Socio Economic Impact Assessment of Tissue Culture Bananas in Kisii highlands and South Nyanza in Kenya

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Declaration

I, **Kassim Were Ali** hereby declare that this thesis is my original work and has not been presented for a degree in any other University.

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Approval

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Dedication

This work is specially dedicated to my late father Ali Kubende Were, my mother Zainabu Kubende Nabwoba, my friends from Kenya Agricultural Research Institute in Kisii for their contributions; Kidula, Nasambu and Divina, my late brother Ismael Omukonyi for the encouragement and mentorship.

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Abbreviations and Acronyms

AC	Average Cost
ANOVA	- Analysis of Variance
AR	-Average Revenue
BA	-Benefits After Adoption
BB	-Benefits Before Adoption
BCR	-Benefit Cost Ratio
CGIAR	-Consultative Group of International Agriculture Research
FAO	-Food and Agriculture Organisation
FFS	- Farmer Field School
GIA	-Gross Income After Adoption
GIB	-Gross Income Before Adoption
GMOs	-Genetically Modified Organisms
IDRC	-International Development Research Center
IPR	-Intellectual Property Right
IRR	-Internal Rate of Return
ISAAA	International Service for the Acquisition of Agri-Biotech Applications
ISNAR	-International Service for Agricultural Research
JKUAT	- Jomo Kenyatta University of Agriculture and Technology
KARI	-Kenya Agricultural Research Institute
KAPP	-Kenya Agricultural Productivity Project
MC	- Marginal Cost
MoA	-Ministry of Agriculture
MR	- Marginal Revenue
NPV	-Net Present Value
RF	-Rockefeller Foundation
SPSS	- Statistical Package for Social Scientists
TC	-Tissue Culture

Abstract

Biotechnology can make very important contribution to the socio economic welfare of citizens in developing countries (Qaim, 1999). This study was therefore set up to assess the social and economic impacts brought about by the dissemination of the Tissue Culture banana technology to resource poor farmers in Kisii highlands and South Nyanza in Kenya. The survey purposively selected seven districts where 100 households were interviewed using a structured questionnaire. Data was analyzed using economic surplus model.

The study established that Tissue culture banana technology had a positive social and economic impact in Kisii highlands and South Nyanza. The technology led to an increase by 86 percent in quantity of bananas demanded for the market as compared to the conventional bananas. Increasingly, the bananas were being taken to the market due to high yields using human transport. The yields rose by 79 percent due to clean planting materials. The cost of plantlets made the largest cost item in the TC banana enterprise establishment. The survey established a high elastic price elasticity of supply and demand at 1.67 and 1.77 respectively. This indicated the sensitivity of the banana fruit to price changes. The enterprise was a worthwhile investment indicating a rise in income from banana earnings by 84 percent with an internal rate of return of 34 percent on capital invested.

The technology improved the livelihoods of households in the areas it was adopted as funds were available to take care of family's financial needs. The positive total technology surplus indicates improvement in the welfare of those who adopted the technology. The technology improved the social welfare through enhanced food security, diet diversification and an increase in income. Group members were also empowered to take leadership positions in the society. Diseases, lack of micro-credit, poor group dynamics, lack of information, lack of enough land, poor transport network, subsistence farming and limited distribution of plantlets system were identified as constraints to the success of the technology diffusion.

1.0 INTRODUCTION

1.1 Background information

Several recent studies have analysed the impact of biotechnologies in developing countries, both from ex ante and ex post perspectives (e g. Andrea et al. 2009; Ssennyonga, 2005; Qaim, 1999, 2000, 2003; Wambugu, 2004; Steffen, 2007; Pachico et al, 2002; ISAAA, 2004; Mbogo, 2002; Pray et al.,2001;Nyamori, 2003). The results consistently show that especially the tissue culture (TC) technology in crops like rice, sweet potato and banana can bring about increased social and economic gains. Nonetheless, controversies about the impact of TC bananas in smallholder farming persist. Furthermore, most of the existing studies were done before the completion of the 10 years life cycle of bananas in tropical regions. The question as to whether the technology has had an impact on social and economic affairs of those who have adopted it is still unresolved. The study therefore contributes to this debate by assessing the socio economic impact of TC bananas in Kisii highlands and South Nyanza in Kenya.

Banana is often considered an export crop of developing countries grown by multinational companies for consumption in USA or Europe. In Asia and Sub-Saharan Africa the crop is consumed domestically (Qaim, 1999). In East Africa bananas are grown by small scale farmers for home consumption and for local markets (ISAAA, 2003) The crop is often managed by women and considered as a staple food. However, the yields of about 10 tonnes per hectare are significantly behind the potential yields of more than 40 tonnes per hectare in tropical areas (Qaim, 1999). In Kenya, Kisii highlands are leading in production of bananas. The national farmer average production is 12t/ha while potential yield is 60 t/ha (Kwach et al., 2000). The poor production is due to adoption of low yielding cultivars, infestation of diseases and pests, poor farming methods and lack of clean planting materials. The TC banana technology was conceived to reverse the decline in production. The TC banana technology is a form of biotechnology that refers to the production of plants from very small plant parts, tissues or cells grown aseptically under laboratory conditions where the environment and nutrition are rigidly controlled (ISAAA, 2003). To boost adoption of TC banana technology among the resource poor small scale farmers, sustainable credit scheme using

a group based lending approach was made operational under the auspices of K-Rep Development Agency, which is an established micro-finance institution in Kenya. Institutions that have been at the forefront to disseminate the technology include; ISAAA AfriCenter, Africa Harvest, K-Rep Development Agency, KARI through KAPP, IDRC, Rockefeller foundation, FARM Africa through MATF. In assessing the impact of the technology, data for the study was gathered in the two regions using a structured questionnaire.

The study is structured as follows; chapter 1 has the background, statement of the problem, research objectives and justification. Chapter 2 gives theoretical literature, empirical literature and an overview of the literature. Chapter 3 offers the theoretical foundation of the model, model specification, and sensitivity analysis, area covered under the study, sources of data and the sampling procedure. Chapter 4 provides results and discussions of the survey. Chapter 5 gives summary, conclusions, policy recommendations and areas of further research.

1.2 Statement of the problem

The international debate about the socio economic repercussions of agricultural biotechnology in developing countries is often emotional and on most occasions its split according to ideological beliefs (Qaim, 1999). This is occasioned by the dearth of sound information available for analysis. This study contributes to the rationalization of the discussion by providing an assessment of the social economic impact of tissue culture banana technology to farmers in Kenya Kisii highlands and South Nyanza. The adoption rate of the technology has been promising in the region compared to other parts of the country since banana is a staple food in the region. However, analysis of the socio-economic impact has not been undertaken. The survey will also improve on previous ex ante studies by using comprehensive survey data.

The study will therefore concentrate on farmers who have embraced the technology since its inception in 1997.Banana production in Kenya unlike other export oriented banana growing regions of the world is predominantly grown by peasant farmers for home

consumption and the national market. It is the most popular eating fruit in the country and the cooking varieties serve as important staple food (ISAAA, 2003).

In 2005 the area in Kenya under bananas was 83,687 hectares (MOA, 2006). To individual producers banana is usually part of a diversified cropping pattern including semi-subsistence commodities and domestic cash crops that render a continuous in-kind and in-cash income flow under very low input regimes.

1.3 Research objectives

1.3.1 General objective

To assess the social economic impact of tissue culture bananas.

1.3.2 Specific objectives

i) To estimate the economic impact of TC technology in the region.

ii) To assess the social impact of TC technology on the existing social set up.

iii) To give policy recommendation based on (i) and (ii) above on enhancing the technology uptake in order to have a higher impact.

1.4 Justification

Solid information is available about the short and long-term effects of TC technology under farmer's conditions in Kenya (Qaim, 1999). The impact assessment is therefore carried out within an ex-post analytical framework. It builds up on farm level data. The data would help rationalize discussions on the impact of agricultural biotechnology in various forums and debates both at national and international levels. In view of the benefits accrued socially and economically the study would prompt the government through the ministry of agriculture and trade to come up with a policy framework to support the players along the banana sub sector value chain. Already a banana policy exists (Karembu, 2007) but a lot has to be done in terms of quantifying the importance of the fruit. The empirical analyzed data would act as a catalyst to attract investors into the banana value chain that is currently characterized by lack of clarity and information about the potential gains of banana as a commercial fruit.

The information generated will form a basis for stakeholders in the banana sector and the government to make informed decisions about the potential of the crop in alleviating food insecurity. The socio economic impact documented will be used as evidence by researchers and policy makers for the need to come up with farmer and market driven biotechnologies that would help improve livelihoods of the society.

2.0 LITERATURE REVIEW

2.1 Theoretical Literature

Technology has great impact on production. It improves quality, efficiency, output and lowers costs (Gittinger, 1982). Investment in technology through research and development leads to inventions and innovations that lead to high production. It also improves factor productivity through training of labour (Graff, 2000). Technology leads to capital labour substitution for capital intensive technology. It also requires heavy investment in education, research and development that may be costly to the society and firms. It sometimes violates ethics like cloning. Despite all these, technology is vital for production and its demerits to benefits are insignificant (Alston et al., 1995).

Genetic modified technology as evaluated by (Graham et al , 2008) showed that it has substantial net economic benefits at the farm level. The technology reduces pesticide spraying by 224 million kg (equivalent to about 40 percent of the annual volume of pesticide active ingredient applied to arable crops in the European Union) and as a result, it decreases the environmental impact associated with pesticide use by more than 15 percent. He further notes that GM technology has also significantly reduced the release of greenhouse gas emissions from agriculture, which, in 2005, was equivalent to removing 4 million cars from the roads.

Biotechnology as discussed in an international symposium organized to assess its social economic impact on modern vegetable production in tropical Asia by (Jayamangkala et al. 2009) found out that the improved technology led to a rise in farmers profits, facilitated industry restructuring, enhanced industry professionalism focusing on market development and increased consumption. In Philippines, (Morooka, 1982) asserted that land reform and improved biotechnology are the major factors that influence the socio-economic situation of a village society.

Tissue culture technology as evaluated by (Wambugu, 2004) has had positive impact to those who adopted it. The benefits include potentially unlimited multiplication of selected plant lines, elimination of pathogens, production of true-to-type multiplication material of

desirable plant lines, indefinite storage of genetic resources through long-term maintenance of propagule inventories.

The socio economic impact of the tissue culture technology done by (FAO, 2005) in China, Kenya, Vietnam and Benin, on sweet potato, banana and rice, respectively showed that the technology increased yields and agricultural incomes, had high internal rate of return compared to capital investment, led to availability of affordable seeds, led to creation of rural micro enterprises, improved health standards, shorter growing seasons and resistance to local stresses

2.2 Empirical Literature

Technology adoption has been the main agenda in international forums (Qaim, 1999). Recent studies done by (Andrea, et.al, 2009) show significant impacts of technology on the socio economic welfare of those who adopt it. One of the studies assessing the impact of biotechnology applications use interdisciplinary approaches as summarized in the table below by (FAO, 2009).

Table 1: The approaches for assessing the impact of biotechnology applications

Level	Stage	Impact	Indicators used	Time frame	Approach/model
Micro	Farm (family village)	Agronomic	Yield, cost of production factors	ex ante ex post	Effects on production function
		Socio economic	Workload, family income, health of workers, additional time	Ex ante Ex post	Household approach
	Market of a single product in single country		Benefit Cost Ratio	Ex ante	Dynamic Research evaluation for management (DREAM)
			Internal rate of return		Scenario analysis
			Net present value		Aggregate economic welfare analysis(single market partial equilibrium models)

Sector		Economic	Distribution of benefits between operators of the production chain	Ex post	Economic surplus models
Macro	Market of many products in a single country market of a single product in many countries multi commodity market in many countries	Economic	International price of	Ex ante	Partial equilibrium models (few commodities computable general equilibrium (CGE) models (across commodities and sectors) (DREAM) multi market analysis
			Distribution of benefits between regions or countries (adopters/non adopters)		
			Distribution of benefits between society categories	Ex post	

Source: FAO, 2009

The surveys by (Andrea et al, 2009) assessed the socio economic impact of non transgenic sweet potato in Zimbabwe. It adopted a sustainable livelihood model by (Chambers and Conway, 1991; DFID, 2001) that was capable of capturing interrelations among ecological, agricultural, economic, social, cultural and political factors affecting technology adoption and its outcomes. The study was carried out in Chigodora Ward (Hwedza district, Zimbabwe) a sluggish economic and institutional environment that has staple food cropping, local markets for crop sales and several years of extension programmes managed by the state. The survey showed a rise in adoption rate, revenue from tubers and vines. The majority of households grew the crop on 0.5 acres or less. The crop was also not very attractive opportunity for investment by more endowed households. It was also established that sweet potato is a secondary, risk spreading income generating activity.

Andrea et al, 2009, carried out a similar study to assess the socio economic impact of tissue culture banana in Uganda. The study was carried out using the same approach in Bananankika Parish (Luwero district in Uganda). The site is a fast growing economy with staple food cropping, local markets for crop sales and several years of extension programmes managed by the state. The survey showed a rise in adoption rate, area under banana farming, yields, and income with a high benefit cost ratio. The households reinvested their increased earnings in livelihood assets such as improved houses, school fees and cattle. The survey recommended that projects aimed at diffusion of new

technology should include service packages to technically assist the adopters and that adoption patterns and impacts should be considered ex ante in the project design in order to maximize the socio economic impact.

Qaim, 1999, assessed the potential impact of banana biotechnology in Kenya. The aim of the study was to find out the benefits of adopting the technology by small scale farmers. The study employed the economic surplus model where aggregate benefits and distribution outcomes were analysed using an ex-ante conceptual frame work. Data was collected during the second half of 1998. The study showed a potential increase in yields and incomes. It also established a per unit cost reduction in production and high internal rate of return compared to capital invested in the banana enterprise. The findings led to conclusion that the technology would change the livelihoods of the small scale farmers. It was also established that for the technology to have a higher impact it has to be accompanied by capacity building of farmers and a financial package to help in purchase of plantlets and inputs.

Mbogo, 2001, undertook a survey on economic analysis of the production of TC bananas and an assessment of their market potential in relation to Nairobi as a metropolitan market The study had five specific objectives as follows;

i) To develop on station and on farm activities linked with farmers, extension services, NGOs and other end users to ensure that TC bananas are evaluated distributed marketed and utilized, primarily but not exclusively, by small scale farmers.

ii) To investigate the market opportunities for different banana cultivars in relation to the TC banana production technology.

iii) To explore the possibility of using TC plants to establish "in situ" nurseries from which clean suckers can be obtained as a preferred source of planting material of a Juvenile TC plants and convectional suckers.

iv) To create a model project to show successful application of biotechnology for bananas and other commodity crops.

v) To suggest policy interventions under which the optimal conditions under which TC innovations could be adopted to benefit small scale farmers.

The data for the study was gathered from groups in Maragua that had adopted the technology The study established that banana value chain was not clear and the cooking varieties were most preferred in the market. It also revealed that good agronomic practices would help in use of suckers to disseminate the technology. The survey recommended a diffusion project for the technology and proposed an intervention by the government to control the quality of plantlets production in order to reduce the number of somaclonal variants.

Mbogo, 2002, conducted a baseline survey on the socio economic impact of TC banana project in Kenya. The study was done in a project funded by FARM Africa and implemented by ISAAA and KARI. The study aimed at evaluating the economic worth of TC banana project. Data analysis was done using discounting benefits costs ratio model. Data for the study was gathered using a stratified random sample of 72 banana farmers in Maragua and Murang'a region in Central Province, Kenya were interviewed using a structured questionnaire. The survey showed that the TC banana enterprise was worthwhile investment with a high rate of return compared to the capital invested. The technology adoption led to a rise in income, women participation in farming activities and high trade margins. The discounted streams of costs and benefits over 10 years period showed a benefit cost ratio of 4.8. The survey recommended up-scaling of the technology diffusion with a micro-credit component.

Nyamori, 2003, analysed the socio economic background of tissue culture banana production in Nyanza. The project was funded by FARM Africa and implemented by ISAAA and KARI-Kisii. The aims of the study was to identify the empirical social economic factors that influence adoption of the TC technology in the region, identify constraints to adoption with a view to recommending strategies that would boost take up of the innovation, to gather information that would form a basis for monitoring and evaluation. The data for the study was gathered from six groups that had 123 members. The study showed that the main socio economic factors influencing adoption were gender, price of plantlets, food culture, yield, information dissemination. The main

constraints to adoption were; high plantlets prices, small land sizes per household, lack of information, lack of capital and high level of illiteracy among the residents. The information gathered that formed a basis for monitoring and evaluation was that: female participating in the technology were more than males, majority of the households that were members of the farmer field schools were poor. The survey also established that banana provided an average of Kshs 500 per month that constitutes 20 percent of the total income generated from farm activities. Land handling within the three districts was found to be 1.8 acres with approximately 0.153 acres devoted to TC and 0.223 acres to non TC banana production.

Ogunsumi et al., 2005, analyzed the socio economic impact assessment of maize production technology to farmer's welfare in South West, Nigeria. The aim of the study was to assess the socio economic impact of improved maize technology on farmer's welfare. The study was carried out in three States namely Oyo, Osun and Ondo States out of the 8 States in South West Nigeria The economic surplus model was used for the ex post assessment. The data to calculate social gains was categorized into 4 broad areas; market data on observed prices and quantities, agronomic evidence and costs of the technology being adopted, economic parameters on the market response to change (elasticity's of supply and demand), research and extension costs incurred in obtaining the new technology. The study revealed a higher internal rate of return compared to initial capital investment indicating that the maize technologies had contributed significantly to members well being The survey recommended that technologies should be pro-poor, farmers driven and that young people should be encouraged to take to growing maize as it had proved to be a remunerative crop.

2.3 Overview of literature

The literature review has shown that there is a need to conduct a socio economic evaluation of the TC banana technology 10 years after its adoption because no study has been done. The study would add value by providing sound up to date data of 10 years which is a period that completes the life cycle of bananas in tropical regions (Qaim, 1999).

3.0 Methodology

3.1 Conceptual framework

Socio economic impact assessment of technology can be done through eight approaches namely; House hold approach, Economic surplus model ,Partial equilibrium model, Scenario analysis, Dynamic Research Evaluation for Management (DREAM), Multi market and multi commodity model, Computable General Equilibrium models (CGE), Sustainable Livelihoods Approach (SLA) frame work (FAO, 2009).

This study adopts economic surplus approach. The model is able to ascertain distribution benefits between operators of the banana production value chain with an ex post time frame as the technology is already in the field at varying levels of adoption by farmers.

The data needed to calculate social economic gain falls into seven categories namely;

1) Household socio economic characteristics;
2) Market information on prices and quantities;
3) Costs of the technology being adopted;
4) Economic parameters on market response to change (elasticity's of supply and demand, technology shift factor, supply share for producers and per unit cost reduction);
5) Technology adoption and agronomic evidence;
6) Total technology surplus; and
7) Sensitivity analysis.

Household social economic characteristics that include; sex, age, marital status, highest level of education, number of years in school, relationship with the household head and occupation, expenditure pattern, infrastructure, decision making, contribution of family labour, nutrition, asset purchase and banana ranking was found from the survey questionnaire.

Market information on the Price (P) and Quantity (Q) of the bananas that is affected by technology change was found by the average of prices from respondents. The quantity demanded (qd) was established as the sum of the marketed produce after adoption. The

quantity demanded for home consumption was found by getting the sum of home consumption (h). The quantity supplied was found as the total production (Qs). Marketing information of the region was also established through the survey questionnaire.

The TC banana technology adoption costs which include; plantation establishment costs and recurrent costs required to obtain the increased yields associated with the new technology were found from the surveyed households. Investment costs before and after adoptions were obtained from the survey data. The per unit reduction in cost of production and interest rate used by the micro finance institution was established as useful data for analysis. Per unit cost reduction was calculated by finding the difference between per unit cost before adoption and per units cost after adoption of the TC banana technology. Information on economic parameters on market response to change; the price elasticity of banana supply ($E_{s,l}$) was calculated using the formulae in equation (1)

$$\frac{\Delta Qs}{\Delta p}\frac{P}{Q} \quad \text{.....(1)}$$

Price Elasticity of bananas demanded (E_d) was calculated using the formulae in equation (9)

$$\frac{\Delta Qd}{\Delta p}\frac{P}{Q} \quad \text{.....(2)}$$

The supply share for producers (SS i) was calculated by dividing the quantity supplied of bananas by the total number of producers.

The technology shift factor (K_{i}) was calculated by multiplying the cost reduction per unit factor by the adoption rate as shown in equation (3)

$$Ki = Ci + Ai \quad \text{.....(3)}$$

The technology uptake and agronomic data on the adoption rate, stream of benefits before and after adoption, consumption behaviour, changes in income, yield gains, value addition, number of farmers reached by the technology and the micro credit were found

from the household surveys. The streams of benefits and costs were discounted to establish the benefit cost ratio. The information on adoption rates came from farm surveys and extension workers estimates. The adoption rate (t) is the ratio of area of improved varieties to total area of the crop in Kisii highlands and south Nyanza region. The data found served as an input in the economic impact assessment determination. The total technology surplus was established by getting the sum of producer surplus and economic surplus. Sensitivity data was found by varying the variables found from the survey.

3.2 Theoretical framework

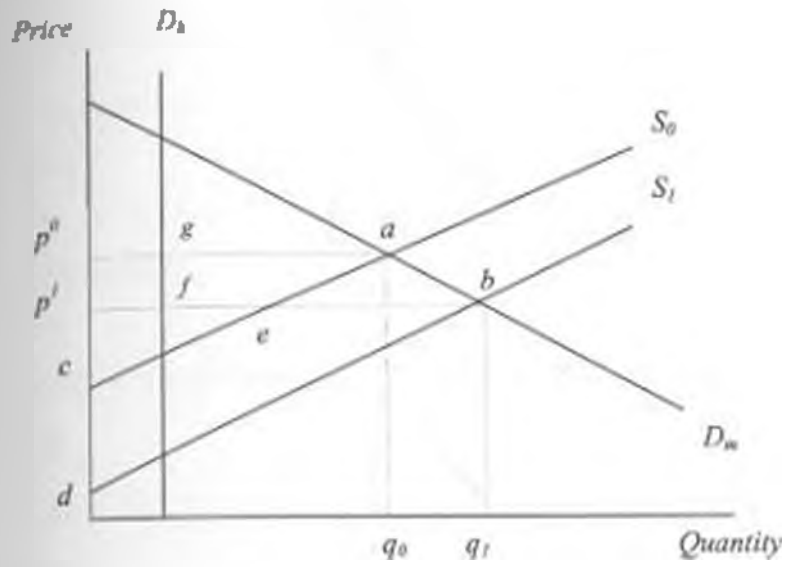
The socio economic impact of TC banana technology in Kisii highlands and South Nyanza in Kenya is projected using the consumer surplus model. The model is the most common approach for the evaluation of commodity related technological progress in agriculture (Norton and Davis, 1981; Alston et al., 1995). Recently the approach has been used in ex ante and ex post impact assessment of different non transgenic crop technologies impact studies (e.g. Qaim 1999, Qaim 2003, Zephaniah, 2009; Ogunsumi et al. 2005, Krishna and Qaim, 2007).

The assumptions of the model are that:

i) The market clears at a single price (p) i.e. price being the same for consumers;
ii) Bananas are assumed to be a homogeneous product regardless of who produces them or where they are produced;
iii) There are (n) producer groups in the project area;
iv) A closed economy since foreign trade in banana is negligible;
v) Equilibrium price is determined by domestic demand and supply; and
vi) Spill over to other markets are disregarded as banana employs a small fraction of all factors of production in Kenyan agriculture.

The rationale of the economic surplus model is that the technology adoption results in a rightward shift of the supply curve from S_0 to S_1. On condition that the constant demand curve D_m prevails, this results in a new equilibrium with lower price P_1 and an increased quantity demanded, Q_1 for the commodity (Fig 1)

Figure 1: Model of biotechnology progress in Kenya banana market



Where

S_0 initial banana supply curve without use of tissue technology

Dm -demand curves of market purchasers

Dh-demand curve for home consumption.

a - quantity equilibrium that represent the reference price

S_1 Shift of the supply curve due to productivity that lowers cost per unit output.

b -new equilibrium.

gabf - Change in consumer surplus for market purchasers i. biotechnology application

ebcd minus area **gaef** - change in producer surplus

Note

abcd -change in economic surplus area is exactly the same as if there were no home consumption. The only difference occurs in benefit partition between producers and consumers. Whereas in addition the area captures the rectangle **p_0gfp_1** in the semi-subsistence setting producers retain that benefit due to home consumption.

Following the analysis by (Alston et al., 1995) the changes in annual producer surplus (PS), consumer surplus (CS) and the change in total economic surplus (TS) due to technical progress can be derived algebraically from fig 1 above as follows;

Supply

$q_{s,i} = q_{s,i}(p, t_0)$ .....(4)

Demand

$q_d = q_d(p)$ .....(5)

Market clearing

$q_{s,i} = q_d$ .....(6)

Differentiating equations (3) to (5) leads to the following system of equations

Supply

$$\frac{dq_{s,i}}{q_{s,i}} = \varepsilon_{s,i}\left(\frac{dp}{p} + K_i\right) \quad \text{..... (7)}$$

Demand

$$\frac{dq_d}{q_d} = \varepsilon_d \frac{dp}{p} \quad \text{..... (8)}$$

Market change

$$\sum_{i=1}^{n} ss_{s,i} \frac{dq_{s,i}}{q_{s,i}} = \frac{dq_d}{q_d} \quad \text{.....(9)}$$

Equation (8) can be solved for the relative change of the equilibrium price.

$$\sum_{i=1}^{n}\left[ss_i\,\varepsilon_{s,i}\left(\frac{dp}{p} + K_i\right)\right] = \varepsilon_d \frac{dp}{p} \quad \text{..... (10)}$$

$$\frac{dp}{p} = \frac{\sum_{i=1}^{n}\left(ss_{s,i}\varepsilon_{s,i}K_i\right)}{\varepsilon d - \sum_{i=1}^{n}\left(ss_{s,i}\varepsilon_{s,i}\right)} \quad \text{..... ....(11)}$$

The change in the equilibrium price and the changes in the quantities produced and consumed are sufficient for calculating the implications of economic surplus. The annual change in producer surplus (PS) for the individual producer group, the annual change in

consumer surplus (CS) and the change in the total economic surplus (TS) due to technical progress are defined (Alston et al., 1995)

Change in PS:

$$\Delta PS_i = p.q_{i,1}\left[\frac{dp}{p} + K_i\right]\left[1 + 0.5.\frac{dq_{i,1}}{q_{i,1}}\right].....(12)$$

Change in CS:

$$\Delta CS = -p.q_{d,1}\frac{dp}{p}\left[1 + 0.5.\frac{dq_d}{q_d}\right].....(13)$$

Change in TS:

$$\Delta TS = \sum_{i=1}^{n} \Delta PS_i + \Delta CS .....(14)$$

In the open economy alternative, there is no change in consumer surplus. The change in producer surplus of the individual groups is

Change in PS:

$$\Delta PS_i = p.q_{i,1}.K_i\left(1 + 0.5.K_i.\varepsilon_{s,i}\right).....(15)$$

Incorporating home consumption that is prevalent in the banana production in the equation (10) above we get the following set of equations;

Change in consumer surplus (CS)

$$\Delta CS = -p.q_{d,1}.\frac{dp}{p}\left(1 + 0.5.\varepsilon_d.\frac{dp}{p}\right) - \left(-dp.q_{d,1}.\sum_{i=1}^{n}\left(h_i.s_i\right)\right).(16)$$

Change in (PS)

$$\Delta PS_i = p.q_{i,1}.\left(\frac{dp}{p} + K_i\right)\left(1 + 0.5.\varepsilon_{s,i}\left(\frac{dp}{p} + K_i\right)\right) + \left(-dp.q_{i,1}.h_i\right)...(17)$$

The change in total economic surplus was computed as the sum of change in consumer surplus and change in producer surplus as indicated in equation 16 and 17 respectively.

3.3 Sensitivity analysis.

Sensitivity analysis was done by estimating the internal rate of return of the banana enterprise and then varying variables that are prone to uncertainty and have an influence on the welfare and the profitability of the banana enterprise. The supply shift factors, the per unit cost reduction, the price elasticity of supply and the demand and the adoption rates were varied to establish their impact on the data found from the survey.

3.4 Area of study

The study covered seven districts namely: Kisii highlands (Gucha, Kisii central, Masaba, Nyamira, Kisii south), South Nyanza (Rachuonyo and Homabay).

3.5 Sources of data

The study used both primary and secondary data. Primary data was collected using a structured questionnaire where the statistical data collected was on market information on prices and quantities, costs of the technology, data on market response to change, total technology surplus and data on technology adoption.

Secondary data was obtained from TC banana technology stakeholders who include; KARI, ISAAA, K-REP Development Agency, Plan International, National AIDS Control Council JKUAT, Africa Harvest and MoA. The statistical data collected was on technology adoption and agronomic issues.

3.6 Sampling procedure

A survey methodology was modeled to enable estimation of the impact of TC banana technology. The districts that had benefited from the TC banana technology were purposively selected. Data from KARI-RRC was used to determine number of farmers who had adopted the technology from various districts and the numbers to be interviewed were fixed per district. The various District Agricultural Officers were contacted to send enumerators from their various districts who had knowledge of the areas. The district Agricultural Officers employed cluster sampling technique to identify divisions where respondents were to be selected. The enumerators sampled the respondents randomly from the divisions and interviewed them. The Ministry of Agriculture staffs were also interviewed to add objectivity in the study. The total number of households surveyed was

100 with 60 from Kisii highlands and 40 from South Nyanza. The sample size was chosen based on time, resources, population, desired result and confidence level of data to be analyzed.

4.0 RESULTS AND DISCUSSIONS

4.1 Results and Discussions

4.1.1 Household socio economic characteristics

The survey established that the number of individuals in 100 households was 588. The gender distribution in the households was found to be 55 percent males and 45 percent women as shown in Table 2.

Table 2: The gender distribution of household members

District	Distribution		Gender (%)	
	No. of	Percentage	Male	Female
Gucha	199	34	55	45
Kisii central	115	20	54	46
Rachuonyo	106	18	52	47
Masaba	62	11	58	42
Nyamira	55	9	49	51
Homa bay	28	5	68	32
Kisii south	23	4	55	45

Source: Author's Survey Data (2008)

The survey established that 46 percent of the respondents were never married while 32 percent monogamous marriages. In terms of the level of education 47 percent of the population had primary, 33 percent secondary, 8 percent had not attended school and 7 percent had the post secondary education. The population comprised of 47 percent students, 34 percent farmers and 8 percent were not engaged in any occupation. The mean age of the population was 24 years with an average of 8 years education. About 94 percent of the household heads are males.

The expenditure pattern by the respondents showed a high expenditure on food, followed by education, shelter, fuel, water, health and clothing in that order as shown in the Table 3 below.

Table 3: The total expenses across districts

Item	N	Mean	Std Dev	Minimum	Maximum
FUEL	95	10448.25	15731.53	500	106800.00
FOOD	95	66043.99	51274.41	3000	294000.00
EDUCATION	95	20837.68	46332.79	0	343680.00
SHELTER	95	18083.16	71471.31	0	600000.00
WATER	95	9938.32	21414.06	60	182580.00
HEALTH	95	8695.57	20268.95	0	180000.00
CLOTHING	95	6405.05	7395.05	300	36000.00

Source: Author's Survey Data (2008)

The survey found out that 58 percent of the households had semi permanent houses, 32 percent had temporary ones and 10 percent have permanent houses. About 50 percent of the respondents had access to telephones while 13 percent had access to electricity.

The survey found that decision making at household level on bananas comprised of three types of decisions namely; quantity of banana fruit for home consumption, banana sales and decision on allocation of money from banana sales. Table 4 below shows the findings

Table 4: The decision making at household levels

No	Decision type	Men		Women		Children	
		Access	Control	Access	Control	Access	control
1	Banana fruit for home	44%	50%	58%	52%	0	0
2	Banana sales	42%	55%	60%	47%	2.7%	0
3	Money/income from	58%	71%	45%	32%	0	0

Source: Author's Survey Data (2008)

The survey data shows women having a higher percentage of access and control of the banana fruit for home consumption. The situation is different in the decision for banana for sale where the women have an access but men have a slightly higher percentage in control. In terms of the decisions on spending the money incomes from banana sales the men have a high percentage of access and control.

The survey data as shown in Table 5 showed adult female taking up activities previously provided by the adult males. Most notable was the contribution of the female child and

the adult female in ground breaking/ digging, de-suckering, harvesting and marketing activities.

Table 5: The ranking of family labour contribution to banana related activities

No	Activity	Rank			
		Adult male	Adult female	Male child	Female child
1	Bush clearing	1	2	3	4
2	Ground breaking / digging	1	2	4	3
3	Digging holes	1	2	3	4
4	Manure/ Fertilizer application	1	2	3	4
5	Planting(with banana plantlets)	1	2	3	4
6	Weeding	1	2	3	4
7	Drawing water and watering	1	2	3	4
8	De-suckering	1	3	2	4
9	Propping	1	2	3	4
10	Harvesting	1	2	4	3
11	Marketing in general	1	2	4	3

Source: Author's Survey Data (2008)

The study found that families that had adopted the TC banana technology would afford at least two meals a day. Bananas featured as food consumed in typical week for breakfast, lunch, supper and as baby food.

The income from TC banana technology was used by different households to purchase assets. About 49 percent of the respondents bought farm tools and 6 percent bought livestock and furniture. Other assets acquired were television sets, land, dam, solar panels and bicycles.

Table 6: The assets acquired through income generated from TC bananas

ASSETS AQUIRED	No. of respondents	Percentage (%)
Farm tools	53	49
Livestock	6	6
Furniture	6	6
Television set	4	4
Land	1	1
Building materials	1	1
Furniture	4	3
Household items	2	2
Bananas	1	1
Dam	1	1
Hiring farm	1	1

Source: Author's Survey Data (2008)

The survey data as shown in annex 3 showed banana being ranked first as the highest contributor to income followed by livestock, maize, tea, vegetables, coffee, tomatoes, beans, sweet potatoes, Onions, fruits, Napier grass, groundnuts, sugarcane, finger millet, cassava and tobacco.

The results therefore indicate that the household social economic characteristics reflect high level of dependency on household heads with agriculture employing the bulk of the population. The introduction of the TC technology had led to an improvement in gender balance in decision making. These shows that with consistent adoption of the technology gender balance could be realized in the long run in terms of household labour provision due to good returns. However, much more needs to be done in empowering women to take strategic decisions on incomes from bananas. The fruit was consumed frequently in a day's menu from breakfast to dinner indicating its nutritive value, preference by consumers and diet diversification. The purchase of assets by the households shows that the TC technology increased disposable income thus empowering players along the banana value chain to be able to buy commodities, equipment, animals and amenities.

4.1.2 Market information on prices and quantities

The survey found estimated market information variables as shown in Table 7 below.

Table 7: The estimate market information variables

No	Variable	Estimate
1	Price (P)	177
2	Change in price due to TC technology (ΔP)	86.58
3	Quantity demanded (qd)	7063550
4	Change in quantity demanded (Δd)	6109560
5	Increase in quantity demanded due to TC technology ($\Delta d / Qd$)	0.864942
6	Quantity demanded for home consumption (hi)	8655.34
7	Quantity supplied (qs)	7807910
8	Change in quantity supplied to the market (ΔQs)	6404270
9	Increase in quantity supplied due to TC technology	0.90
10	Percentage of bananas consumed at home	0.10

Source: Author's Survey Data (2008)

The survey as shown in Table 7 found the average price to be 177 Kenya Shillings per bunch .The change in prices due to technology compared with the convectional varieties was estimated at 86.58 percent. However, the price was varying from one area to another The price data indicate variations of prices from as low as 30 Kenya shilling to a high of 600 Kenya shillings per bunch. The variations are attributed to the remoteness of the areas and distance to the main trading centers.

The quantity demanded was found as shown in Table 7 to be 7,063,550 bunches and the change in quantity demanded was 6,109,560 bunches. These reflected an increase by 86 percent from the previous convectional bananas. Quantity demanded for home consumption was estimated to be 8655.34. The rise in demand is attributed to the uniformity in growth and maturity of the fruit because production could be predetermined making it easier to source for markets before maturity.

The survey showed in Table 7 that the quantity supplied was 7,807,910 bunches. These indicated a change in quantity supplied to the market by 6,404,270 bunches that reflects an increase by 90 percent with the 10 percent remaining being consumed at home.

The survey found out that over half the buyers of bananas were traders with the remaining half being bought by women groups, brokers and travelers. The point of selling the product, the local market ranked highest followed by farm gate.

The survey data indicated Kiamokama to be the highest recipient of bananas from Kisii highlands followed by Miriri and Tombe. Rodi Kopanyi received the highest number of bananas in South Nyanza followed by Oyugis and Ringa.

The human transport registered the highest percentage as a means of transport to the nearest markets followed by bicycles and wheelbarrows. The rest of the means which were not regularly used were; pick ups, Nissan matatus, Lorries and motorcycles. The farmers were charged a maximum of 60 Kenya Shillings and a minimum of 5 Kenya shillings per bunch of bananas being transported as indicted in the table 8 below.

Table 8: The distance and transport costs for bananas

Variable	N	Mean	Std Dev	Minimum	Maximum
Distance to market in Kilometers	94	2.4292553	2.0312633	0.0200000	10.0000000
Transport cost in Kenya shillings	94	29.1489362	15.9912324	5.0000000	60.0000000

Source: Author's Survey Data (2008)

The increase in quantity supplied to the market is due to high production occasioned by good agronomic practices and training that was introduced with the technology. The big bunches that would fetch good prices at the market also increased the temptation to take the fruit to the market as the technology was gearing farmers towards commercial agriculture. The large bunches also aroused the interest of middlemen who approached farmers with better farm gate prices for their produce. However, the farmers preferred taking their products to the market in order to get better prices mostly using human transport to save on costs. Other means of transporting the product to the market were high due to poor infrastructure.

4.1.3 The Cost of TC Technology

The survey found that the largest cost item in the establishment of TC bananas was the cost of plantlets as shown in Annex 1. It makes up 84 percent of the total establishment

cost The current commercial price of vitro plants in Kenya was found to be Kenya Shillings 100 from KARI and Genetic Technologies International Limited (GTIL) which combined with inputs is high.

The recurrent annual cost for banana production is shown in Annex 1. The expenditure for fertilizer and manure made the larger component of the recurrent expenditure. Other costs included; weeding, de-suckering and mulching, pesticides, watering, pre-harvest propping of stems and interest on loan given to purchase plantlets. The recurrent cost expenditure for manure and fertilizer was high because the TC bananas require appropriate nutrients for satisfactory growth and development. The need for clean field conditions also increased the costs of the recurrent expenditure on the crop.

The interest on loan from K-Rep Development Agency was established to be 16 percent on reducing balance. About 51 percent of those interviewed had access to micro-credit to purchase dairy cows, farm tools, establish businesses, purchase of TC banana plantlets and inputs. The main sources of credit funds to establish the orchards were from K-REP Development Agency, KARI, personal savings, Plan International and National Aids Control Council, Merry go round and Kenya Commercial Bank. The funds especially from K-Rep Development Agency came inform of micro credit which was considered as an innovative component put into TC banana technology to boost adoption and diffusion of the technology to farmers The survey found the following as problems encountered in repaying the loans advanced to them in kind; the farmers who had good harvests diverted the funds meant for repayment to other financial activities including payment of school fees, the grace period for loan repayment was too short, the interest rate of 16 percent was quite high for agricultural produce. It was established that during the project period funds were also embezzled by a loans officer and records disappeared. The survey found that the production was not as good as projected due to unfavorable weather conditions making repayment difficult.

Table 9: The estimated cost of TC technology adoption

No	Variable	Estimate (Kenya Shillings)
1	Cost after adoption of technology	2491750
2	Investment cost before adoption	299980
3	Percentage per unit cost reduction	0.003

Source: Author's Survey (2008)

The survey found a high cost after adoption compared to a low investment cost before adoption as shown in table 9. This led to farmers to begin testing the technology with fewer plantlets. These high costs led to some farmers using trained field hygiene to propagate conventional suckers. However, the costs did not deter farmers from adopting the TC Technology as the returns were high compared to per unit cost.

4.1.4 The economic parameters on market response to change

The survey found economic variables due to market response to change as shown in the Table 10 below.

Table 10: The estimate market response to change variables

No	Variable	Estimate
1	Production share (SS_i)	90789.65
2	Price elasticity of Supply (Es)	1.67
3	Price elasticity of banana demand (Ed)	1.77
4	Technology shift factor (Ki)	0.006
5	Rate of change of price (dp/p)	-0.006

Source: Author's Survey Data (2008)

The survey as shown in Table 10 above found an elastic price elasticity of demand and supply. These indicate that the demand function is very responsive to price changes for the banana fruit where slight changes in the price would lead to high variation in the demand of bananas.

The positive technology shift factor indicated that the use of the technology would have an equally positive impact on the supply side of the factors of production in the banana sub-sector.

The survey established a negative rate of change of price. This shows that a reduction in price due to increased supply occasioned by high production of bananas due to the TC technology adoption.

4.1.5 The Technology Adoption and agronomic issues

The survey data showed a progression in adoption during the years 2001-2003 showing the highest rate of adoption. The number of tissue culture plantlets planted by the 93 households that adopted the technology over the years was 20,456 plantlets.

Table 11: The Estimate of technology adoption variables

No.	Variable	Estimate
1	Adoption rate (t) per household	222.34
2	Stream of benefits before adoption	1151660
3	Stream of benefits after adoption	13124070
4	Percentage increase in income	83.86
5	Net present value	14468224
6	Cost benefit ratio	1.58
7	Internal rate of return	34.34
8	Percentage increase in yield	79
9	Percentage of respondents involved in processing	12

Source: Author's Survey data (2008)

The survey as indicated in Table 11 above shows an estimated adoption rate of 222 plantlets per household. The high adoption rate between the year 2001 and 2003 was due to projects being implemented on dissemination of the technology in the region by Kenya Agricultural Research Institute and other stakeholders.

The estimated data on the stream of benefits before and after adoption shows a high benefit after adoption and thus the enterprise being a worthwhile investment. The survey

also established that bananas produced were consumed at home and a larger volume of the production was sold to the markets in the region while some were taken out for sale in other towns in the country. Farmers boosted their incomes through marketing of the product to which TC bananas recorded an increase in income by 84 percent as shown in Table 11.

The stream of benefits before and after the technology adoption was discounted and a positive net present value was established with a cost benefit ratio of 1.58 indicating that the TC banana enterprise was a worthwhile venture as a business with an internal rate of return of 34 percent to initial cost of investment.

The survey found an increase in yields using the survey data in Annex 2 to be 79 percent It's evident from the streams of incomes that the yield peak occurs in the first five years and thereafter a decline in subsequent years. The rise in yield is attributed to clean planting materials, good orchard management and the superiority of tissue culture bananas over the local varieties that were planted by suckers which were mostly diseased. The research found out that a farmer could access more plantlets unlike the previous scenario in which they depended on suckers which were not readily available.

The survey established that 12 percent of the respondents were involved in processing of bananas in the area. There was only one group Nyangorora women group that was adding value to bananas by producing cakes, chips, banana puree and wine from bananas. The survey revealed that they had been trained by KARI and KIRDI staff. Evidence of processing shows that consumers had several value added varieties to choose from at reasonable prices. This diversified the consumer satisfaction

The survey showed that 40 percent of those who adopted the TC banana technology were affected by diseases and pests, 13 percent had dwarf plantlets and 10 percent of the respondent's plantlets had been affected by moles. The diseases mentioned were cigar end rot and panama disease. The pests included nematodes and the banana weevil. The extension officers recommended use of field hygiene, trapping, deep planting, use of a break crop and use clean planting material as preventive measures.

A number of problems including: inadequate capital, unfavorable weather conditions, lack of market, difficult management practices, low yields than expected, lack of enough land, poor transport network, lack of funds for inputs, accessibility of plantlets not easy, poor soils, low prices, poor ripening methods were mentioned as problems encountered by farmers who adopted the technology. It was also noted that limited distribution system for plantlets was a major constraint compounded by the high cost of the plantlets.

4.1.5 Total technology surplus

The survey found the change in producer surplus, change in consumer surplus and the total TC banana technology surplus as shown in the Table 12 below.

Table 12: The estimate of the total technology surplus

No	Variable	Estimate
1	Change in producer surplus ΔPS	7,177,008,291
2	Change in consumer surplus ΔCS	5.89479E+15
3	Change in Total technology Surplus ΔTS	7177008291+5.89479E+15

Source: Author's Survey Data (2008)

The positive producer and consumer surplus from the survey in Table 12 shows that the welfare of those who adopted the technology improved and that the enterprise showed high returns making it a worthwhile investment. This is an indicator that the technology adoption enabled households to improve their livelihoods. These led to diet diversification and food security, increased capacity to buy equipment, increased real income to take care of other family expenses, moderate recurrent annual cost and taking leadership positions. The increased yields reduced the strain on real income indicating that the technology made the consumers better off. These shows that; there was increased capacity to buy commodities, equipment and animals, increased capacity to afford school fees, enhanced social capital, personal development and gender relations. The positive consumer surplus also confirms that the level of satisfaction and welfare by the consumers was improved.

4.1.6 Sensitivity analysis

Sensitivity analysis was done on variables that are prone to uncertainty and have an influence on the welfare and profitability of the banana enterprises. The supply shift factors: per unit cost reduction (c) and adoption rate (A) were varied and had no influence on the internal rate of return which was still above 16 percent. The percentage is considered as the profitability cut off point as it was the interest rate used by the micro finance institutions that funded the capital investment during the TC banana technology dissemination.

Sensitivity to price elasticity of supply and demand was tested. The variation had an effect on the distribution where a reduction in supply elasticity shifts more benefits from consumers to producers. The reduction in price elasticity of demand leads to an increase in consumer surplus that impact negatively to producers thus reducing the yield.

5.0 SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND AREAS FOR FURTHER RESEARCH

5.1 Summary

Tissue culture banana technology had a positive social and economic impact in Kisii highlands and South Nyanza. The technology led to an increase by 86 percent in quantity of bananas demanded for the market as compared to the conventional bananas. Increasingly, the bananas were being taken to the market due to high yields using human transport. The yields rose by 79 percent due clean planting materials. The cost of plantlets made the largest cost item in the TC banana enterprise establishment. The micro credit component in the project was innovative as it helped in easing capital constraint to adoption.

The survey established a high elastic price elasticity of supply and demand at 1.67 and 1.77 respectively. This indicated the sensitivity of the banana fruit to price changes. The enterprise was a worthwhile investment indicating a rise in income from banana earnings by 84 percent with an internal rate of return of 34 percent on capital invested.

The technology improved the livelihoods of households in the areas it was adopted as funds were available to take care of family's financial needs. The positive total technology surplus indicates improvement in the welfare of those who adopted the technology. However, diseases, dwarf plantlets and moles affected the adoption rate.

5.2 Conclusions

Tissue culture banana technology improved the welfare of residents in Kisii highlands and South Nyanza in Kenya. The crop was readily accepted as it's a staple food in the region. The technology led to an increase in yields, rise in income and diversity in consumer satisfaction due to value 0addition. Despite the rise in plantation establishment cost, the benefits were higher than capital invested. Pre-determined production made it easier for producers to source for markets and the remaining surplus delivered to processors for value addition. The funds generated were utilized for wealth creation and thus increasing the economic worth of the residents. It was also established that banana is an individual business where marketing boards and cooperatives do not exist.

Diffusion of the technology led to gender balance in decision making on households issues especially on funds usage after sale of produce and contribution of household labour to production. Food security and diet diversification was enhanced due to an increase in production. The availability of food led to a rise in disposable income that was used to purchase assets, pay school fees, health and other family related costs.

The TC banana technology improved livelihoods of women who were able to access income from the sale of the produce. These enhanced social, personal development and gender relations. The group members were also empowered to take leadership at different levels in the region. It should be noted that the micro credit component factored in the technology diffusion process was crucial to the success of the project as it solved the capital problem.

However, it's crucial to note that diseases, lack of farmers driven micro credit package , lack of a good sustainability mechanism, banana marketed as subsistence crop, lack of enough land, poor transport network and limited distribution of plantlets were constraints to the success of the technology.

5.3 Policy recommendations

Policy recommendations target the ministry of agriculture and trade which play a major role in the banana value chain. Technologies should be developed and disseminated bearing the socio economic status of users in mind that is poor resource farmers and should be cost effective for proper adaptation. Sustainability of the technology should be the focus of research and extension. In order to enhance the social economic impact of TC banana technology more research needs to be done to reduce disease prevalence in the banana sub sector. Policy support is required for input delivery system of micro finance institutions to be farmers driven other than their present focus of being profit oriented. The government should market banana as a high value crop through provision of good infrastructure and favourable investment environment to facilitate value addition of the crop. The government should work with the players along the banana value chain to establish low cost village laboratories and satellite nurseries in the banana growing areas to solve the problem of plantlets distribution. There is a need to educate young

Kenyans to take to agriculture and especially to growing of TC bananas since it has been proven in this study to be a remunerative crop enterprise for those who adopted and sustained the use of recommended practices.

5.4 Areas for further research

i) Technology spill over - Is the wide utilization of research products over a range of agricultural production conditions or environments and cutting across geographical boundaries. The TC banana technology has had a wide ranging spillover effects arising from cross border trade in bananas and coming up of TC banana hardening nurseries. The estimated impact does not include these spillovers due to trade between the regions. This is meant for future research.

ii) Tissue culture banana has been adopted in the whole country and the project went far as Tanzania, Uganda and Rwanda. Therefore it's imperative that future research could encompass data from these countries for comparison purposes.

iii) Research on banana diseases needs to be stepped up for further research in order to increase the yields.

6.0 REFERENCES

Andrea. S., Zephania. D., Fabio. M., Patrizo. W., 2009. Socio Economic Impacts of non transgenic biotechnologies in developing countries: case of plant micro propagation in Africa. FAO 2009.

Alston, J.M, Norton, G.W. & Pardey, P.G. 1995. Science under scarcity: principles and practice for agricultural research evaluation and priority setting. Cornel University Press, Ithaca, NY.

Ashley. Carney. 1999. Sustainable livelihoods: lessons from early experience. DFID, London

Bagamba,F.,Ssennyonga,J.W.,Katungi,E.,Ragana,P.,Katwijukwe,A.,Tushemereirwe,W.K .& Gold 2001. Current Banana Production and productivity in Bumunanika Sub-County, Central Uganda. Baseline Study. ICIE, Nairobi.

Beam Business Options Ltd 2001.Survey of Institutional Consumption of bananas in Nairobi. ISAAA AfriCenter, Nairobi, Kenya.

Beam Business Options Ltd 2002. TC banana project micro credit Annual report for year 2002, ISAAA AfriCenter, Nairobi, Kenya.

CGIAR. 2006. Guidelines for preparing 2007-09 medium term plans and 2007 financial plans, Washington, D.C.

Chambers, R. & Conway, G. 1991. Sustainable rural livelihoods: practical concepts for the 21st century, institute of Development studies (IDS), Discussion paper No 296.

CIMMYT economic program (1993): The adoption of agricultural technology: A guide for survey design, Mexico, D.F, CIMMYT.

DFID. 2001. Sustainable Livelihood Guidance Sheets

Falck-Zepeda, J., Traxler, G. &Nelson, R.G.2000. Rent creation and distribution from biotechnology innovations. The case study of Bt cotton and herbicide-tolerant soybeans in 1997, Agribusiness, February 2000, Vol.16.issue1, p. 21-32.

Falck-Zepeda, J., Cohen, J., Meinzen-Dick, R &Komen, J.2002. Biotechnology and sustainable livelihoods. Findings and recommendations of an international consultation. ISNAR, Briefing paper 54

FAO.2005. Annotated Bibliography on the Economic and Socio Economic Impact of Biotechnology in Developing countries, Rome

Gittinger, F. 1982. Economic Analysis of Agricultural projects. The John Hopkins University Press: Baltimore, Maryland, USA.

Graff, E. 2000. The role of economic research in the Evolution of International Agricultural Biotechnology

Graham, B., Peter, B., 2003. Global impact of biotech crops: socio economic environmental effects in first 10 years of commercial use. Vol.9 number 3, article 2 Economics ltd., Dorchester, UK.

Hareau, G., Norton, G.W., Mills, B.F. Peterson, E.2005. Potential Benefits of Transgenic Rice in Asia: A general equilibrium Analysis, Quarterly Journal of international Agriculture, Vol.44, No.3, p.229-246.

Harsch, E. 2004. Farmers embrace African Miracle rice high yielding Nerica varieties to combat hunger and rural poverty, in: Africa recovery, Vol.17, No.4, p.10-22.

Hossain,F.,Pray, C.E.,Lu,Y.,Huang,J ,Fan,C.&Hu,R. 2004. Genetically Modified cotton and Farmers health in China, International Journal of occupational and Environmental health, vol.10, No. 3, p.296-303.

ISAAA 2000-2004. Diffusion of tissue culture banana biotechnology to small holder farmers in Kenya. Annual report

Jayamangkala, N., Batt, P., 2009. International symposium on the social economic impact of modern vegetable production technology in tropical Asia Chiang Mai Thailand.

Jennett, C., Affleck Hall, L., Hailey, D. 2003. Journal of Telemedicine and Telecare

KARI 2000. Biotechnology to benefit Small scale Banana producers in Kenya-phase II. Project proposal submitted to International Development Research Center (IDRC) and the Rockefeller Foundation.

Kamau and Beam Business options. 2000. Banana Market Survey in Nairobi City and its Environs, ISAAA AfriCenter, Nairobi, Kenya.

Karembu, M., 2007: Banana policy. Nairobi, Kenya.

Kamrany, C., Nake, M., 1974. Technology: measuring the socio economic impact of manufacturing automation. Cambridge, Massachusetts. USA.

Kung'u, C.2000. An Evaluation Report on the project "Biotechnology to Benefit Small-scale Banana producers in Kenya" ISAAA AfriCenter, Nairobi, Kenya.

Krishna, V., Qaim, M., 2007. Potential impacts of BT egg plant on Economic surplus and farmer's health in India. University of Hohenheim, Stuttgart, Germany.

Kwach 2000.Performance of banana cultivars in South Western Kenya. Acta Hort. (ISHS) 540: 239-246.

Lusty, C. &Smale, M.2003.Eds. Assessing the social Economic Impact of Improved banana varieties in East Africa, proceedings of an interdisciplinary research design workshop jointly organized by INIBAP and IFPRI in Kampala, November 7-11, 2002.

Mbogo, S.2002. Economic Analysis of the production of Tissue culture bananas and Assessment of their Market potential in Relation to Nairobi as a metropolitan market, ISAAA AfriCenter Economics Research Report, Nairobi Kenya, April 2001.

Mbogo, S., Wambugu, F.M. & Wakhusama, S. 2003. Socio economic Impact of biotechnology applications: some lessons from the pilot tissue culture banana production promotion project in Kenya, 1997-2002. paper submitted at the XXV/IAAE conference, Durban, South Africa.

MOA, 2006. Annual agricultural report in Kenya.

Morooka, Y., 1982. Socio economic impact of technology transfer on a Philippine Village; Same lessons from technical cooperation with Japan. FFTC books series no. 31.

Moschini,G ,I apan,H &Sobolevsky,A.200. Roundup Ready soybeans and welfare effects in the soybean complex, Agribusiness, Vol.16, P.33-35.

Moschini,G.,&Lapan,H.1997.Intellectual Property rights and the welfare effects on Agricultural R&D, American Journal of Agricultural Economics,Vol. 79,No.4,p.1229-1242.

Mugwagwa, J. 2004. Assessing the State of adoption, Development and Commercial utilization of Micro propagation Technologies in Zimbabwe .FAO-SDRR, Rome.

Nyamori, 2003. Socio economic background of tissue culture banana production in Nyanza

Ogunsumi, G., Omobolanc, L., Olu, S., 2005. Socio economic impact assessment of Maize production technology on farmer's welfare in South West, Nigeria.

Pachico, D., Escober, Z., Rivas, L., Gottret, V. &Perez, S. 2002. Income and employment effects of transgenic herbicide resistant cassava in Colombia: a preliminary simulation, in Evenson, R., Santaniello, V., Zilberman, D. (Eds), Economic and Social issues in agricultural biotechnology, CAB, Wallingford.

Pray C., Ma, D., Huang, J. &Qiao, and F. 2001. Impact of Bt cotton in China, World development, Vol.29, No.5, p.813-825.

Posada, B. C., P. Knight., G. Fain, C. Coker, D. Veal, and R. Coker. 2004. Socio-Economic Survey of Nursery Automation. Poster presented at the 49th Annual Southern Nursery Association Research Conference and Trade Show, Atlanta, Georgia, August 11-12, 2004.

Qaim, M. 1999. Assessing the Impact of Banana Biotechnology in Kenya, Assessing the Impact of Banana Biotechnology in Kenya, ISAAA Briefs No. 10, ISAAA: Ithaca, New York,

Qaim, M. 2000. Potential Impacts of Crop Biotechnology in Developing countries, Peter Lang Verlag, Frankfurt.

Qaim,M.&de Janvry,A. 2003. Genetically Modified Crops, Corporate pricing strategies, and farmers adoption :The case study of Bt Cotton in Argentina, American Journal of agricultural Economics,Vol.85,No.4,p.814-828.

Qaim, M. &Zilberman, D.2003. Yield effects of genetically modified crops in developing countries, science, February7, 2003, vol.299, issue 5608, p.900-903.

Republic of Kenya, Ministry of Planning and National Development, Central Bureau of Statistics. (ROK/CBS).1997.Welfare Monitoring Survey in Kenya (WMS, 1997): Basic reports (Nairobi, Central Bureau of Statistics, Kenya).

Ssennyonga, J.W.2005. Assessing the socio economic impact of micro propagated technologies on farming households in Uganda.

Sonia, H., 2008. Socio economic impact of low cost carriers on the central Eastern European market. Poznan University of Economics, Poland.

Steinfield, C., White, P., 2003. Community level socio economic impact of electronic commerce

Steffen, A. 2007. Report on the peer review of the paper "The Socio-economic impact of plant micro propagation technologies in selected African Countries", FAO-SDRR, Rome

Uyen,N.V.,Ho,T.V.,Tung,P.X.,Vander Zaag,P.&Walker,T.S.1996. Economic Impact of the rapid multiplication of high yielding, late blight resistant varieties in Dalat, Vietnam.In:T.S. Walker and C.C.Crissman (eds) Case studies of the economic impact of CIP related technologies. International potato center, Lima, Peru.

Wambugu, F.2001. The Benefits of Biotechnology for Small-Scale Banana Producers in Kenya, ISAAA Briefs No.22: ISAAA: Ithaca, New York, USA

Wambugu, F. 2001. Modifying Africa: How biotechnology can benefit the poor and the Hungry, A case Study from Kenya, Nairobi, Kenya.

Wambugu, F.2004. Food, Nutrition and Economic empowerment: the Case for scaling up the Tissue Culture Banana project to the rest of Africa, Paper presented at the NEPAD/IGAD regional conference "Agricultural successes in greater horn of Africa" held in Nairobi, Kenya, November 22-25, 2004.

Zimmermann, R &Qaim, M. 2004. Potential health benefits of Golden Rice: a Philippine case study, Food policy 29, p.147-168

7. ANNEX

Annex 1: costs before and after adopting banana TC technology

COSTS BEFORE ADOPTING:

Variable	N	Mean (Kenya	Std Dev	Minimum	Maximum
CB land preparation	79	579.4936709	817.0363874	50.0000000	6560.00
CB digging purchase	79	716.9620253	1341.05	40.0000000	10000.00
CB plantlets	59	418.5593220	933.8472752	20.0000000	5000.00
CB planting	73	346.1643836	416.2652404	20.0000000	2000.00
CB manure	59	431.0169492	691.4445023	20.0000000	4000.00
CB fertilizer	28	743.5714286	410.7014261	100.000000	1500.00
CB weeding	71	428.1690141	767.6835469	50.0000000	6160.00
CB pesticides	30	346.0000000	317.9633464	50.0000000	500.00
CB watering	21	488.8095238	1279.92	25.0000000	6000.00
CB harvesting	60	222.0000000	293.4586276	20.0000000	2000.00
CB transport	65	283.2307692	421.9601125	20.0000000	3000.00
CB labour	48	386.8750000	880.2034490	20.0000000	6160.00

COSTS AFTER ADOPTING:

Variable	N	Mean(Kenya	Std Dev	Minimum	Maximum
CAlandpreparation	91	936.7032967	1099.57	50.0000000	6160.00
CAdiggingholes	91	1270.88	2085.98	100.0000000	12500.00
CAplantletspurchase	91	14618.68	59228.74	100.0000000	550000.00
CAplanting	91	672.3076923	996.6032053	80.0000000	7000.00
CAmanure	86	812.8953488	983.9105654	20.0000000	5700.00
CAfertiliser	56	1664.46	2014.34	100.0000000	10000.00
CAweeding	85	829.7647059	1517.15	50.0000000	10400.00
CApesticides	41	690.0000000	664.3906983	50.0000000	3200.00
CAwatering	35	2634.43	12605.34	20.0000000	75000.00
CAharvesting	72	473.3333333	679.3830051	10.0000000	3000.00
CAtransport	76	572.5657895	709.5146197	20.0000000	4000.00
CAlabour	59	737.7118644	1104.94	10.0000000	6160.00
CAinterestonloan	36	6200.72	24748.54	80.0000000	150000.00

Annex 2: Benefits before and after TC banana technology adoption
BENEFITS BEFORE ADOPTING

Variable	N	Mean	Std Dev	Minimum	Maximum
BB total production in Kenya shillings	78	18594.10	38651.44	120.0000000	250000.00
BB marketed produce in Kenya shillings	63	15523.65	36372.92	60.0000000	212500.00

BB home consumption in Kenya shillings	76	6232.24	10807.61	40.0000000	81000.00

BENEFITS AFTER ADOPTION

Variable	N	Mean	Std Dev	Minimum	Maximum
BA total production in Kenya shillings	88	88585.34	267275.95	300.0000000	1800000.00
BA marketed produce in Kenya shillings	87	81190.23	256066.43	800.0000000	1650000.00
BA home consumption in Kenya shillings	81	9189.63	17766.61	300.0000000	150000.00

Annex 3: Enterprises Ranking

Enterprise	No. of respondents	Percentage (%)
Bananas	60	17
Livestock	56	16
Maize	46	13
Tea	39	11
Vegetables	27	8
Coffee	24	7
Tomatoes	12	4
Beans	9	3
Sweet potatoes	9	3
Onions	9	3
Horticulture	9	3
Fruits	8	2
Poultry	7	2
Napier grass	7	2
Groundnuts	5	2
Sugarcane	5	2
Finger millet	3	1
Cassava	3	1
Potatoes	2	1
Tobacco	2	1
Trees	2	1
Sorghum	1	0.3
Green grams	1	0.3

Other sources

Sources	#	%
Business	9	89
Employment	5	5
Self employed	2	2

Brick making	2	2
Self employed	2	2
Stone mining	2	2
Children	1	1
Brokerage	1	1
Casual labour	1	1
Driving	1	1
Workshops	1	1
Savings	1	1
Merry go round	1	1
Pension	1	1
Lumbering	1	1
Stone mining	1	1
Theatre	1	1
Savings	1	1
Plumber	1	1

Annex 4: Questionnaire

Social Economic Data Survey in Kisii Highlands and South Nyanza: Year 2008

Household Number: _____ Date: _____

District: _____ Division: _____

Location/County _____ Sub location/county: _____

Name of Enumerator: _____ Village: _____

Name of respondent _____

1. 0 Household Details

1.1 Make a complete list of all individuals who normally live and eat their meals together in this household, starting with the head of Household

Name (see code). A1	Sex (see code) A2	Age(years) A3	Marital status(see code) A4	Highest level of education(see code) A5	Number of years in school A6	Relationship with head (see code) A7	Main Occupation (see code) A8

A2 1-male 0-female

A4 Monogamous Married =1, Polygamous Married =2, Living Together=3, Separated=4, Divorced=5, Widow or Widower =6, Never Married=7

A5 1=None 2=pre-unit 3=Primary 4=secondary 5=Post secondary 6=others

A7 Head= 1, Spouse =2, Son =3, Daughter= 4, Father/Mother= 5, Sister/Brother= 6, Grandchild= 7, Other Relative (Specify) = 8, Servant (Live-In) =9, Other Non-Relative (Specify) =10

A8 farming=1, Casual labour =2, Employed=3 Family business=4, Self-employed=5, Student=6 none=7 others (specify) =8

2.0 Adoption of the tc technology

2.1 Total Farm Size (1) Own _____ (Acres) Leased---------- (Acres)

2.2 Have you adopted TC technology? Yes ☐ No ☐

2.3 If yes, which year? _____

2.3 If yes, what are the problems you experience? _____

2.4 If no, why? _____

2.5 If yes, where did you get funds to purchase the plantlets and fertilisers? _____

2.6 How much was it? _____

3.0 Infrastructure

3.1 House type: Permanent ☐ Semi permanent ☐ Temporary ☐

3.2 Accessibility to telephone Yes ☐ No ☐

3.3 Accessibility to Electricity Yes ☐ No ☐

3.4 Distance to an all-weather road _____ Kms _____Hours

4.0 Income and economic welfare impact

4.1 Since you adopted TC technology which assets have you acquired?

Assets	Assets bought from TC income	Amount(Kshs)

4.2 List and rank in order of importance the major farm enterprises and other sources income

Farm enterprise	Rank	Amount (Kshs)	Others sources	Rank	Amount (Kshs)

4.3 On which items do you spend your income and how much? *(Please specify unit)*

Fuel		Food		Education		Shelter		Water		Health	Clothing
Type	Amount	Type	Amount	Type	Amount	Type	Amount	Type	Amount	Amount	Amount
Kerosene		Day		College		Rental		Mobo			
Gas		Week		Secondary		Own		Jerry can			
Firewood		Month		Primary		Parents					
Charcoal				Pre-unit		Others (specify)		Others(specify)			
Total		Total		Total		Total		Total			

4.4 List most common foods eaten at home in a typical week for

Breakfast	Lunch	Supper	Baby food

4.5 Main source of farm labour

Sources	Own Family Labour 100%	Own Family labour plus Hired Labour		100% hired Labour	Others (Specify)
Tick Appropriately		Less than 50% hired	More than 50% hired		

5.0 Gross Margins Analysis for Technology

5.1 How would you compare your benefits and costs after adopting this technology?

Before adopting the Technology	Amount (Kg, bunches, etc)	Price /Unit (Kshs)	After adopting the technology)	Amount (Kg, bunches, etc)	Price /Unit (Kshs)
Benefits			**Benefits**		
1) Total Production			1)Total Production		

2) Marketed Produce			2)Marketed Produce		
3) Home Consumption			3)Home Consumption		
Costs			**Costs**		
1) Land preparation			1) Land preparation		
2) Digging holes			2) Digging holes		
3) Plantlets purchase			3) Plantlets purchase		
4) Planting			4) Planting		
5) Manure			5) Manure		
6) fertilizer			6) fertilizer		
7) Weeding			7) Weeding		
8) Pesticides			8) Pesticides		
9) Irrigation/watering			9) Irrigation watering		
10) Harvesting			10) Harvesting		
11) Transport			11) Transport		
12) Labour			12) Labour		
13) Interest on loan			13) Interest on loan		
14)Others (specify)			14) Others (specify)		

6.0 Details of banana Type

6.1 Banana details

Information	**TC banana**	**Non- TC banana**
Acreage farm size under		
How many bananas do you have in your farm		
Source of planting materials		
Source of technical information on orchard management		
Which are the dominating variety		
How many bunches do you sell per month		
How much do you sell per month		

6.2 Why do you prefer these varieties (TC banana, non-TC banana)?

_____

6.3 Number of plantlets that did not do well/Lost

Reason	Tc plantlets	Non tc plantlets
Diseases		
Dwarf plantlets		
Physical damage		
Drought/Bad weather		

6.4 Harvesting and Sale

	Tc Bananas	Non-Tc Banana
No. of Bunches Harvested PM		
No. of Bunches Consumed at Home Pm		
No. of Bunches Sold/Pm		
Price: Kshs. Per Bunch		

6.4 What is your future plans for (TC banana, non-TC Banana)

_____

7.0 Marketing:

7.1 Who are the major buyers of your bananas? _____

7.2 At what point(s) do they buy your bananas? (Tick appropriate selling/buying point):

(a) At farm-gate _____

(b) At a local market/buying point _____

(c) At some other market/buying point (Please specify where _____

7.3 Distance to Nearest Local Market/Buying Point (km) _____

7.4 Name of Local Market/Buying Point _____

7.5 Type of transport used for the different markets where the bananas are sold e.g. wheelbarrows, bicycles, and Lorrie's

_____

7.6 Name(s) of markets and distances (in km) for the different markets or buying points

_____

7.7 Charges for Transport (Kshs. Per Bunch of Bananas) to nearest Local Market/Buying Point

_____

7.8 Charges for Transport (Kshs Per Bunch of Bananas) in relation to the different Market/Buying Point(s)

_____

7.9 Do you know of any banana processing in your area? Yes ☐ No ☐

If yes (a) what is the name of the unit? _____

(b) What products does it produce? _____

(c) Have you supplied them with bananas? Yes ☐ No ☐

8.0 Gender roles and Participation in the project

8.1 What is the percentage (man hours) (%) contribution of labour by the different categories of the household members in the different types of banana-related activities (as tabulated below)?

Activity	% Contribution of Labour by Household Member Category			
	Adult male	Adult female	Male child	Female child
Bush clearing				
Ground breaking/digging				
Digging holes				
Manure/Fertilizer application				
Planting (with banana plantlets)				
Weeding				
Drawing water & Watering				
Desuckering				
Propping				
Harvesting				
Marketing in general				

8.2 Gender roles in decision-making: in percentage (%) terms, what are the contributions of the different household gender categories in the making of decisions related to the following items?

Type of Decision	% Contribution to Decision by Household Member Category					
	Men		Women		Children	
	Access	Control	Access	Control	Access	Control
Banana fruit for Home Consumption						
Banana sales						
Money income from Banana sales						

9.0 Micro credit

9.1 Have you ever had access to credit on farm activities? Yes ☐ No ☐

9.2 If yes, which farm activity _____

9.3 If yes, Which institution gave you credit_____

9.4 How much did you receive from the micro credit firm?

(a) In kind _____

(b) Cash _____

9.5 How much have you managed to repay? Kshs _____

9.6 Have you encountered any problems in repaying? Yes ☐ No ☐

9.7 If yes what were the problems?

_____

9.8 How would you want the credit scheme to be conducted next time?

_____

9.9 What was the percentage interest rate on the money you received as credit? _____

Thanks and May God bless you