notes: ***p≤0.01; and **p≤0.05 denote significance at the 1%, and 5% levels respectively
Source: Survey data 2012.

In level one the factors that significantly influence the choice of TCB and NTCB were sex, experience and experience squared ($p \leq 0.01$). Thus being a male farmer increases the tendency to prefer TCB innovation and putting it into practice. This implies that probably in the short run, experience (number of years of growing banana) of farmers is likely to reduce their preference for using TCB technology. However, in the long run (number of years growing banana squared), farmers are likely to increasing use/revert to TCB plantlets because of the disease and pest free attribute.

Farmers with primary level of education are more likely to prefer using TCB technology than those without any formal education. Probably education enhances a better understanding of the science behind the TCB innovation. This is in line with what has been hypothesized in literature on education-adoption link that education is directly related to knowledge gain for enhanced income generation and thus representing an income effect as reported in similar studies (Kikulwe *et al.*, 2010; Smale & De Groote, 2003).

Experience of the farmers negatively influenced preference for TCB indicating that the more the farmers gain experience in banana growing the less likely for them to use the TCB technology. In the short run, this could be due to farmers using TCB suckers to expand the area under banana orchard thus, saving themselves from the purchase of TCB plantlets. However, in the end the use of suckers may lead to disease and pest built-up and less yield. This implies that there is need for more education for not only TCB users but also potential users about the technological requirements for optimal performance.

Level two on cooking and ripening banana nested in level one (TCB and NTCB nests) is presented (Table 4-4). Technology specific variable did not have any significant effect on probability of preference between cooking and non-cooking banana. Further analysis of results showed that the factors that significantly influenced the choice between cooking and non-cooking in the TCB and NTCB nests were primary level of education and experience. The primary level variable was positive and significant while that of experience was negative and significant. In addition, experience squared was positive and significant.

Table 4-4: Nested multinomial logit parameter estimates of level 2: Cooking and ripening in western Kenya.

Technology specific characters	Coef.	SE	z	P>z
Rating index	-0.005	0.020	-0.24	
Technology attribute	-0.003	0.005	-0.48	
Rating of TCB	-0.224	0.437	-0.51	
Cooking and ripening level equations				
Type of banana 1=ripening ; 0= Cooking)				
Benefit	-0.011	0.021	-0.53	
Annual banana revenue	-0.000	0.000	-1.16	
Banana fruit price (KES)	0.003	0.003	0.98	
Age of HHH	0.044	0.066	0.67	
Age squared of HHH	-0.001	0.001	-0.9	
Sex of HHH (1=male; 0=female)	-0.043	0.349	-0.12	
Primary level education_HHH (1=Prim; 0=0therwise)	1.346	0.801	1.68	*
Secondary level education_HHH (1=Sec; 0=0therwise)	1.189	0.841	1.41	
Post-Secondary level education_HHH (1=P-Sec; 0=0therwise)	1.210	0.834	1.45	
Occupation of HHH-off-farm (1=Sec; 0=0therwise)	-0.436	0.405	-1.08	
Family size	0.0584	0.059	0.99	
Years growing banana	-0.165	0.078	-2.12	**
Years growing banana squared	0.006	0.004	1.54	
Farm size	-0.002	0.003	-0.5	
Farm type (1=SSF; 0=LSF) ftype	-0.304	0.436	-0.7	
Land ownership (1=With title;0=otherwise)	0.001	0.262	0.00	
Wald chi2		17.48		
Prob > chi2		0.006		
Log likelihood		-506.881***		

***p≤0.01; **p≤0.05; and *p≤0.10 denote significance at the 1%, 5% and 10% levels respectively.

Source: Survey data 2012.

TCB variety level analysis (level 3)

Presented in Table 4-5 are level 3 results on the choice among the TCB and NTCB cultivar nests. The results revealed that perceived benefits from TCB significantly ($p \leq 0.05$) influenced adoption of the five TCB cultivars. This implies that probably the perceived benefits accruing from all the TCB cultivars were relatively high compared to non-TCB cultivars. In addition, the revenue generated from banana proceeds was positive and significant ($p \leq 0.05$) on two banana cultivars (TCB Chinese Cavendish and TCB Giant Cavendish). This implies that the higher the revenue from TCB the higher the preference and likelihood of preference to the TCB cultivars. Foster and Rosenzweig (2010) advanced similar arguments. However, this can be enhanced if markets are available and reliable.

Table 4-5: Nested multinomial logit parameter estimates of level 3: banana variety alternatives (base variety is TCB grand naine)

Variables	TCB-Chinese Cavendish	TCB Dwarf Cavendish	TCB Giant Cavendish	TCB Nusu Ng'ombe	TCB Ng'ombe
Benefit	0.104(0.05)**	0.1275(0.065)**	0.126(0.056)**	0.099(0.046)**	0.126(0.056)**
Revenue	0.000(0.00)*	0.0001(0.000)	0.000(0.000)*	0.000(0.000)	0.000(0.000)
Price	-0.007(0.01)	0.002(0.011)	-0.004(0.010)	-0.006(0.008)	-0.004(0.010)
Age	0.142(0.13)	0.268(0.102)***	0.085(0.160)	0.112(0.110)	0.085(0.160)
Age2	-0.002(0.01)	-0.003(0.001)**	-0.001(0.001)	-0.001(0.001)	-0.001(0.001)
Sex	-0.790(1.04)	0.550(1.258)	-1.326(1.115)	-0.662(1.040)	-1.326(1.115)
Educ	0.169(0.41)	-1.550(0.713)**	0.094(0.476)	0.163(0.406)	0.094(0.476)
Occ_off	-0.642(0.88)	1.054(1.278)	-0.209(1.050)	0.005(0.860)	-0.209(1.050)
Fam	-0.005(0.14)	-0.544(0.233)**	-0.191(0.176)	-0.097(0.145)	-0.191(0.176)
Exp	0.210(0.16)	0.010(0.378)	0.397(0.281)**	0.264(0.160)	0.397(0.281)
Exp2	-0.010(0.01)	-0.014(0.030)	-0.022(0.018)**	-0.012(0.006)	-0.022(0.018)
Farmz	-0.636	-1.16(0.367)***	-0.63(0.005)***	-0.63(0.005)***	-0.63(0.005)***
Wald chi2			17.48		
Log likelih.			-506.8809***		
Prob > chi2			-.00010		

***p≤0.01; **p≤0.05; and *p≤0.10 denote significance at the 1%, 5% and 10% levels respectively. Figures in parenthesis are standard errors.

Source: Survey data 2012.

The variable age, age squared, education and family size were positively and significantly different from zero ($p \leq 0.05$) on only one cultivar (TCB Dwarf Cavendish). The variables experience and experience squared in growing banana were positive and significant on TCB Giant Cavendish production. The higher the age of the famers, the more likely the adoption of some of TCB cultivars which include Giant Cavendish. The variable farm size was negative and significant

($p \leq 0.05$). Implying that the larger the farm size the less the probability of adopting the TCB cultivars. This implies that probably there is need to target smallholder farming community. Subsequently age is an important factor to consider in targeting TCB cultivar technologies. These results are consistent with previous studies on crop variety choice is an important component in technology dissemination for enhanced adoption (Foster & Rosenzweig, 2010).

4.4 Conclusions and recommendations

The results of this chapter revealed that farmers preferred banana cultivar because of certain attributes they had. Some cultivars were limited in some and this contributed to their low preferences. The highly preferred TCB cultivars were Grand naine, Ng'ombe, Chinese Cavendish, Uganda green and Williams Hybrid. The least preferred were Gold finger and Solio. A number of these attributes were identified and important in choice of different banana cultivars. The important attributes revealed were; disease tolerance, pest tolerance, yield potential, sweetness, cookability, lodging, finger size, finger length and bunch size. The other attributes included feed, drought tolerant, maturity period, ripening, and storability. The key factors that significantly influenced the cultivar preferences education level, years of planting banana, benefits, revenue generated (yield) and age.

Farmers as producers and consumers of banana fruits and derived products also looked for the specific varietal attributes, such as pest tolerance, disease tolerance, yield potential, sweetness, cook-ability, lodging, suckering ability, finger size, finger length, bunch size, feed potential, drought tolerance, maturity period, ripening quality and storability (shelf-life). The finding suggest that farmer perceptions of technology-specific characteristics significantly condition technology adoption decisions is consistent with recent evidence in the literature, which suggests the need to go beyond the commonly considered socio-economic, demographic and institutional factors in adoption modelling

The results of the survey give rise to three broad, interrelated sets of recommendations: (1) to enhance supply of TCB cultivars, (2) the banana cultivars to be supplied, should meet the attributes revealed by farmers and to provide farmer/consumer education and information on the TCB cultivar attributes including agronomic practices. Subsequently these attributes need to be integrated in generation and upgrading of banana cultivars for enhanced adoption and impact on the target groups.

CHAPTER FIVE

5 THE IMPACT OF TCB TECHNOLOGY ON FARMERS' LIVELIHOODS

5.1 Introduction

Promotion of productivity enhancing technologies like TCB was perceived to have significant impact on farmers' welfare and including other actors along the banana value chain. The effects can be revealed through welfare indicators at household, plot, and regional levels. This study focused on household level effects. The welfare indicators are related to poverty and food security and nutritional security (Pangaribowo *et al.,* 2013; UN., 2005) The effects TCB innovation on targets groups require frequent monitoring in order to plan and fine-tune appropriate research and extension interventions. TCB technologies are seen as an important route out of food security alleviation and poverty reduction in Kenya and other developing countries. The technology has been in existence for quite some time yet its impact is not been fully realized. This is due to low adoption of the technologies.

The purpose of this chapter is to evaluate the current impact levels of the TCB technology on farming community. However, the main difficulties in assessing this impact are: (i) how to separate the effect of TCB from the effect of other interventions, (ii) how to separate the effects of these TCB technology interventions from those of other interventions and socioeconomic factors that simultaneously affect household living conditions. This section focus to analyse the impact of the Tissue Culture Banana (TCB) interventions on selected outcomes of banana productivity, food security, and income generation at household level in Kenya. We utilize the Propensity Score Matching technique to assess the effects.

In the TCB technology intervention in Kenya, there are a group of farmers who participated in the project and adopted the technology while other groups have not. The TCB innovation was hypothesized to have positive and significant impact on food security and income generation among the farmers farming communities.

Literature on impact and challenges of TCB technology in Kenya mixed reactions by stakeholders is scanty because there are limited post-intervention studies carried out attributing socio-economic benefits to TCB intervention. This information gap coupled with emerging impediments including the identification of weak segments along the banana VC structure that constrain the attainment of set project objectives demands further research. The banana production and marketing structure is characterized by product perishability and bulkiness with many actors (input suppliers, farmers, processors, wholesalers, retailers, consumers and change agents), each with diverse interests, perceptions and preferences on TCB technology. For example, each actor aims at maximizing individual benefits from functions and activities performed. However, there is limited information on economic relationships among these TCB actors that govern transactions along the value chain structure. This study was designed to address these information gaps for effective and efficient TCB up scaling for enhanced and perceptible impact on the target population. The broad objective of this study is to determine the impact and challenges of TCB technology along the along the VC chain in Kenya. The specific objective of the study was to evaluate the extent to which TC banana technology has influenced farmers' welfare.

5.2 Methodology

5.2.1 Theoretical framework and Analytical techniques

The TCB technology impact on the economic decision process manifests in the changes in household food and income generation among other indicators. This may occur through the following five channels/outcomes: (i) *banana production*: By adopting TCB banana the production of banana would increase and subsequently more yields and per capita banana production. (ii) *Enhanced consumption of banana by having more months eating bananas*: The increased yield would lead to more food and subsequently more months of eating banana at household level and (iii) Income *generation*: Through increased banana production. Households would have enough to eat and surplus for sale. The later reflects having more revenue from marketed bananas to meet the family financial obligations.

There are a number of models that can be used to assess the impact of TCB on target communities along the value chain. They include; PSM, difference in difference (DD), regression discontinuity design (RDD) and instrumental variables models. In this study we utilize PSM (Khandker *et al.,* 2010). DD is an option when baseline and subsequent outcome measures are available for the treatment and control groups. The advantage with this method is that it uses each individual as their own control, no time invariant sources of heterogeneity will bias the estimate of treatment effect. The limitation with this method is that it does not estimate the treatment effect on the untreated directly. If the aim of research is to estimate the global or total treatment effect or to estimate the treatment effect on the untreated, careful justification of the comparability of the treatment and control groups is necessary. As given by Green (2003), Instrumental Variable (IV) method is only possible when a good instrument is available. Good instruments must be fully and empirically demonstrated to be correlated with treatment but not with unmeasured predictors of the outcome. However, good instruments can be hard to find and justifying instruments' lack of correlation with unmeasured predictors of the outcome can require substantial substantive knowledge.

According to Wooldridge (2002), regression discontinuity modelling can be conducted when the data do not support other causal methods of treatment effect estimation. This is because it only requires eligibility measures and outcome measures for the control and treatment groups. He observes that the limitation with this technique is that if eligibility rules were inconsistently applied, the treatment is likely to be correlated with unmeasured sources of heterogeneity and the validity of the treatment effect estimate is compromised. Thus, the regression discontinuity estimates, only describes the treatment effect in the neighbourhood of the cut-off points. Subsequently, if the researcher is seeking an estimate of the treatment effect for a large group, this technique is insufficient. It is proposed that extensive robustness checks are necessary to validate the model and make it more efficient.

Propensity score matching uses observed factors to model the propensity to be in the treatment group and then estimates the treatment effect as the mean difference in differences for pairs of treatment and control individuals with similar propensities. Propensity score matching is a three-step process. First propensities are estimated. Second, treated and untreated individuals are matched. Third, the treatment effect is estimated as the mean of the difference in outcomes within the pairs. This method is used when both baseline characteristics and outcome measures are available for treated and untreated individuals. Three conditions are necessary for propensity score matching to yield a valid estimate of causal effect (Khandker *et al.*, 2010): 1) Unobserved characteristics must not account for treatment receipt. 2) Common Support. The distributions of propensities for treatment in the control and treatment groups must overlap sufficiently to allow the pairing of treatment and control individuals. 3) Conditional Independence Assumption (CIA). Individuals in the treatment group must not benefit from treatment differently than individuals in the control group would have, conditional on propensity to be treated. The method allows for causal modelling when only cross sectional data are available as in the case of this study. In addition, since some time-invariant and frequently collected personal characteristics like age, gender, education, employment status and income levels might be drivers of propensity for treatment the method was suitable as an analytical tool in this study (Khandker *et al.*, 2010).

In order to evaluate the impact of the TCB technology intervention an appropriate counterfactual identification is basic to organizing principle of an impact evaluation (Imbens & Wooldridge, 2009). The counterfactual tells us what would have happened to the beneficiaries if they had not received the intervention. As a household cannot be both a participant and non-participant of the same TCB intervention programme, the counterfactual is identified by selecting a control group. A group of control households is chosen from non-beneficiaries to be representative of the group of participants with one key difference: the control households did not receive the intervention. If the two groups are dissimilar in other dimensions, the outcomes of non-beneficiaries may differ systematically from what the outcomes of participants would have been without the programme, producing selection bias in the estimated impacts. This bias may derive from differences in observable characteristics between beneficiaries and non-beneficiaries or unobservable characteristics as indicated by Diagne *et al*., (2012). Some observable and unobservable characteristics do not vary with time while others may vary (such as skills). Furthermore, the existence of un-observables correlated with both the outcome of interest and the program intervention can result in additional bias. This analytical model is built from the causal inference theory (Brady, 2002; Hoover, 2006). We can view the TCB adoption decision as a" treatment" undertaken. The estimation of the post-adoption of household performance is an evaluation of the "treatment effect." To evaluate the effect of TCB intervention on farmers' performance/target group, we estimate the average treatment effect on the treated group.

We adopted the Propensity Score Matching approach which is a semi-parametric matching method which does not require an exclusion restriction or a particular specification of the selection equation to construct the counterfactual and reduce selection problems (Jord & Taylor, 2014; Rubin, 2001). Our main purpose of matching is to find a group of treated individuals (treated households) which are similar to the control groups (non-treated households) in all relevant pre-treatment characteristics. The only remaining difference being that one group accessed the treatment and other group did not. A number studies have utilized the PSM method (Caliendo & Kopeinig, 2005; Dehejia & Wahba, 2002; Diagne *et al.,* 2012; Imbens & Wooldridge, 2009; Koppelman & Garrow, 2004).

5.2.2 Counterfactual framework

Counterfactual scenario tells us what would have happened to the treated subjects, had they not received treatment. The key assumption of this framework is that individuals selected into treatment and non-treatment groups have potential outcomes in both states: the one in which they are observed and the one in which they are not observed (Acemoglu *et al.,* 2014; Fong & Imai, 2014; Thoemmes, 2012). This framework is expressed as given in equation 5-1.

$$Y_i = W_i Y_{i1} - (1 - W)Y_{10} \quad 5\text{-}1$$

The key message conveyed in this equation is that to infer a causal relationship between W_i (the cause) and Y_i (the outcome) the analyst cannot directly link Y_{1i} to W under the condition $W_i=1$; instead, the analyst must check the outcome of Y_{0i} under the condition of $W_i=0$, and compare Y_{i0i} with Y_{1i}. The step-by-step procedure for conducting PSM method is as follows as stipulated by Caliendo and Kopeinig, (2005), Imben and Wooldridge (2009) and Diagne *et al.* (2009), were (Figure 5-1) *Step 1*: estimate a logit model of the endogenous choice variable, adopting TCB, based on farmer observable characteristics. *Step 2*: Each observation of the treated group (TCB adopters/practitioners) was matched with a control group observations (counterfactual) based on the generated propensity score in step 1. *Step 3*: After matching, we perform *t*-tests in order to see whether the means of each characteristic differ between treated and control units. We also use a joint test for the equality of means in all the covariates in the $d_i=1$ and $d_i=0$ groups. The *F*-test or *Hotelling* test was also used for this purpose. *Step 4*: to evaluate the effect of adopting TCB technology on target groups, we calculate the average treatment effect (equation 3.17) after TCB adoption.

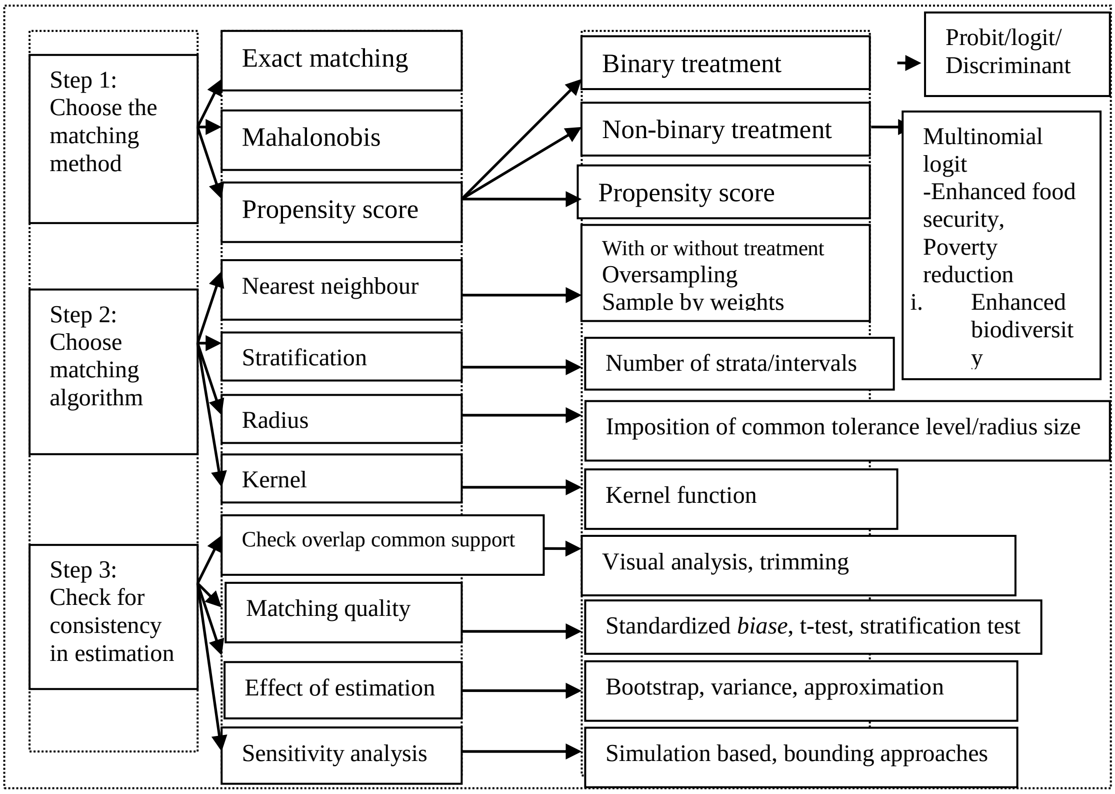

Figure 5-1. Matching implementing steps in TCB impact study
Source: Caliendo and Kopeinig, (2005).

PSM technique involved generating p-scores using individual observed characteristics (Thoemmes, 2012) (e.g. age, sex, education level, employment status, membership in groups, credit, experience, farm size, and family size) and matching control and treated groups based on the computed propensity score. In this study TCB technology was the treatment variable while banana production, food security indicators and income generation were outcome/impact variables of interest. The PSM technique gives the difference in outcomes/impacts over the common support weighted by PS distribution of subjects who benefited from TCB (d=1). The PS for subject *'i'* is the conditional probability of being assigned treatment (d=1) versus the control (d=0) given a vector of observed covariates X_i. Thus PS is an estimated probability score of selected household/individual 'i' and is given as; P =pr $\{d=1|X_i\}$ =E $\{d=1|X_i\}$ with assumption that $d_i \perp X_i$ where $\perp$ denotes independence. The PSs are computed using logit or probit model but in this study, we will use logit model, which is specified as shown in equation 5-2. The independent variable will be the probability of receiving the treatment (d $\in$ {1,0}) and the pre-treatment characteristics will be independent variables (Ouma *et al.,* 2013; Samano, 2014; Wooldridge, 2005).

$$\ln\left[\frac{\exp(x_i)}{1-\exp(x)}\right] = \ln\left[\frac{pr(d_i = 1 \mid X_i = x_i)}{1 - pr(d_i = 1 \mid X_i = x_i)}\right] \quad 5\text{-}2$$

After generating *p*-scores, several matching techniques were used to create a matched control, treated groups, and adopt the one that gives the best results. This was done by imposing a common support condition and drop cases whose scores were not comparable. After matching, the two groups should have similar characteristics. In order to check this similarity two balancing tests through t-test and Hotelling's T-squared test was carried out. The t-test involves examining the mean of each covariate. According to Caliendo and Kopeinig, (2005), Hottelling'test is done by re-running logit model and comparing pseudo-R^2 before and after matching. Likelihood ratio was also examined to test the significance of the coefficients.

Bootstrapping was done to get SE for PSM. We assume that the treated group (d=1) and non-treated group (d=0). Based on the composite assumption, to estimate the average treatment effects (ATE) of TCB on target groups, the model is specified as given in equation 5-3.

$$ATE \equiv E\{E(Y_{1i} - Y_{0i} \mid d_i = 1\} = E\{E\{Y_{1i}\}d_i = 1, p(X_i)\} - E\{Y_{0i} - \mid d_i = 0, p(X_i)\} \mid d_i = 1\} \quad 5\text{-}3$$

where Y_{1i} and Y_{0i} are potential outcomes/impacts in the two treatments and no treatment conditions, P are propensity scores for subject i, as in equation 5-4.

$$\Delta \bar{Y}_i = \sum_{j=1}^{T} \omega_j (Y_{ji} - \sum_{i=1}^{k} W_{ij} Y_{ij0}) \qquad 5\text{-}4$$

$\Delta \bar{Y}$ is the post-intervention effect indicators, $\forall$ i = 1....., k

Y_{ij0} is the outcome/impact indicator of the i^{th} non-treated matched to the j^{th} treated group

Y_{ji} is the outcome/impact indicator of the i^{th} non-treated matched to the j^{th} treated group.

T is the total number of treatments

C is the total number of non-TCB treated households

ω_j s' are the sampling weights used to construct the mean impact estimator

W_{ij} are the weights applied in calculating the average income from matched non-TCB participants.

The PSM method works based on a number of assumptions and Rubin (2001) showed that if exposure to treatment (e.g. TCB technology) is random within each cell as defined by individual pre-treatment characteristics X_i, it was also random within cells defined by the propensity score variable p. The assumption underlying this approach is commonly referred to as conditional independence or strong ignorability. Mathematically as stated by Rosenbaum and Rubin (2001) the assumption states that $(Y_0, Y_1) \perp d|X)$ (the simple $\perp$ means independence) which means that conditional on X_i the outcome Y is independent on treatment assignment $[(Y_0, Y_1) \perp d|\ p]$ (Lemma 1). In addition, if p is the PS, then, under some conditions, exposure to the treatment and the observed covariates are conditionally independent given the propensity score, $d \perp X \mid p$ (Lemma 2).

The model assumptions include:

i) Conditional Independence Assumption

According to Caliendo and Kopeinig, (2005), this assumption states that given a set of observable covariates, (X_i) on the study units, which are not affected by treatment (in our case, TCB participation/beneficiaries), the potential outcomes/impacts (which in this study are banana production, revenue generated, and period the household utilized banana in the house) are independent of treatment assignment. Thus, it is independent of how the TCB participation decision is made by the household.

ii) The assumption of unconfoundedness (Equation 5-5) is very strong, and its plausibility heavily relies on the quality and the amount of information contained in the covariates, *X*. Instead of matching directly on X_i , we match on the predicted probability of using the treatment. This probability is calculated as shown in equation 5-5.

$$\Pr(\text{TCBadoption} = 1 \mid X_i) = \beta_0 + \beta_i X_{ki} + e_i \qquad 5\text{-}5$$

iii) Common support

This assumption is a slightly weaker assumption. It is associated with the treatment effect evaluation and it is also referred to as the overlap or matching (common- support condition) assumption. The common support is the region where the balancing p-scores have positive density for both treatment and comparison/control/counterfactual study units. It recognized that no matches can be formed to estimate the average treatment effects on the treated (ATT) parameter when there is no overlap between the treatment and counterfactual/control groups. The assumption ensures that for each value of *X*, there are both treated and untreated cases. The assumption is expressed as shown in equation 5-6.

$$0 < \Pr[d = 1 \mid X] < 1 \qquad 5\text{-}6$$

This implies that there is an overlap between the treated and control/untreated samples. This implies that the control and treated groups have comparable observed characteristics/pre-treatment effects. Under the two assumptions (CIA and overlap), the average treatment effect on the treated (ATT) can be identified as in equation 5-7.

$$E(Y_1 - Y_0 \mid d = 1) = E(E(Y_1 - Y_0 \mid d = 1, X)) \qquad 5\text{-}7$$

This assumption rules out perfect predictability of *d* given X as shown in equation 5-8.

$$0 < P\,(d = 1 \mid X) < 1 \qquad 5\text{-}8$$

Balancing Test

Balancing tests and testing for the plausibility of the Conditional Independence Assumption. The main purpose of the propensity score estimation is to balance the observed distribution of covariates across the groups of adopters and non-adopters. The balancing test is normally required after matching to ascertain whether the differences in the covariates in the two groups in the matched sample have been eliminated, in which case, the matched comparison group can be considered a plausible counterfactual.

Estimators Employed

Estimators that were used for matching the subjects in the two groups were (Treated group and the counterfactual) (Figure 5-2); nearest-neighbor caliper, kernel (Gausian & Epanechnikov), and radius following the procedures given by Caliendo and Kopeinig, (2005); Diagne *et al.,* (2012); Imbens and Wooldridge, (2009); Koppelman and Garrow, 2004 Dehejia and Wahba, (2002). Matching was implemented using the Stata module Becker and Inchino commands. More than one technique was used to assess which one gave the best matching (Owuor, 2009).

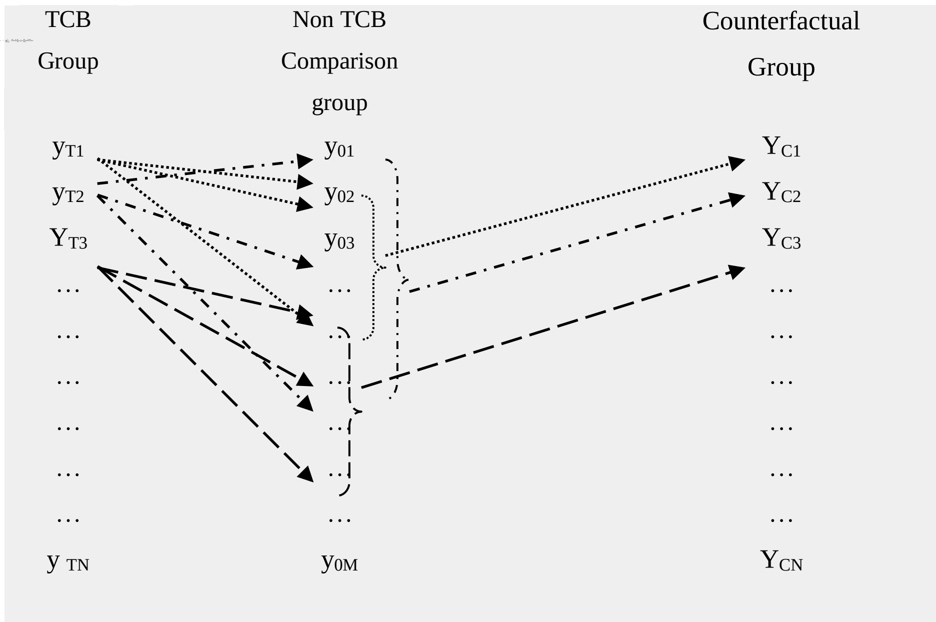

Figure 5-2: Propensity Score Matching Counterfactual Constructing Procedure

5.2.3 Data and data sources

In order to identify the TCB intervention impacts at the household level, data collection was extended beyond the data set normally collected by impact evaluations whose objectives align with income generation and food security improvements. Based on the conceptual framework of TCB impacts shown in Table 5-2, data was collected on household personal characteristics, farm related factors, Economic indicators, and Institutional factors.

5.3 Results and discussions

5.3.1 Determinants of probability of TCB adoption

Prior to running the logistic regression model to estimate propensity scores, existence of severe multicollinearity problem among the explanatory variables was checked. Variance inflation factor (VIF) was calculated to detect the problem of multicollinearity among continuous explanatory variables while Contingence Table (CT) was used to check among the non-continuous. Accordingly, the VIF result showed that the data had no serious problem of multicollinearity. This is because, for all continuous explanatory variables, the values of VIF were less than 10. Therefore, all the explanatory variables identified were included in the model.

The matching process, which utilized four techniques, used the variables that capture the situation before the start of the intervention. The logit result revealed a low pseudo R^2 of before and after matching 0.1333 and 0.1073, respectively. The pseudo-R^2 indicates how well the regressors ***X*** explain the participation probability (Caliendo & Kopeinig, 2008). A low R^2 value means participant households do not have much distinct characteristics overall and as such finding a good match between participant and non-participant households becomes easier. Cultivated land holding, family size, and livestock holding significantly influenced participation in project intervention. Speaking differently, those farmers who have larger size of land, more number of family size and higher number of livestock holding have high chance to be included as participant. Cultivated land holding influenced participation at 5% significant level while, family size and livestock holding influenced the probability of participation at 10% level of significance (Table 5-1).

The maximum likelihood estimate of the logistic regression model result shows that participation in TCB production was significantly influenced by four variables (Table 5-2). The education level, family size, cultivated land holding in hectares, and total affected the chance of participation. Meaning those farmers who have better level of schooling, larger cultivated land acreage and those with relatively larger land holding had high chance of being TCB participant.

Table 5-1: Marginal Effects for Factors that Influence participation in TCB production

Variable	Coef	SE	dy/dx	SE	z-test	P>|z| [	95%	C.I.]	X
Gender of head-q1hhsex	0.589	0.429	0.078	0.050	1.560		-0.020	0.175	0.818
Age of head-lnhhage2	0.290	0.310	0.041	0.046	0.890		-0.049	0.131	7.809
Head Education-q1hheduc**	0.432	0.192	0.066	0.028	2.310	**	0.010	0.121	1.612
Farming-occupation of head	0.511	0.498	0.076	0.063	1.210		-0.047	0.199	0.733
Off-farm-occupation of head	0.117	0.596	0.023	0.095	0.240		-0.164	0.210	0.148
Family size-q1faml*	-0.114	0.062	-0.017	0.009	-1.840	*	-0.035	0.001	7.048
Years in farming-lnperi~2	-0.058	0.176	0.008	0.026	-0.310		-0.060	0.044	2.199
Total farm size-Lnhect*	-0.539	0.296	0.080	0.044	-1.830	*	-0.166	0.006	0.136
Total arable land-lnq2ar~a*	0.514	0.305	0.077	0.045	1.700	*	-0.012	0.165	-0.054
cons	-4.287	2.357							
Number of obs	329								
LR chi2	17.93								
Prob > chi2	0.036								
Pseudo R^2	0.054								
Log likelihood	-155.943								
Predicted probability of Y	0.183								

**p≤0.05; and *p≤0.10 denote significance at the 5% and 10% levels respectively

Source: Farm survey 2012.

After generating the propensity scores, we proceeded to estimate the average treatment effects on the treated (ATET) by taking the mean difference in mean outcomes between treatment and control/counterfactual groups. In the estimation of ATET, we impose common support as well as calliper. Imposition of common support excluded the treatment observations with propensity scores outside the boundary of the highest and lowest propensity scores (maximum and minimum) of the control group. The imposition of calliper ensures the matching of treatment observations with the control observations only within a limited range of probability and we arbitrarily determine the level of calliper in our case as 0.0005. Applying common support as well as calliper enhances the match quality as well as precise estimation of ATET. Use of common support and calliper reduces significant number of observations however. The number of observations from treated and control groups were *off-supported* due to application of common support and calliper were analysed.

Common support or overlap region

Figure 5-4a, and 5-4b provides a histogram of the density function of the propensity scores for treated and untreated countries, both on and off support. It reveals that most treated (untreated) group can be paired with corresponding untreated (treated) group with similar propensity scores, a property that should facilitate matching. Visual inspection of these figures shows that the propensity scores for all treated groups off common support were substantially higher than the propensity scores for the nearest untreated groups. The visual evidence is, however, not as compelling for untreated groups off common support.

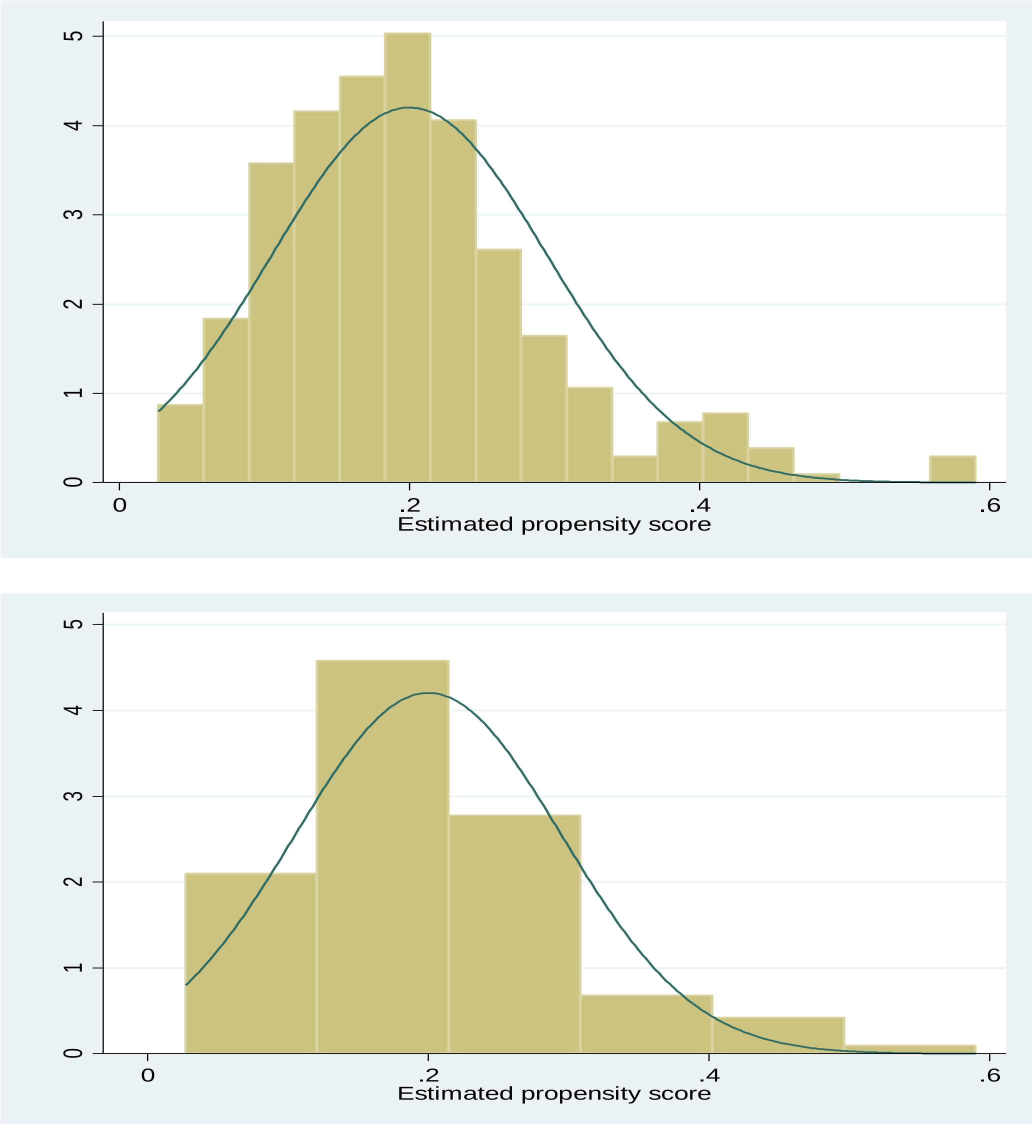

Figure 5-3a: Histogram showing common support region-Propensity score distribution
Source: Farm survey 2012.

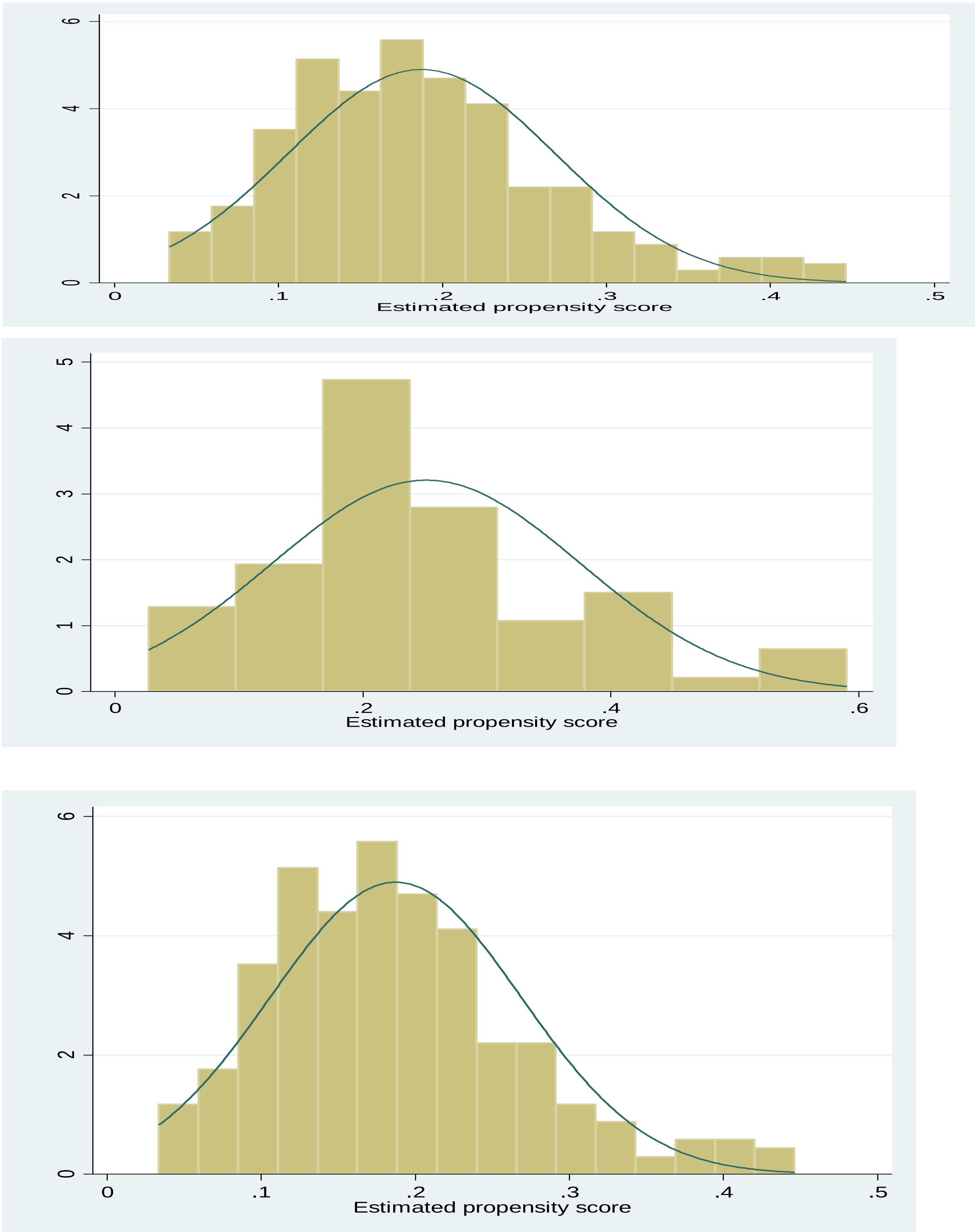

Figure 5-4b: Histogram showing common support region-Propensity score distribution
Source: Farm survey 2012.

Covariate balancing before and after matching

The joint *F* test in Table 5-3, demonstrates that the conditioning variables are well balanced jointly (*F*=1.9635, p<0.05**).** The third balancing test re-estimates the propensity score on the matched sample, and compares the *pseudo-R^2* before and after matching (Sianesi, 2004). The *pseudo-R^2* indicates how well the regressors explain the probability of going public. After matching, there should be no systematic differences in the distribution of covariates between both groups and hence the *pseudo-R^2* should be low.

The Hotelling T^2 tests the hypothesis that the sample mean vectors X_1 and X_2, from two samples, assuming common population covariance matrices, are equal. That is, for the variables, X_1, X_2, X_3... X_p, the sample mean vectors include the mean from each sample for each variable. In practice, Hotelling's t^2 statistic is calculated as $T^2 = n_1 n_2 (X_1 \_ -X_2)' \mathbf{C}^1 (\mathbf{x}_1 \_ \mathbf{x}_2)/(n_1 \_ n_2)$. Where n_1 and n_2 are the number of observations for each sample 1 and 2, **C** is the pooled variance-covariance matrix of X_1 and X_2, and the transformed statistic, $F=(n_1-n_2-p-1)T^2/\{(n_1+n_2-2)p\}$, is distributed according to the F distribution with p and (n_1+n_2-p-1) degrees of freedom. From this study, *Hotteling* test 2-group *Hotelling's* T-squared=18.113, F-test statistic: ((330-9-1)/ (330-2)) x 18.113 = 1.963.

Table 5-2 summarizes the results from the balancing tests described in the previous section, and reassuringly we find that the balancing conditions are met in all years. Thus, the tests give robust support for the soundness of the matching approach adopted. The standardised differences are calculated for each of the matching variables using this expression. The bias reductions relative to the standardised differences in the unmatched samples are given in squared brackets. Note that the lower the standardised difference, the more balanced or similar the treatment and comparison groups will be in term of the variable under consideration. Although a formal criterion as to how large a standardised bias should be for it to be considered serious enough does not exist, Rosenbaum and Rubin suggest that standardized differences greater than 20 should be considered problematic.

Whereas the above balancing test calculates the cross-sample difference of each variable entering the logit model separately, there also exists a test that considers whether those differences can be taken as jointly insignificant. This test is known as the Hotelling's T-squared test. It has the flexibility of being based either on all observations or for separate segments of the sample defined by the propensity score estimates. In this study we divide the sample into two equal parts (i.e. above and below the propensity score median), and conduct the Hotelling's T-squared test within each part. The Hotelling's tests are conducted by dividing the relevant sample into two, based on the estimated propensity scores. The test is conducted for all explanatory variables included in the logit specification. The p-value shown is the minimum value obtained among all the tests conducted. A value greater than the specified significance level of say 5% is evidence in favour of balancing.

Table 5-2: Covariate balancing before and after matching-Joint test (*F-test*)

Statistic	Before matching	After matching			
		Kernel	Radius	Nearest neighbour	Stratified
Mean standardized biases	0.21641791	0.14114615			
Pseudo R^2	0.0545	0.1073		0.1140	
LR chi2 R^2 (p-values)	42.55 (0.0000)	35.59(0.0000)			
Matched sample size					
F(9,320)	1.9634989 (Prob > F(9,320)= 0.0430)				

Source: Farm survey 2012.

5.3.2 Estimation of ATET- Impact of TCB adoption on Household outcomes

Table 5-3 presents the estimated treatment effects on the treated of TCB technology. The PSM estimation algorithms were Kernel (0.06), Radius (0.10), nearest neighbour and Stratified 3. The effect of enforcing common support requirement showed that less than one percent of the observations was dropped. The implication is that these levels were very low and were therefore unlikely to compromise the representativeness of the results.

The outcome indicators considered were the number of months that households were consuming banana, average annual banana revenue per household, annual number of banana bunches harvested. Across all the algorithms used except for a few, results revealed that adoption of TCB technologies had a significant positive impact on all outcome indicators (months eating banana, banana revenue, number of banana bunches, banana weight-kg). The values of ATET shows the increase of the amount of outcome indicator of treated farms relative to the controls/counterfactuals.

Table 5-3, shows the ATT estimates on all the outcome indicators. The results showed a positive effect of TCB on the number of months that households were consuming banana, average annual banana revenue per household, annual number of bunches of banana harvested and statistically significant for all except for months of eating bananas for Kernel, nearest neighbour and radius algorithms. This means that, on average, the treated farmers had higher banana performance than those without. All point estimates had a positive coefficient and are similar in magnitude across different performance measures. The non-significance on the three algorithms could be because Kenyan households are not banana eating banana alone as a full meal.

Adoption of crop varieties can have significant effect on crop yield (Wiredu *et al.,* 2014). From the results in Table 5-3, it can be deduced that there was a statistically significant increase in banana productivity at household level. The results showed that Kernel matching (KM) and stratified matching (SM) matched 57 participants matched with 270 controls, with an average treatment effect on household production of 2199 kg and 2130 kg annually respectively (Table 5-3). The results showed that Nearest Neighbour Matching (NNM) matched 270 non-TCB adopters to 47 controls, with average effect on annual revenue of 2293 kg per household. Equally, Stratified matching matched 264 non-TCB adopters to 66 controls, with average effect on annual revenue of 8636 kg. This results are supported by other studies that have shown that adoption of crop varieties stimulate high yields (Awotide *et al.,* 2012; Dontsop *et al.,* 2012), household expenditure (Adekambi *et al.,* 2009), and income. Kabunga *et al.,* (2011a) and Qaim, (1999) equally found a similar effect on impact of TCB on household production.

Increased banana income would arise from surplus banana production sold. The analysis of the impact on household income however revealed that there was a significant increase in total household banana revenue resulting from implementation of TCB. The results showed that KM and SM matched 57 participants matched with 270 controls, with an average treatment effect on household income of KES 39,379 and KES 39,157 annually (Table 5-4). NNM matched 270 non-TCB adopters to 47 controls, with average effect on annual revenue of about KES 45014 per household. The results were significantly at 1% level. Further analysis showed that in a household made up of seven members. This translates to additional cash KES 7,502 per person annually. Equally stratified matching matched 264 controls to 66 treated, with average effect on annual revenue of KES 20,668. Significant positive impact of TCB technology on household revenue generation was observed by other authors both in ex-ante and *ex-post* studies.(Kabunga *et al.,* 2011; Qaim, 1999) Wiredu *et al* (2014) also reported similar results of enhanced income generation from the adoption of crop varieties in Ghana (Rice *et al.,* 1997).

The results in Table 5-3 showed that KM matched 57 participants with 268 controls with an average treatment effect on net number of months of 0.177 months annually. Radius (Caliper=0.10) and NNM (Three neighbors) matched 57 participants with 270 controls, with an average treatment effect on household of 0.137 and 0.293 months annually respectively (Table 5-3). Further analysis showed that NNM matched 270 non-TCB adopters to 47 controls, with average effect on annual revenue of 0.293 months per household. The results were significantly at 1% level ($p \leq 0.1$).

Table 5-3: Effects of adopting TCB on selected household impact indicators in Kenya

Outcome variables	Matching method/estimator	n. treat	n. contr	% dropped	ATT	SE	*t* -value
Banana production-kg	Kernel (Bandwidth=0.06)	270	57	0.01	2198.86	1,205.62	1.82**
	Radius (Calliper=0.10)	270	57	0.01	2129.70	1,211.53	1.76**
	Nearest neighbour(Three neighbours)	270	47	0.04	2292.52	1,253.85	1.83**
	Stratified (Strata=3)	264	66	0.00	8636.05	4,674.72	1.85**
Banana Revenue (KES)	Kernel (Bandwidth=0.06)	270	57	0.01	39379.05	1,8912.97	2.08**
	Radius (Calliper=0.10)	270	57	0.01	39156.60	2185.44	1.79**
	Nearest neighbour(Three neighbours)	270	47	0.04	45014.30	2159.13	2.08**
	Stratified (Strata=3)	264	66	0.00	20667.61	5816.40	0.355
Months eating bananas	Kernel (Bandwidth=0.06)	268	57	0.02	0.18	0.355	0.497
	Radius (Calliper=0.10)	270	57	0.01	0.18	0.496	0.276
	Nearest neighbour(Three neighbours)	270	47	0.04	0.29	0.662	0.442
	Stratified (Strata=3)	264	66	0.00	0.94	0.469	2.006**

Notes: the number of observations includes only observations that fall within the common support area.

[a] Bootstrapped standard error with 100 replications

For the matched sample standard errors are generated via bootstrapping (200 replications); for the nearest neighbour matching calliper=0.05; *** denotes 99% significance level, ** 95% significance level, * 90% significance level respectively

Exchange rate: US$1.00=KES 80.00.

***p≤0.01; **p≤0.05; and *p≤0.10 denote significance at the 1%, 5% and 10% levels respectively; contr means counterfactual group; treat=treated group

Source: Author's computation from survey data 2012.

5.4 Conclusions

The main objective in this chapter was to assess the impact of TCB on target groups. The results of the household survey data from western region using propensity score matching methodology, aimed at analysing the impact of the TCB interventions on agricultural productivity, income and food security. The results show a significant increase in agricultural productivity, income and food were weakly significant effect on food security. This can be attributed to small land sizes and over-reliance on maize as food. The results indicate the need to upscale the distribution of TCB technology to enhance access of TCB plantlets.

In addition, the dataset offers a number of ways of measuring impacts of TCB on the target groups, which includes total output at household level, revenue generated, and consumption levels of the products using the number of months as a proxy variable. From these results, the contribution of the TCB to household outcome indicators was significant. The TCB adopters were generally better off than they would have been without the TCB. It was felt that they are better off compared to those households who had not adopted the TCB. The farmers' eagerness to have the TCB was revealed through using TCB suckers to expand their banana orchards.

CHAPTER SIX

6 DETERMINANTS OF INTENSITY OF MARKET PARTICIPATION AMONG BANANA TRADERS IN WESTERN KENYA

6.1 INTRODUCTION

Markets are driving forces to increasing production and productivity of any farm enterprise like banana. Subsequently markets contribute to economic growth at both household and national levels. The growth of agricultural based economies like that of Kenya are dependent of markets (RoK., 2013). This implies that enhanced agricultural production may be accompanied by improving output and input market considerations. This change occurs at household, regional, and national levels. Since independence, the policy of Kenya government has been to enhance food security and poverty reduction. As manifested in all Development Plans since 1963 to Kenya Vision 2030, the emphasis of has been on food security, poverty eradication and health for all (RoK., 2007). Banana enterprise has been one of the food crops that contribute to food security in the country. (Njoroge *et al.*, 2013). The acreage and production of the crop has progressively increased over years as shown by Republic of Kenya.

It is imperative that self-sufficiency in food production is now an important political-economic goal of the many governments including Kenyan (Watson, 2013). The central Government and now the County Government have intentionally invested in banana productivity increasing strategies. About two decades ago. Some of the interventions targeted smallholder farmers. There are a number of government interventions in banana production. Such intervention included the tissue culture banana technology which was developed to enhance production targeting smallholder farmers (Wambugu & Kiome, 2001). This intervention coupled with other agronomic technological components addressed the supply side of the banana value chain by progressively increasing banana production over years. However, the banana market development has not grown in tandem with production (Mwangi & Mbaka, 2010). This implies that despite efforts of some market stakeholders to enhance its marketing, banana markets has not been good (Wanjiru *et al.*, 2013).

Middlemen play a key role in banana marketing. They are categorized into two major groups: the merchant and agent middlemen. The agents perform distribution functions and they receive commission for the work done for consumers, wholesalers, and producers. The merchant middlemen own the goods they sell and bear the risk involved in marketing them.

They stand to make profits or losses from the sale of the goods. The two main types of merchants who are involved in banana trade are wholesalers and retailers.

It is hypothesised that trader (retailers and wholesalers) participation in banana market is important because they promote banana distribution and subsequently promote the upgrading of technologies. The trader (wholesalers and retailers) participation in banana markets has not been fully documented not only in Kenya but also in the east African region. In addition, banana markets are not well in Kenya developed unlike other cereal crops like maize, wheat, rice, and beans for many years. Market participation is regarded as the participation of any stakeholder (as the wholesalers, retailers, processors or consumers) in any market related activity, which promotes the sale of produce. This study was designed to identify determinants of level/intensity of banana market participation among banana traders in western Kenya; and identify constraints faced by traders. It is believed that banana production, marketing, and consumption are crucial for all value chain actors in banana sub-sector.

The number of traders and volume of banana fruits traded are increasing over years. This is manifested presence of fruits in super markets, and street/roadside involvement in the trade. However, most research has given emphasis on farmer participation in markets in Kenya and outside Kenya (Chegea *et al.*, 2015; Fischer & Qaim 2012; Fischer & Qaim, 2011) but limited work on traders' banana trade. This is against the background that the banana traders and volumes of sales could be increasing over years. Traders play significant roles in transportation and distribution of goods to distant markets where the products are in scarcity. The market participation studies have used a number of techniques which included logit, probit and Tobit (Adenegan *et al.*, 2012).

6.2 Methodology

6.2.1 Sampling Procedure

A multistage sampling technique was used to generate market data. The target population composed of all traders involved in banana fruits trade in all the markets in western Kenya. The first stage involved purposive sampling of four counties based on levels of banana production and sell. Kisii and Bungoma counties were net exporters while Trans Nzoia, Busia, Uasin Gishu and West Pokot were net banana importers. The second stage involved random sampling of all active banana markets. The final stage involved the choice of the respondents using the linear systematic sampling technique. A list of banana traders (sample frame) was made with the help of local government officials (Ministry of Agriculture, Livestock Development & Fisheries staff and County Government staff) who were in-charge of the various markets. The sample frame was established before the actual survey began in each market. The number of banana markets sampled were; 72 (Bungoma), 69(Dubois et al.), 27 (Trans Nzoia), 11 (Uasin Gishu), 6 (West Pokot and 5 (Busia). Sample size computations are important in ensuring that estimates are obtained with required precision. An estimated sample size of 190 were chosen using Cochran (1963)'s sampling formula (Equation 6-1) based on 2009 human population census (RoK., 2009).

$$n = Z^2(1-p)p \big/ e^2 \qquad 6\text{-}1$$

where *n* is the sample size, *Z* is the desired confidence level, *p* is an estimated proportion of an attribute that is present in the population in this proportion of banana traders in Kenyan markets, and '*e'* is the absolute size of the error in estimating '*p'* that researcher adopted. From previous studies it assumed that about 25% of all traders in western Kenya are engaged in banana trade. Against this background, the sample size was computed at 95% confidence interval with ± 3% margin of error. The sample size was approximately 188 traders (Equation 6-2).

$$n = \left((0.95^2(1-0.25)0.25) \big/ 0.03^2 \right) \approx 190 \qquad 6\text{-}2$$

The data collection clerks were selected based on their good knowledge from on the local markets and banana markets. They were also selected based on fluency in the local language/Kiswahili. They were trained for three days on survey design/implementation and were allowed to pre-test the questionnaire in the neighbour markets that were not in the study area.

6.2.2 Data Collection

The study was based on primary data collected with structured questionnaire from a cross-section of cassava farmers. Data collected included demographic characteristics of the farmers; socio-economic, living standard and farm-specific variables; as well as income and expenditure variables.

Data for the study were collected from both primary and secondary sources. Primary data were collected with structured questionnaire, Personal interviews and direct observations were conducted. Data for banana traders (wholesalers and retailers) included quantities of banana fruits sold, market cost and selling prices, pricing strategies, sources of banana products, problems encountered, market information sources, market channels, personal characteristics of traders, distance to markets, sources of funds and personal characteristics of traders. Data collected were analysed using descriptive and inferential statistics. The descriptive statistics such as frequencies distribution and percentages, mean, standard deviation, and variance were used and Tobit model.

6.2.3 Tobit model specification

One of the major decisions of banana traders is how much of the banana fruits to sell influences the profits. The purpose of the study was to assess the factors that influence the level of magnitude of market participation among banana traders. It was hypothesized that trader characteristics, Institutional factors, biophysical factors look at factors that influence the level of banana sales.

In consumer theory, utility is a relative measure of satisfaction after consumption of goods (e.g. banana fruits) or services. Utility functions give us a way to measure traders' preferences for capital accumulation and the amount of risk (by investment in banana business) they are willing to undertake in the hope of attaining greater wealth through banana sales. Traders make decisions about what crop to trade, how much to trade, when and where to establish and sell the sell banana fruits in such a manner that they get maximum satisfaction.

Traders' behaviours are based on the basic idea that they aim at maximizing a utility function subject to availability of resources for investment (e.g. initial capital, market information, stores, education) or budget with which to satisfy benefits they receive. In this study the Traders maximize the utility (U_i) by buying and selling banana fruits (U_{Trd}). Thus, a trader rationally engages in banana trade if utility from profits received from banana trade is greater than a given threshold. The more the quantity sold the more the profits.

In this study the traders maximize the utility (U_i) by selling more produce to consumers (U_{Trad}) in an effort to maximize profits (U_π). Thus, a trader rationally sell more and more banana fruits if and only is total utility is increasing from the enhanced sales (TU_{sales}). This decision is influenced by a number of factors (U_X) (e.g. investment costs, sources of cash,), as shown in equations 6-3.

$$Max - TU_{Trad} = F(U_X, U_{uo}) \qquad 6\text{-}3$$

This is subject to resource (Cash, profits, and marketing strategies) constraints.

Where TU_{trad} is the Total utility derived from total banana sales, U_X is the banana sales while U_{uo} is the unobserved factors and *F* denotes function of. The Tobit model or censored normal regression model for situations in which *y* is observed for values greater than 0 but is not observed (i.e. it is censored) for values of zero or less (Adenegan *et al.,* 2012; Greene, 2003). The standard Tobit model is given in equation 6-4.

$$Y_i{*} = \beta_0 + \beta_i X_i + \varepsilon_i \qquad 6\text{-}4$$

where $N(0,\sigma^2)$ *i*, Y_i*=quantity of banana sold in kg. These quantities were observed only for traders who participated in the market. β_{1i} =parameters to be estimated. ε_i=error term. The independent variables specified as determinants of volume of banana sold/intensity are defined as X_i. Thus *Xi* =vector of explanatory variables included in the model as shown in Table 6-1. The variables were hypothesized to affect the level of market participation. The variables were derived from empirical literature review (Kabunga *et al.,* 2014) and researcher's reconnaissance experiences. With *Y* representing the volume of sales in kilogram while the X_i represents the explanatory variables where *Y* = Value of total banana produce handles and X_1 X_2, X_3... X_{19} were independent factors. The variables are as described in Table 6-1. Several functional forms (ordinary regression, Cobb Douglas and Tobit models) were fitted onto the data set and Tobit was best fit. It was specified as in Equation 6-5 and 6-6.

$$Y = 0 .... If .. Y{*} = \beta_0 + \beta_1 X_i + \varepsilon \leq 0 \qquad 6\text{-}5$$

$$Y = \beta_0 + \beta_1 X_i + \varepsilon ... If .. Y{*} = \beta_0 + \beta_1 X_i + \varepsilon \geq 0 \qquad 6\text{-}6$$

For ease of interpretation, the marginal effect for Tobit model was computed as shown given in equation 6-7.

$$\frac{\partial Y}{\partial X} = \alpha \left(\frac{\beta_i X_i}{\sigma} \right) \beta_i \qquad 6\text{-}7$$

This is interpreted as, a one unit change in an independent variable X_i and its effects on the observations.

Table 6-1: Definitions and hypothesized sign of the variables

Variable name	Description	Expected sign
LNintagres~1	Log of age of HoH (LNintagres~1),	±
LNq11sellp~2	Banana selling price per bunch(LNq11sellp~2),	+
LNq6estdis~1	Log of distance to the nearest market (LNq6estdis~1),	-
LNprofit	Log of profit received by traders (LNprofit),	+
Aqrdln	Used loan as initial source business (aqrdln),	+
Srcfnd	Friends as initial source of cash for business (srcfnd),	+
Sxown	Sex of trader (sxown), 1=male; 0=female	+
Othertraders	Other traders as market information source (othertraders),	-
Phones	Use phone as market information source (phones),	+
Ripening	Ripening banana (ripening),	±
Kisicode	Traders in Kisii banana markt (kisicode),	+
Westcode	Traders in western region (westcode),	+
Educrpim	Primary level of education for trader (educrpim),	+
Educrsec	Secondary level of education for trader (educrsec),	+
Educrtert	Tertiary level of education for trader (educrtert),	+
Vehiclecode	Vehicle as main mode of transport (vehiclecode),	+
Bicyclecode	Bicycle transport as main mode of transport (bicyclecode),	+
motocyclec~e	Motor-cycle as main mode of transport (motocyclec~e)	+
Wholesaler	Wholesale in banana (wholesaler)	+
Awareness	Retailer (awareness).	+

6.3 Results and discussion

6.3.1 Socioeconomic characteristics of traders

The descriptive statistics of sampled traders are shown in Table 6-2. Out of 190 traders, 97% were business owners and 3% were workers/managers. There were no significant differences between buying and selling prices for traders and wholesalers. However, there was a positive price margin between the two levels for both traders. The wholesaler received a higher price margin (36%) compared to retailers (2%). The average age of the traders was about 40 years. However, the wholesalers had a slightly higher age (40 years) than retailers (39 years). There was significant difference of the distance to banana sources between wholesalers (99km) and retailers (41km). This implies that probably transaction costs are high because of long distances to banana sources. The average period in business was 13 years with wholesalers having stayed in banana trade for more years (14years) than retailers (12years). Further analysis by gender revealed that there were more female traders than male traders. This implies that probably banana trade is more of a women affair than men. Majority of the business visited and interviewed were individually owned (96%) and about 4% were owned in partnership. Majority of both traders (>87%) interviewed had attained primary and secondary education and very few of them (2%) had post-secondary education. There were significant differences ($p<0.05$) in the distribution of the proportion of traders who received loans for banana trade (wholesaler=28.3% and retailers=13.5%).

Subsequently, very few traders acquired loans for business operations and this constraints growth in the entrepreneurship. Training is an important activity for banana trade to keep abreast of new trends and strategies to improve on business practices. There was significant difference ($p<0.05$) between the proportion of wholesaler and retailer traders who received business training. About 24% of the wholesalers and 8% of retailers received training in business entrepreneurship skills. Pooled analysis showed that out 190 traders of about 13.2% received training. This number is relatively low and demands for intervention in order to improve entrepreneurial skills in banana trade.

Table 6-2: General characteristics of sampled traders

Variable name		mean±sd			t-value	χ-square
		Full sample n=190	Wholesaler n=40	Retailer n=150		
Average buying price per bunch		229.7±18.2	220.1±20.5	257.6±38.8	0.90	…
Average selling price per bunch		298.2±25.5	300.0±	261.9±81.7	0.48	…
age of respondent		39.78±11.6	40.4±10.01	39.4±12.4	0.49	…
Distance to nearest market		64.2±11.5	98.7±33.7	40.6±9.2	2.33***	…
Period trading in bananas		13.2±9.7	14.3±10.1	12.4±9.7	1.18	…
% Respondent in West Pokot (N=6)		3.2	66.7	33.3		
% Respondent in Trans Nzoia (N=27)		14.2	18.5	81.5		
% Respondent in Bungoma (N=72)		37.9	20.8	79.2	…	15.67***
% Respondent in Uasin Gishu (N=11)		5.8	45.5	54.5		
% Respondent in Kisii (N=55)		36.3	45.5	54.5		
% Respondent in Busia (N=5)		2.6	20.0	80.0		
% Respondent Acquired loan (1=yes)		18.3	28.3	13.5	…	5.24**
% Respondent by sex of owner	Male	9.7	14.5	7.5	…	2.13
	Female	90.3	85.5	92.5		
% Respondent in by highest educational level	None	8.9	9.4	8.6	…	
	Primary	55.0	67.9	49.1	…	6.51**
	Secondary	34.3	20.8	40.5	…	
	Tertiary	1.8	1.9	1.7	…	
% attended any training in trade (1=yes)		13.2	23.6	8.4	…	7.61**
% Respondent in by banana business ownership	Individual	93.6	90.7	94.9	…	
	Private company	3.5	3.7	3.4	…	1.97
	Partnership	2.9	5.6	1.7	…	
% Aware of TCB technology (1=yes)		54.5	61.8	51.2	…	1.7

***p≤0.01; **p≤0.05; and *p≤0.10 denote significance at the 1%, 5% and 10% levels respectively.

Source: Survey data, 2012.

6.3.2 Market price information behaviour of banana fruits

Producers and traders are direct beneficiaries of the accurate and timely market information and equally timeliness of the same can benefit other actors like consumers. This trend may also lead to market efficiency and enhanced competition among chain actors. Subsequently, producers, traders, and consumers require appropriate market information on the most current banana prices in the markets. In this study, banana information sources were diverse. About 52% of the sample traders used radio as their primary source of market price information (Figure 6-1). The other 33% of traders got information by visiting the markets, 36% through Cell phones and the remaining 24% traders got from other traders dealing with the same commodity (Figure 6-1). This implies that farmers did not rely on a single market information source but multiple. Probably they triangulate the prices from different sources to confirm the reliability and accuracy of the prices (Asiabaka & Owens, 2002). It is recognized that if banana traders had limited market and weak bargaining power partly due to limited market information and seasonality in production. These information sources are prone to low accuracy, inconsistent and delayed transmission for production and marketing decision.

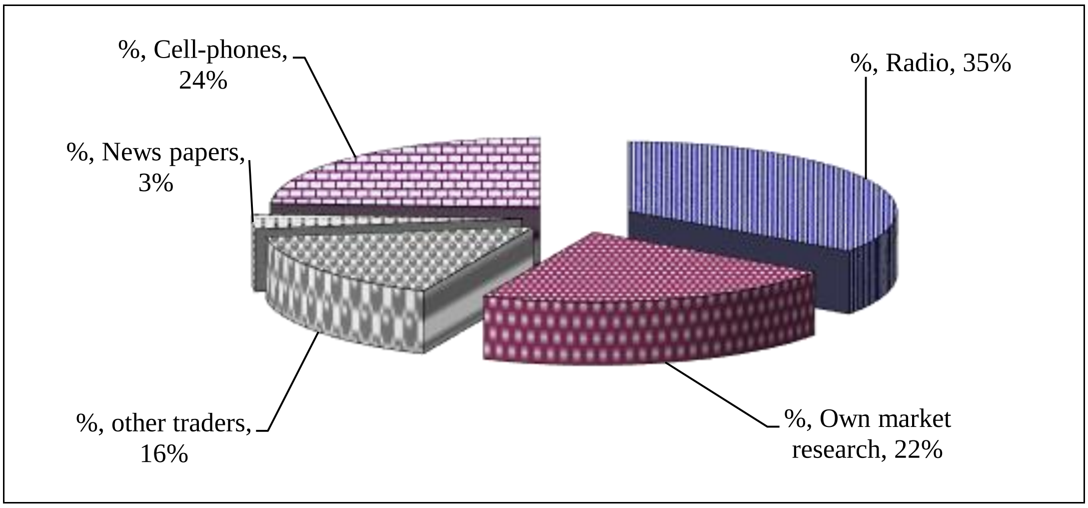

Figure 6-1: Market information sources on banana fruits for traders
Source: Survey data, 2012.

6.3.3 Banana transportation

Effective banana distribution depends on efficient transportation system. The traders interviewed revealed that they used multiple modes of transport. These included; head-load (foot), bicycles, motorcycles, tricycles, cars, and buses. Most of the traders (wholesaler and retailer) used vehicles (57-60%) and bicycles (17-33%) in the transportation of banana fruits and the least was motorcycles (2-12%) (Figure 6-2). The use of multiple mode of transport in metropolis and non-metropolis environments have reported by other authors (Emerole *et al.*, 2007). Solutions to some of these problems require active involvement of both public and private partners. This implies that, road infrastructure need to be improved as one of the initiatives to increase banana production and marketing.

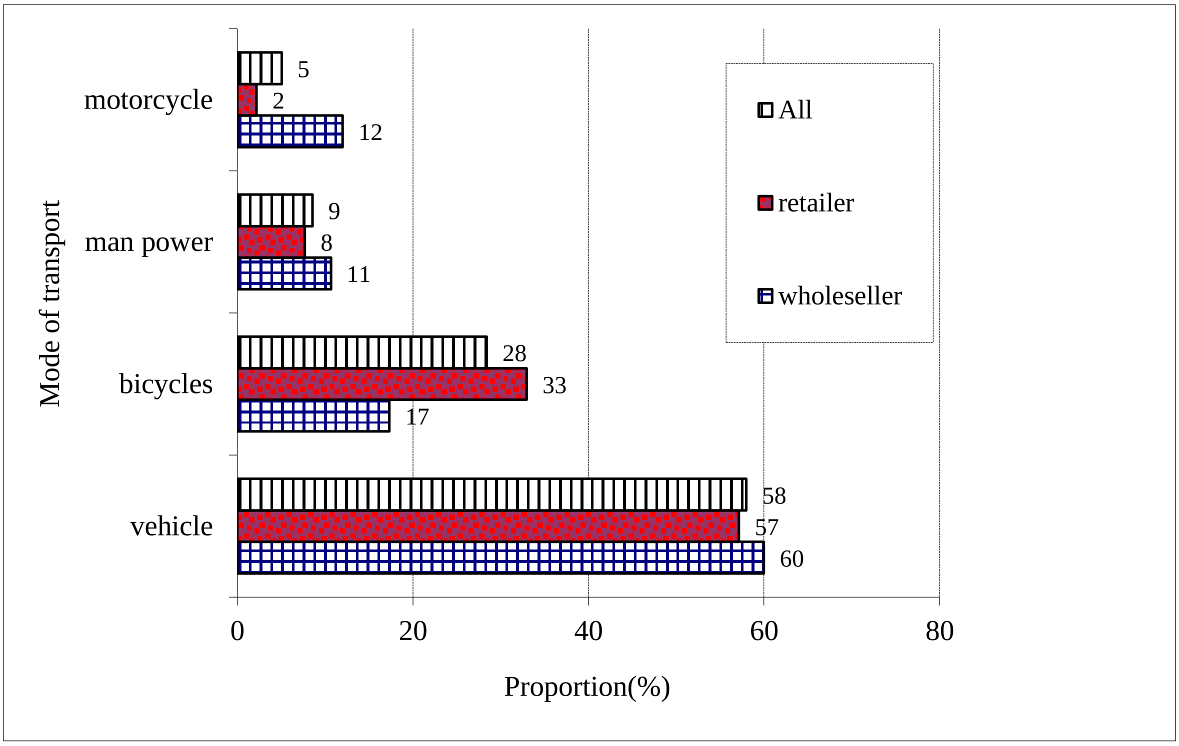

Figure 6-2: Percentage response on mode of transportation for banana trade

Source: Survey data, 2012.

6.3.4 Constraints to banana trade

The banana marketing system in western Kenya is afflicted with diverse problems. The problems noted by traders were lack of premise, high rents, insecurity, bureaucracy, and rent-seeking (Figure 6-3). Some of these problems have been raised in a number of studies in Kenya and outside (Kahangi *et al.*, 2004). These constraints are likely to discourage expansion of banana trade in Kenya. Eventually farmers may not have incentives to invest in innovative technologies like Tissue culture banana. The County and National Government including the private sector support could be geared towards solving the problems for enhanced market efficiency. The use public transportation, private transportation, camel, donkeys, and head load to transfer their goods across the borders to local and regional markets. Private transportation included animal-drawn carts, cars, small trucks and vans, and large trucks.

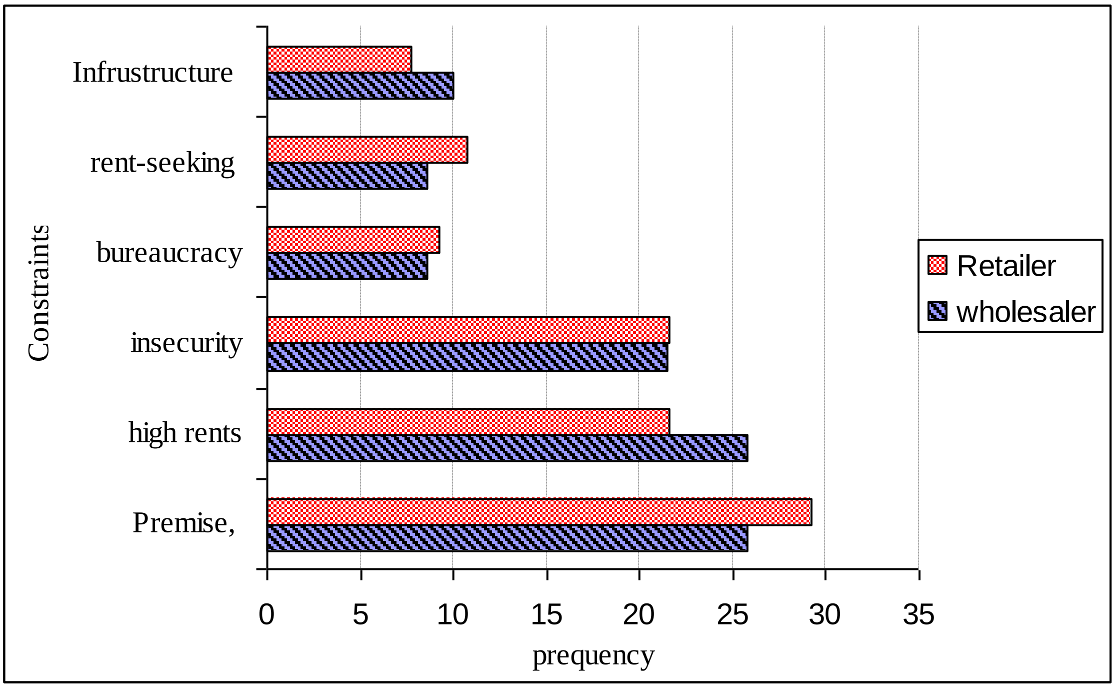

Figure 6-3: Constraints in banana trade

Source: Survey data, 2012.

6.3.5 Determinants of market participation

The Tobit model results are presented in Table 6-3. Some variables were dropped during the estimation process because of multicolinearity. The estimated result showed a good fit with R^2 of 0.43 and F-ratio that is significant at $p \leq 0.001$ level. This implies that the explanatory variables jointly explained about 43% of the variation in the dependent variable. The results of the model revealed that only five variables were significant. The explanatory power of the specified variables as reflected by Pseudo R^2 value (13.4%) of the censored Tobit seems to be relatively low. This is relatively low but it is common among survey studies though this value is outside the values of 0.2 to 0.4 are considered as highly satisfactory. Age of the trader had a negative and significant effect on intensity of banana sales. One percentage increase in the trader's age would decrease the intensity of banana sales by about 17%. This is probably because as traders increase in age they divest into other business activities other than banana.

The variable distance to banana market (LNq6estdis~1), was positive and significant, ($p \leq 0.10$). One percentage increase in distance to banana fruits markets would increase banana sales by about 4%. The more the distance to the product markets sources the more banana sales handled by traders. This could be because traders who transport banana from far tend to use relatively big trucks for transportation. Bulk transportation reduces transportation cost per unit.

Therefore, this demands for the good road systems network to give incentives for traders to engage in the activity. In addition, there should be good packaging done to avoid losses. Similar observations on bulk transportation have been made by other authors (Vigneault *et al.*, 2009; Wasala *et al.*, 2015).

Being a male trader reduces the likelihood increasing volume of banana sales compared to female traders. One percent increase in the proportion of male banana traders reduces banana sales by about 47%. Probably this could be attributed to the fact that there are more female banana traders than men who have specialized in the business.

Market information sources are key performance indicators for traders. The market information source from other traders (othertraders) had a negative effect on volumes of traded. This implies that those traders who relied on market information from other traders tended to sell less volumes of banana. This could be attributed to market competition among traders.

Cooking and ripening are the main types of banana consumed in green and ripe stages. The coefficient on type of banana dealt by traders was negative a significant. This revealed that trading in ripening types (ripening) tended to reduce the volumes of banana sold compared to dual and cooking banana. This could attribute to probably the low shelf life (and losses) of ripening banana which discourages traders from dealing in them. This may imply that probably traders dealing in more volumes of cooking banana compared to other types. This could be attributed to non-duality (sold as cooking and ripening) of the same unlike the cooking banana fruits.

Being a wholesaler (wholesaler) enhances the likelihood of trading in larger volumes of banana compared to being a retailer. The wholesalers normally deal in large volumes probably due to the resource and experience they have compared to retailers. However, some wholesalers were engaged in retailing business. This practice enhanced their ability to sell more fruits of banana volumes.

Table 6-3: Determinants of market volume of sales/participation – The Tobit model

Variable	Coef.(SE)	ME(SE)
LNintagres~1	-0.313(0.1794)*	-0.165(0.0946)*
LNq11sellp~2	-0.196(0.1872)	-0.103(0.0986)
LNq6estdis~1	0.072(0.0425)*	0.038(0.0224)*
LNprofit	-0.029(0.0334)	-0.016(0.0176)
Aqrdln	0.110(0.1609)	0.059(0.0884)
Srcfnd	0.026(0.0472)	0.014(0.0248)
Sxown	-0.897(0.2067)***	-0.472 (0.111)***
Othertraders	-0.561(0.1571)***	-0.315(0.095)***
Phones	-0.110(0.616)	-0.056(0.302)
Ripening	-0.378(0.190)**	-0.182(0.084)**
Kisicode	-0.032(0.194)	-0.017(0.101)
Westcode	0.241(0.178)	0.129(0.097)
Educrpim	-0.255(0.198)	-0.135(0.105)
Educrsec	-0.078(0.211)	-0.041(0.109)
Educrtert	0.019(0.467)	0.010(0.248)
Vehiclecode	0.065(0.188)	0.034(0.099)
Bicyclecode	0.221(0.190)	0.119(0.105)
motocyclec~e	0.197(0.313)	0.1098(0.184)
Wholesaler	0.533(0.156)***	0.311 (0.100)***
Awareness	-0.119(0.136)	-0.063 (0.073)
Cons	4.316(1.264)	1.822
/sigma	0.818(0.042)	0.7352
No. of obs.	190.000	
Prob > F	0.000	
LR chi2(16)	52.43	
Prob > chi2	0.000	
Pseudo R2	0.098	
Log likelihood	-240.992	

Notes: ME means marginal effects.

***p≤0.01; **p≤0.05; and *p≤0.10 denote significance at the 1%, 5% and 10% levels respectively;

Source: Survey data, 2012.

6.4 CONCLUSION

This study examined various characteristics of Banana farmers in western, Kisii and north rift regions. Most of the trader's initial sources of funds were from their own sources followed by loans. Traders received market information from multiple sources probable to check on the reliability and accuracy. The traders also received banana fruits from multiple sources. The results of the regression showed that the age of the trader, sex of trader, distance to markets, type of banana and fellow traders as information sources, and wholesaling and mode of transport (motor vehicle and bicycle) used significantly influence the volume of banana fruits handled by traders. The multiple constraints identified require public-private active involvement. This implies that the interventions may be different in different regions. Some target zones and traders may demand increased production in order to enhance supply while other areas may not. The findings from this study also indicated the need to increase trader participation in banana trade, as the volumes dealt were low. Therefore, based on the study findings, some of the suggested policy recommendations include the need to fostering development of banana infrastructures and effort should be geared towards improving market information sources among traders.

CHAPTER SEVEN

7 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Study aims and objectives.

This Chapter contains a summary, conclusions and implications of the adoption, cultivar preferences, and adoption of TCB on target groups. The purpose of this chapter is to summarize and discuss the thesis research and suggest research and policy recommendations including areas further analysis. The first section of the chapter will discuss the objectives of the research and the methodology used to accomplish the analysis. A summary of the major results are described. The second part of the chapter will discuss policy implications of the research and propose recommendations for further research impact and challenges of TCB technology

7.2 Summary

Food security and poverty are major problems afflicting the majority of the population of Kenya and other Sub-Saharan African countries. Banana is one of the crops that contribute to alleviating food security and income generation of many Kenyans. One of the interventions to these problems is through increased production of food crops through innovations like biotechnology. TCB innovation was introduced and up-scaled during the last two decades ago to contribute to food security enhancement and poverty alleviation among the Kenyan population. There are about 12 TCB cultivars that were developed and up-scaled in Kenya. The power of technology like TCB is manifested in its ability to solve food security and poverty problems currently witnessed in Kenya. This can be done through continuous monitoring and evaluation of the performance of the technology in order to inform various actors along the value chain on the successes and challenges. The actors having varying knowledge on accumulated benefits of TCB. The objectives of this study were to: analyse factors influencing farmers' uptake of TCB technology, examine factors influencing farmer knowledge, attitude and preferences to TCB, investigate the extent to which TC banana technology has impacted on farmers' welfare and asses determinants banana traders' intensity of participation in the fruit markets.

Review of literature showed currently there are about 600,000 ha of banana acreage in Kenya, the number of banana farmers are estimated to be about 2.9 million, an increase from about 380000 in 2004 as documented by Njuguna *et al.,* (2010). Previous studies on performance of TCB and related aspects have shown varying performance including perceptions on the innovation.

The final beneficiaries of TCB promotion were the households as producing and consuming units. One of the qualities of successful farmers is the ability to acquire and apply innovations and other agricultural entrepreneurship skills on their farms. One of these agri-entrepreneurship skills was the adoption of TCB innovation. For example despite the declining farm size in central region and other parts of Kenya, farmers intercrop TCB crop with other crops like coffee, maize, beans and other annual crops (Mwangi, 2011). The perceived impact of the target communities could only be enhanced if TCB adoption is fully adopted. One of the options to assess the impact was to assess the adoption then evaluate the impact.

Chapter five dealt with adoption while chapter six dealt with impact of TCB on the target communities. Subsequently, this study has contributed to banana industry by identifying the factors that influence the likelihood of and intensity of TCB technology adoption using the double hurdle model and assessing the impact of TCB using PSM among farming community in Western Kenya. The study revealed that the TCB adoption has had a significant impact on among the farming community in terms of duration of eating banana in households, quantity of banana produced and amount of income generated per household growing TCB.

Double hurdle model was used to analyse factors influencing likelihood and intensity of TCB adoption. The assumption was that farmers make two decisions in TCB adoption. The results showed that these two separate decisions of likelihood and extend of TCB adoption were determined by sets of factors of which some were the same and others different. The analysis showed that the variables that significantly influenced the probability of TCB adoption were availability of TCB planting material (probability and intensity), proportion of banana income to the total farm income (intensity), per capita household expenditure (probability), and the location of the farmer in Kisii County (probability), farmer location in Bungoma (Intensity). The availability of TCB planting material (q8tcavl) significantly influenced both the decision and intensity of TCB adoption. Majority of farmers use TCB suckers to expand their banana orchards. This shows that the supply of TCB planting material needs to be enhanced. Despite the opening up of new TCB Laboratories in other parts of the country like in KALRO Njoro, KALRO Kakamega, the demand for TCB plantlets may not have been made. Based on this scenario, there could be need to open up more TCB laboratories in Western Kenya and other parts of Kenya. This will not only reduce the transportation costs of moving TCB plantlets to farmers but also increase quantities supplied to farmers. This correlates with the distance to the significant effect the distance to TCB source significantly influencing intensity of adoption.

In order to assess farmers' preferences of TCB cultivars a nested multinomial model was utilized to take care of cooking and ripening of the cultivars. It is important to understand the farmers' preferences for TCB cultivars and link the same to the market demand. The understanding of the factors influencing farmers' preferences given in this study offers insights to biotechnologies and change agents to enhance dissemination. The results of this chapter revealed that farmers preferred banana cultivar because of certain attributes they had. Some cultivars were limited in some and this contributed to their low preferences. The highly preferred TCB cultivars were Grand naine, Ng'ombe, Chinese Cavendish, Uganda green and Williams Hybrid. The least preferred were Gold finger and Solio. A number of these attributes were identified and important in choice of different banana cultivars. The important attributes revealed were; disease tolerance, pest tolerance, yield potential, sweetness, cookability, lodging, finger size, finger length and bunch size. The other attributes included feed, drought tolerant, maturity period, ripening, and storability. The key factors that significantly influenced the cultivar preferences education level, years of planting banana, benefits, revenue generated (yield), and age. These results in resonance with other studies conducted and can be utilized to enhance the up scaling of the TCB in Kenya.

Farmers as producers and consumers of banana fruits and derived products also looked for the specific varietal attributes, such as pest tolerance, disease tolerance, yield potential, sweetness, cook-ability, lodging, suckering ability, finger size, finger length, bunch size, feed potential, drought tolerance, maturity period, ripening quality and storability (shelf-life). The finding suggest that farmer perceptions of technology-specific characteristics significantly condition technology adoption decisions is consistent with recent evidence in the literature, which suggests the need to go beyond the commonly considered socio-economic, demographic and institutional factors in adoption modelling.

The results of this study give rise to three broad, interrelated sets of recommendations: (1) to enhance supply of TCB cultivars, (2) the banana cultivars to be supplied should meet the attributes revealed by farmers and to provide farmer/consumer education and information on the TCB cultivar attributes including agronomic practices. Subsequently these attributes need to be integrated in generation and upgrading of banana cultivars for enhanced adoption and impact on the target groups.

In order to assess impact of TCB on farmers' welfare, PSM technique was used. TCB innovation is a noble technology, which is rapidly expanding in Kenya and has a huge potential substantial promise increase production and supply of banana. It was hypothesized that the innovation will have significant impact on Kenyan population. The results revealed that although the adoption of TCB technology was low, it has a significant effect on target population in terms of income generation, food security, and production as shown in Table 6.4. The enhanced impact could be attributed to the superior TCB technological attributes of early maturity, higher yield, and having pest free orchards, which makes out-yield the conventional banana production. However, the full impact is not fully achieved because there is still a lot of room to further expand the TCB area in the country. Some of the factors hindering the attainment of the higher impacts range from personal, farm, socio-cultural and institutional factors. Some of these variables include farmer perceptions as influenced likert scale rating index of the technology, family size, employment status, farm size, income level, input availability (planting material and fertilizer), distance to markets, dissemination methods and location of the farmers. All these factors influence the deployment of TCB technology to farmers and therefore may be considered in the upgrading strategy of TCB in the banana value chain.

Past research focused more on production-enhancing technologies without due consideration to market of banana markets. Descriptive statistics and Tobit model was utilised to analyse the factors influencing the intensity of trader participation in fruit markets. Banana traders both wholesaler and retailers play a significant role in banana markets. In Kenya, the banana market is not fully developed and a number of factors are hypothesized to affect traders engaging in trade. The results showed that traders received market information from multiple sources. It has been revealed that market information is not fully availed to actors in the market. Against this background, traders check on the reliability and accuracy of the market information received by using multiple sources. The results of the Tobit regression showed that the age and sex of traders, distance to markets, type of banana and information sources significantly influence the volume of banana fruits handled by traders. Therefore, based on the study findings, some of the suggested policy recommendations include; the need to foster development of banana infrastructures and efforts be geared towards improving market information sources among traders.

A number of challenges and opportunities for further technological, institutional, and organizational innovation exist for upgrading the TCB technology. The main challenges faced in TCB technology adoption and banana production in Kenya include the following:

Lack of post-harvest processing pathway

Many farmers during survey time expressed an interest in expanding the production of bananas through growing of TCB, but their interest to engage in it is closely tied with the presence of efficient marketing and processing. Currently, farmers sell their banana to local traders for their household consumption needs. However, the absence of banana processing factories to get value added products like flour, starch, and wine could act as pull factors to adoption of productivity enhancing technologies like TCB. This demands that such processing and storage infrastructure.

Limited access to and supply of TCB planting material

The most important physical inputs for banana production is availability of the planting materials, manure, and inorganic fertilizer. This has been one of the challenges identified by previous studies and addressed by subsequent interventions. However, there is an overwhelming demand for the plating material and there are occasions when the supply could not meet demand for some specific cultivars like Williams Hybrid. The cost of plantlets could also be contributing to the use of TCB suckers to extend the technology. The price of TCB has continued to increase over time (see Figure 3-3).

Planting TCB and non-TCB in the same fields

Disease, pests and fertility in banana orchards are some of the key problems given that banana is a perennial crop. In the study area, there was problem of limited access to manures and fertilizers in sufficient quantities. In some small-scale farms, banana stools are close to the homestead and receive some household waste as manure. The quantity and bulkiness of manure, which is an integral part of banana production, could be constraining the enhanced productivity of banana.

Market problem

Marketing is one of the factors for technology adoption for enhanced production. The results revealed that the banana market is not competitive among markets. In addition, most of banana is sold to middlemen who eventually sell it to consumers. There are no set standards for banana fruits and no regulatory system is in place unlike for the cereal crops (Kahangi, 2010). The price volatility over seasons reduces farmer profit margins. As exemplified by Qaim (1999) and Kahangi, (2010), lack of organized transport system to limit losses further constraints enhanced banana production. Furthermore, there is limited information on market prices constraint banana production. Innovativeness among groups has led to value addition through banana processing in Uganda and India through beer processing among other products. This should be emulated in Kenya. If these problems are addressed, then banana production is likely to be improved.

There are opportunities for TCB technology adoption and banana production in Kenya**.** The increasing banana consumption with current per capita consumption of about 240-400 kg per person per year (translates to 1-3 banana fingers daily) creates a favourable environment for enhanced production. There is the potential for increasing banana production in Kenya through enhanced upgrading of the banana value chain in Kenya. This included continued up scaling and out-scaling of the TCB technology. The value addition through processing of surplus banana fruits and by-products is an option. This will demand extensive training on these aspects. This is a weak and missing link that requires significant and prompt investments. The intervention can be made through private and public domain. This will require enhanced participation of key stakeholders and full support of both County and National Governments. These are some of the innovation that can act as pull factors for farmers to adopt new banana varieties for enhanced production. This has been proposed and practiced in countries other parts of the world where banana industry advanced like India, and Philippines (Pilkauskas, 2002) where processing is taking off.

7.3 Implications of the study findings

Based on the results the technology developers and disseminators need to mitigate negative factors that impede TCB adoption and promote those ones that enhance adoption. Subsequently, the TCB disseminators need to utilize farm, farmer, environmental factors, technological attributes (traits), and environmental factors targeting interventions. This will fine-tune the targeting of TCB intervention strategies for enhanced adoption and impact. In addition, integration of both national county governments in up scaling enhance TCB technology would enhance adoption probably by having TCB nurseries in each county. There is need to increase farmer extension contact probably by employing more extension personnel or utilizing extension strategies that enhance extension services to farmers through ICT. This can be done by using platforms of mobile service providers. In addition, training of farmers on TCB benefits and management of banana orchards might enhance likelihood and intensity of TCB adoption and reduce negative perceptions about the technology. Farmers also need to be sensitized on the importance of seeking extension services regularly for technical support and use productivity-enhancing technological components like application of farmyard manure, effective pest/disease management.

7.5. Suggestions for further research

This study was carried out in four counties in north rift, western and Nyanza regions. Similar studies have been carried out in Central and other regions of the country. The potential impact of the use of TCB bananas for enhanced production is high. However, there is need for assessing the potential for starting industrial processing of bananas given their perishability and less-exploited export markets. Processing banana products into starch juice and wine should be explored as new innovation of TCB options come in the forefront to enhance its production. In addition, specific studies on sensory evaluation and consumption patterns of banana cultivars/types could be carried out to assess consumer preferences.

Cross-border effect in banana trade is another area of research that can be undertaken given the amount of bananas imported from Uganda. The challenge of poor regulatory systems in banana trade that comes from Uganda is another area of research that could be explored further. In addition, an in-depth analysis of gender roles in banana farming systems is necessary to determine how interventions, such as TCB technology and training, could influence a shift in gender roles and increase benefits to women and men. Given the importance of banana in household consumption, the analysis should explore the impact of the shift in roles on household food security and decisions concerning the production and marketing of banana.

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APPENDICES

Appendix 1. Household survey questionnaire on TCB impact along APVC in Kenya

Section A: General information

1. Socio-economic and demographic characteristics of households

Variable	Response
Indicate district name (DSTR)	
Indicate division (Secretariat of the Convention on Biological Diversity.)	
What is Village/Farm name?	
Data collected by (ENUM)	
Respondent's data (RESP)	Name…………….Sex…. Age……… Education…Main occupation……..
Household head's data (HHH)	Name…………Sex……. Age……. Education…Main occupation…….
What is Household family size by gender (FAML)	…….……………………
Indicate Type of Farmer (Tick) (TFAM)	Contact farmer (TCB)………….. Counterfactuals ….
Period of TC banana technology (TCBP)	Year TC banana started…… Year discontinued TC banana……

2. Farm characteristics (Natural capital) Ask questions and fill the table appropriately

Variable	
What is total Farm size in acres (TFARM)	
What is the ownership status Land tenure system (TEN) (1=Owned with title; 2=Owned without title; 3 Communal; 4=Rented; 5=others specify…….)	
What is the acreage under arable land (acres) ARAB)	
What is dominant Soil type and colour (SOILT)	
What is overall fertility levels of the farm (1=low; 2=medium; 3=high) (FERT)	

3. What livelihood strategies are you engaged in?

Name of Livelihood strategy	BEFORE TCB	AFTER TCB
Honey production		
Agricultural wage (AGWG)		
Non-agricultural wage (NAGWG)		
Food for work (FFW)		
Petty trading (PETCS))		

Handicraft (Diaz)		
Transport services TRAP)		
Grain mills (GRANM)		
Fishing S		
Hunting and gathering of wild fruits (HUNT)		
Selling fuel and charcoal (FUCHAC)		
Selling prepared drinks (SDRINK)		
Professional work (PROFW)		
Traditional medicine (MEDT)		
Rent income (RENT)		

Section B: Banana production

4. What are the key farm enterprises on your farm? (enterprise combinations and production)

Ask questions and fill the Table appropriately

Crop and forage/pasture	Tick	What was last year yield per unit area	What amount was sold	At what Price/unit	Who was Buyer
Banana (BAN)					
Maize MAZ)					
Beans (BEN)					
Ground nuts GNUT)					
Finger millets (FING)					
Sorghum SORG)					
Napier grass (NAP)					
Sugarcane (SUG)					
Coffee (COFE)					
Green grams GRAM					
Tea					
Wood lot (WOD)					
Pyrethrum (PYRE)					
Others specify -------					
	Number	Yield levels/annual (milk, eggs)	Amount sold/annual	Average Farm gate price	Buyer
Cattle					
Sheep					
Goats					
Poultry (POLT)					
Others specify…….					
Others specify……					

5. What kind of banana do you plant on your farm? (BNKIN) 1=cooking [ ] 2=ripening; 3=dual [ ]; 4=others specify _____[ ]
6. Do you plant any TC banana on your farm? (PTCB) tick one [ ] 1=yes; [ ] 0= no (If no go to table of Q11 column 4)
7. If you plant TCB what did you use as your planting material? (TCMAT) TC plantlet [ ]; sucker[ ]
8. What was the buying price? (BPRICE) KES ________TC plantlet __________Sucker

9. What was the source of cash? 1= credit [ ]; 2=own savings [ ]; 3=farm sales [ ]
10. What kind of TC banana do you grow? (TCKIND) Cooking [ ]; Ripening [ ]; Dual [ ]
11. What was the source of planting material? (TCSOC) Own [ ] Nursery [ ]; others specify
12. If plant TCB fill the table below

What TC banana variety do you grow? (TCBCG?)	No of stools (TCSTL)	What is the annual yield (TCYLD)	What type of Non TC banana do you grow? (NTCG)	What is the annual yield? (NTCYLD)

13. If not planting TCB why? ____
14. If not planting TCB are you willing to start planting TCB? [ ] 1=yes; [ ] 0= no
15. What TCB varieties do you know but you do not grow them?

Banana varieties you know but growing (BVARNG)	Why not growing it? (WHNGVAR)

16. Agronomic of banana management

Technological component	Response
What was the banana hole size (HOLZ)	
What is the banana spacing (give the units)	
What quantity of manure was used during planting (MANQ)	
What is the frequency of manure application after planting MANFREQ	
What type of organic was used during planting	
What quantity of inorganic fertilizer was used during (INORG)	
What type of inorganic fertilizer use used	
What is the frequency of inorganic application MANFREQ	
Do you do any pruning (PRUNPER)[ ] 1=yes; [ ] 0= no	
When do you do pruning (PRPER) 1=dry season; 2=rainy season	
What is the frequency of weeding per year? (WEDFREQ)	
Do you do de-suckering? [ ] 1=yes; [ ] 0= no	
How do you do the de-suckering? (HDESK)	
How many plants are left on one stool (PLNTSTOL)(give numbers)	
What is the frequency of de-suckering? Give time also	
Do you mulch the bananas? (MULCH)	
What is the mode of weeding? 1=Manual; 2=Herbicide; 3=Both	
Do you practice any irrigation done? (IRIG) [ ] 1=yes; [ ] 0= no	
If yes what is the water source for irrigation	
Do practice earthling up of bananas? (EARTH)	

17. Do you experience any banana **pests**? [ ] 1=yes; [ ] 0= no, diseases? [ ] 1=yes; [ ] 0= no

Pests	Response
Do you experience any pests on bananas (BPES) [ ] 1=yes; [ ] 0= no	
If yes what type of pests? (PESTP)	
Do you control the banana pests? (COPEST) [ ] 1=yes; [ ] 0= no	
If yes what type of pesticides do you use? (PESTYPE)	
Diseases	
Do you experience any diseases on bananas [ ] 1=yes; [ ] 0= no	
If yes what type of disease do you experience? (DISE)	
Do you control the banana disease? (CODISE) [ ] 1=yes; [ ] 0= no	
If yes what type of fungicide do you use? (DISFUNG)	

18. What costs do you incur in banana production?

Banana production costs (KES) (1=TCB; 2=NON TCB)															
(1=TCB; 2=NON TCB)	Acreage/ number stools	Land preparation		Planting						Weeding/ De-suckering/pruning		Pest control		Harvesting	
		Type	Cost	Plant material		Fertilizer/ Manure		Labour		Labour		Chemicals		labour	
				Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost

19. Rate banana cultivars you grow based on the characteristics in the table (1=Poor; 2=Good; Excellent)

Cultivar	Disease free	Pest free	Yield	Sweetness	Cookability	Lodging	Suckering	Finger size	Finger length	Bunch size
Grand naine										
Williams hybrid										
Giant Cavendish										
Dwarf Cavendish										
Chinese Cavendish										
Gold finger										
Nusu Ngombe										
Ng'ombe										
Uganda green										
Solio										
Vallery										
Lacatan										
Kisukari										
Bokoboko										

20. Have you made any modifications on TC banana planting? [ ]; 1=yes [ ]; 0= no

If yes What **modifications** were made	Description of modifications	Reasons for modifications	Give Remarks
Use of TCB suckers			
Others specify …			

21. Have you increased acreage/stools under TC bananas plot? [ ] 1=yes; [ ] 0= no

If yes give initial acreage/number of stools	If yes give current (expanded) plot size/Stool number	What were motivating factors	If not expanded why?

22. After planting TC banana what are your current crop production constraints? (fill the table)

List Problem related to TC banana	Rank	What are your Coping strategy	Ranking

23. Are there any changes on size or number TC bananas? [ ] 1=yes [ ] 0=no (tick)

24. If yes what changes are there on TCB on the following aspects?

What is the Change indicator	Before TC banana	After TCB adoption (Current)
Banana production (bunches) annual		
Quantity of banana sales		
Number of months you eat bananas		
Plant vigour		
Banana quality		

25. Do you do any processing on bananas? [ ] 1=yes [ ] 0=no (tick)

26. If yes, what type of products do you make?

Processed product	Processing cost	Selling price

Section C: Food security

27. What is the food security situation in your household before and after TC banana technology practice?

	Before/without TC banana					With TC banana/Current	
Banana type	# of Months with own banana	Source of banana if not enough (1=bought 2=Gifts; 3=Relief; 4=others	If bought indicate source of cash (1=Formal employment, 2=Casual labour, 3=Business, 4=Remittance, 5=others………………..			# of months with food	Source of banana if not enough (1=bought2=Gifts; 3=Relief; 4=others
			Quantity	Price/unit	Trends: 1=Increasing; 2=decreasing; 0=No change		
Cooking							
Ripening							
Dual							

28. Do you experience any food shortage? [ ]yes [ ] no (tick appropriately)

29. If yes which months do you buy food? (household vulnerability)

	Jan	Feb	Mar	Apr	May	Jun	Jul	…..	Nov	Dec
Before TCB										
After TCB										

30. What are your meals and their compositions eaten in the household?

Causes of food shortages on your farm?	Rank

31. What are your meals and their compositions eaten in the household?

	Before TC banana		With TC banana/Current	
Meal	Composition (At harvest)	Composition (When scarce)	Composition (At harvest)	Composition (When scarce)
Breakfast				
Lunch				
Supper				
Others (specify)				

Section D: Income sources and utilization-poverty

32. What are the main sources of income for you and other household members?

Main sources of income	Rank (Before TCB)	Rank (After TCB Current)	Over all changes in last 5 –10 years in amount (1=increased; 2=Reduced; 0=No change, 3=fluctuations)
Farming			
Formal employment			
Casual labour			
Remittances			
Donations (eg Harambee...)			
Credit-formal			
Credit-informal			

33. What are your own-farm income generating enterprises?

Crop and forage	Yield levels /year	Unit of measure	Amount sold /year)	Price/unit	Place of sale	Buyer
Bananas						
Maize						
Beans						
Tea						
Sugarcane						
Horticulture crops						
Coffee						

34. How have you utilized additional income from banana sales (on-farm income utilization and resource endowment)?

Asset type	Acquired thru' farm sales (yes/no)	Units	Price/unit	Trend in the last 5 years (1=increased; 2=Reduced; 0=No change)
Livestock assets				
Cattle				
Sheep				
Goats				
Chicken				
Fixed assets				
Machinery				
Land				
House				
Motor vehicle				
Others specify….				
Household assets				
Utensils				
Furniture				
Clothing				
Others specify				
Farm inputs last year				
Hired labour				
Basal fertilizers				
Top-dress fertilizers				
Seeds				
Chemicals				

35. How much is your annual household expenditure? (Give wise estimates)

Expenditure item	Cost	Units
Food		
Education School fees		
Medical		
Harambee		
Gifts		
Fertilizer		
Seed		
Chemicals		
Labour		

Section D: Dissemination

36. How do you share TC banana information with others? (strategies for sharing information)

Method of sharing information	Tick		
	Before TCB	After TCB	Type of technological components
Demonstrations			
Personal farm visits			
Group meetings			
Tours and exchange visits			
Others (specify)….			

37. How do you source for TCB agricultural information? (sources of agricultural information)

Source	Before TCB (Tick)	After (Tick) TCB	Score on a scale of 1-10 in order of importance
Government extension			
Agricultural Shows			
Print Media			
NGOs (specify)			
Churches			
Radio/Television			
Brochures			
Farmer Teacher			
Follower farmers			
University			
Research			

38. What is your overall opinion on TC banana technology (over-all evaluations of TC banana project)

TC banana strong points	TC banana weaknesses	Suggestions for improvement on the technology

39. What is the over-all quality of life changes in the last 5-10 years

Overall changes in quality of life	0=No change; 1=increase; 2=decrease	Reasons for change
Health		
Education		

Social status		
Clothing		
Housing		
Others specify……………….		

40. What is the most significant change you have had since you adopted TCB?

Most significant Positive	Most significant Negative Change

Section D: Attitudes on biotechnology-TC banana

41. Use of TC banana technology in food production offers a solution to the Kenyan food problem____
42. Use of TC banana technology in food production enhances farmers income generation
43. TC banana technologies have the potential of creating foods with enhanced nutritional value____
44. TC banana technology has the potential of creating food with enhanced nutritional value____
45. TC banana is not GMO ____

Appendix 2. Role and Impact of TCB trader along value chain

Section A. Background information

1. Name of the Business____
2. Name of proprietor ____
3. Type trader (tick) Wholesaler [ ]; Retailer [ ]
4. Name of respondent [optional] ____________________________________
5. Position of respondent [optional]__________________________________
6. Sex of owner[ ] M; [ ] F;
7. Age of respondent (years) ______________________________________
8. Highest Education level: 0=none; 1=Primary; 2=Secondary; 3=Tertiary
9. What are other key sources of income________________________________
10. Trader Contacts:

- Physical Address and Box No. : ___________________________________
- District __________________Town ___________________________

11. GPS: longitude (W/E): __________________ latitude (N/S)______________
12. Have you attended any training on agribusiness? [ ] Yes; [ ] No
13. If yes in Q12, how long did the training take? __________________________
14. What area were you trained in? ___________________________________

15. How is the business owned? [ ] Individual, [ ] Private company, [ ] partnership,[ ] private and public, [ ] other: ____

16. What is the primary activity in your business as a trader? _______________________

17. Which other activities other bananas are you involved in? ______________________

18. Which year did you first start banana trading? ______________________________

19. What were the initial sources of funds to start your banana trade? [ ] Own savings, [ ] Loan, [ ] other business,[ ] Donation, [ ] other: (specify)__

20. Have you acquired any loan for running any TCB activity in the last three years?

[ ] Yes; [ ] No (If no go Q 23

21. If yes in Question 20 how much cash was it? ____________________________KES

22. At what interest rate was the loan? ____

23. If no why? ____

24. Which are your areas of operation for your banana trade? ______________________

Section B. Characteristics of TC-banana traders

1. Year started trading in banana. ____
2. Have you made any investment in your banana business? [ ] Yes; [ ] No
3. If yes, what are the key investments/assets you put in your banana trading?___________
4. Which types of banana do you trade in?

Type of banana	What is trend in quantities of banana traded in last 5-10 years (1=increased; 2=Reduced; 0=No change)
Cooking	
Ripening	
Dual	
All	

5. Who are your banana supply sources?

Source	% of the total purchased from the source	Estimated distance (Heckman)	How do you rate your relationship with them? (1=Very good; 2=Good; 3=Bad)
Large scale farmers			
Small-scale farmers			
Other Traders			
(other specify)			

6. What other services do you offer to your customers mentioned in question 5 above? ____
7. Do you have any contractual arrangement with you customers? [ ] Yes; [ ] No

8. If yes which ones?____

9. Do you do any processing on bananas before selling? [ ] Yes; [ ] No

10. If yes what types of processing/products do you do?

Product	Cost of processing	Selling price

11. How many tons of bananas do you buy and sell annually? What was the average price you purchased the banana (rough estimate)? Give units on amount of banana

Year	Amount of banana bought	Average buying price/ unit	Amount of banana tonnage sold	Average selling price/unit
2011				
2010				
2009				
2008				

12. Who decides on the banana buying price? Seller____ Buyer____ others specify_________

13. What unit measurements do you use in banana selling______ and buying ______________

14. Who decides on the units of measurement to use? ______________________________

15. What are your key sources of banana prices? 1= Other traders; 2=phones; 3=radio; 4=Others

16. How do you rate reliability of this information sources?1=Low; 3=Good; 4=Very good

Source	Tick	Source	Tick	Source	Tick
Other traders		Radio		Millers	
Phones		Newspaper		NCPB	

17. What are your banana buying specifications? *Tick appropriately*

a. Colour ____, bunch weight______, bunch size ______, bunch qualities ______finger size ______, broken fingers _______, others specify_____________________

18. What are the selling requirements specifications? ________________________________

19. After buying banana what processing do you do before selling banana bunches/fingers? ____

20. Do you make any profit? 1=Yes______________ 0=No_____________________________

21. If yes how much? __________________ unit ___________________________________

22. How do you rate your profit margin on banana? (Tick appropriately)

1=Very low___ 2=Low, ____ 3=Medium, _____ 4=high, ____________________________

23. What marketing costs do you incur?

Year	Rent	Cess/levies	Interest on loans	Taxes	Other expenditures
2011					
2010					
2009					
2008					

24. How do you handle the unsold stocks?________________________________

25. In your opinion what are some of the solutions to the above constraints?

Trading Constraints	Coping strategies

26. Do you do any banana grading? [ ] Yes; [ ] No

27. What factors do you consider in grading banana fruits? ___________________________

28. How do you rate the current banana policy to your business? Tick appropriately

Very poor___ moderate, ____ good, _____ Very good, ___________________________

29. How do you package bananas for sale? ____

Section C. Knowledge and perceptions on TCB

30. Have you heard or read something about TCB? [ ] No, [ ] Yes,

31. If yes what was the source of information:______________________________________

32. Please indicate your reasons (for yes or no) in Q31: ______________________________

33. Have you benefited from TCB? 1= Yes; 0=No.

34. If yes how have benefited from it? State ______________________________________

Section D. Attitudes toward TC-banana.

Indicate your agreement or disagreement to the following statements with: (1) Strongly disagree (2) Disagree Neutral (don't know) Agree (Curtis) Strongly Agree

Benefit Perception (BP) (You may explain what TCB technology is)

1. Use of TCB technology in food production increases productivity and offers a solution to the world food nutrition problem____
2. TC Banana technology has the potential of creating foods with enhanced Nutritional value____
3. TC Banana products only benefit multinational companies and other stakeholders in the banana industry____
4. TC Banana products are being forced on farmers by developed countries_______________
5. TC Banana food is artificial____
6. What are your views on the future of TCB in Kenya?

View	Tick appropriately	Remarks
Good for food security		
Good for income generation		
Risks to the environment		
Difficult to penetrate the market		

Section D. Constraints in trade

1. What are your key constraints in banana marketing? ________________________________
2. You may now ask us any questions concerning TC-banana? _________________________

Appendix 3: Role and impact of TCB input suppliers along banana value chain

Section I. General Information

1. Name of the TC banana firm (NAMEF)____
2. Name of respondent (NAMERESP) [optional]_____________________________________
3. Position of respondent [optional] ____
4. Contacts:

   Physical Address and Box No. : ____

   Location/Town ____

   Telephone____

   Email____
5. GPS: longitude (W/E): ________________________ latitude (N/S)___________________
6. Ownership of the firm [tick]: public [ ], Individual [ ], Private company [ ], partnership [ ], private and public [ ], other specify [ ] specify)___________________

7. What are the primary activities of the firm? (PRIMACT) ___________________________
8. What are other activities are the firm is involved in? (OATCINV) ___________________
9. Which year was the firm/business founded? (YEARF) _____________________________
10. Years started producing TC banana planting material (YRSTAT____________________
11. Who introduced you to the business? (PATNA)__________________________________
12. Is the business continuing? 1= Yes [ ]; 0= No [ ]
13. If no why stopped? (STOP)____
14. I f yes, what are the main activities in TC Banana seedling production? (ACTIV)

Initiation [ ], Multiplication [ ], Shooting & rooting [ ], Primary Hardening in green houses [ ]; Secondary Hardening in shade houses [ ].

15. Where did you get your initial sources of funds to start your business?_______________
16. If credit from which institution? (fill the table appropriately)

Source of credit	1=Yes; 0=No	Amount	Interest rate	Have you completed loan repayment?
Non-formal and informal				
Formal				

Section II. Other Characteristics of supplier/Firm

17. Who are your TC banana seedling producers?

Producers	Tick appropriately	Rank them in order of production
Large scale farms		
Medium scale farms		
Own farms		

18. Which are the areas of distribution of firm?

TC banana distribution zones	Districts	Towns/markets

19. Which TC banana cultivars did you produce last year 2012?

TC banana	Annual plantlet production	% annual plantlet sales	Sale price	Where/distribution zones

20. If yes when did you start producing TCB plantlets? [ ]year
21. What quantities of TCB seedlings have been produced in the past 10 years?

Year	Quantities/units	Sell price	Remarks
2011			
2010			
2009			

22. What are the reasons for low sells of some banana cultivars? ________________________
23. What is the TCB seedling buying price from the farmers? __________per_____________
24. What are the buying and selling prices for the following stakeholders along the banana production value chain? ____

Stakeholder	Buying price	Selling price
Wholesalers		
Retailers		
Farmers		
Others specify		

25. What are the key challenges you face in TCB seedling production and distribution?

Section III. Attitudes toward TC banana

Indicate your agreement or disagreement to the following statements with: (1) Strongly disagree (2) Disagree Neutral (don't know) Agree Strongly Agree

7. Use of TCB technology in food production increases productivity and offers a solution to the world food nutrition problem______________________________
8. TC Banana technology has the potential of creating foods with enhanced nutritional value______________________________
9. TC Banana products only benefit multinational companies and other stakeholders in the banana industry______________________________
10. TC Banana products are being forced on farmers by developed countries______________
11. TC Banana food is artificial______________________________
12. What are your views on the future of TCB in Kenya?

View	Tick appropriately	Remarks
Good for food security		
Good for income generation		
Risks to the environment		
Difficult to penetrate the market		

Section IV. Constraints in banana trade

13. What constraints are there in TCB dissemination in Kenya? ______________________
14. What are the coping strategies to the above problems? ______________________

Appendix 4. Role of super markets in banana trader along APVC in Kenya

Section I. General information

1. Name of the Super market (NAMEF) ______________________________
2. Name of respondent (NAMERESP) [optional]______________________________
3. Position of respondent [optional] ______________________________
4. Contacts:

   Physical Address and Box No. ______________________________

   Location/Town ______________________________
5. GPS: longitude (W/E): ______________________ latitude (N/S)__________________

6. Ownership of the firm [tick]: public [ ], Individual [ ], Private company [ ], partnership [ ], private and public [ ], other specify [ ] specify)___________________

Section II. Banana sales

7. Do you trade in banana fruits____

8. Do you trade in banana fruit products? ____

9. If yes what are your trends in banana fruits and their products? ______________________

Year	Banana fruits	Prices	Remarks
2011			
2010			
2009			

10. What other banana products do you sell?

Banana product	Price/unit	# units sold 2009	Remarks

Agree Strongly Agree

15. Use of TCB technology in food production increases productivity and offers a solution to the world food nutrition problem____

16. TCB technology has the potential of creating foods with enhanced Nutritional value_____

17. TCB products only benefit multinational companies and other stakeholders in the banana industry____

18. TCB products are being forced on farmers by developed countries____________________

19. TC banana increases quality of bananas____

20. TCB food is artificial____

21. TC banana will improve the quality of banana products for sale ______________________

Thank you for your time to participate in the survey

Checklists-Focus group

Start a discussion around the following questions:

• What food items do you purchase normally most often, per period (harvest, pre-lean season, lean season)?

• Did the shock alter the type of products purchased, and the timing? How? Why?

• How would your purchase behaviour change if purchase prices were 25% lower, or higher?

• What commodities (including animals) do you normally sell most, per period (harvest, pre-lean season, lean season)?

• Did the shock alter the type of commodities sold, and the timing? How? Why?

• How would your sales behaviour change if sales prices were 25% lower or higher?

Thank you for your time to participate in the survey

Appendix 6a: Multicolinearity

Contingency coefficients for dummy explanatory variables

	q1resex	q1resmar	q1hheduc	edu_pr	edu_none	edusec	ocup_far	occ_off	q2ldten	q2labhr	q2labfam	credit
q1resex	1											
q1resmar	-0.058	1										
q1hheduc	0.043	-0.120	1									
edu_pr	0.047	0.058	-0.690	1								
edu_none	-0.044	0.153	-0.434	-0.216	1							
edusec	-0.110	-0.120	0.292	-0.602	-0.144	1						
ocup_far	0.106	0.127	-0.369	0.338	0.105	-0.218	1					
occ_off	-0.094	-0.068	0.379	-0.32	-0.057	0.089	-0.706	1				
q2ldten	-0.001	0.012	-0.002	-0.002	0.020	-0.030	-0.042	-0.016	1			
q2labhr	0.004	-0.076	0.109	-0.106	-0.052	0.097	0.019	-0.064	-0.027	1		
q2labfam	-0.128	-0.088	-0.200	0.201	0.003	-0.041	-0.046	0.011	0.153	-0.215	1	
credit	-0.009	0.081	-0.064	-0.042	0.1937	-0.064	-0.067	-0.028	-0.122	-0.033	-0.067	1
q17awrtc	-0.01	-0.085	0.034	-0.000	-0.058	0.031	-0.092	0.023	0.174	0.019	0.165	-0.159
q18wsplt	-0.018	-0.139	0.045	-0.029	-0.041	0.050	-0.142	0.068	0.171	0.011	0.166	-0.198

Source: Survey data 2012

Appendix 6b Variance inflation factors (VIF) of the continuous explanatory variables Multi-collinearity test result for continuous variables

	Collinearity Statistics(n=330)	
Variable	Tolerance	VIF
q1hhage	45.99	0.021744
q1hhage2	45.70	0.021882
q2ar_ha	23.01	0.043465
hect	22.95	0.043573
aveindex	1.17	0.851311
overinde	1.17	0.854231
banprop	1.14	0.878695
q1faml	1.08	0.929894
period	1.03	0.966823
q9dist	1.02	0.966823

Source: Survey data 2012

Appendix 6c: Number of banana farmers in Kenya