ADOPTION AND IMPACT OF IMPROVED AGRICULTURAL TECHNOLOGIES IN DEVELOPING COUNTRIES: THE CASE OF IMAZAPYR-RESISTANT MAIZE IN WESTERN KENYA

BY

DJANA BABATIMA MIGNOUNA

A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2011

ABSTRACT

Declining productivity of food crops in developing countries is associated with several factors including poor adoption of improved technologies against pests and parasites destroying crops with developmental implications on food insecurity and poverty. This study has been undertaken to contribute to the understanding of farm-level adoption dynamics and economic impacts of agricultural technologies. This study was done using a case of imazapyr-resistant maize technology for combating noxious *Striga* weed which has devastating effects on maize production in western Kenya.

A cross sectional survey that included randomly selected samples of 169 adopters and 431 non-adopters. The relevant data were collected and analysed using descriptive statistics, stochastic production frontier and tobit regression models. The net present value (US $21 680 402), benefit-cost ratio (4.77) and net benefits per capita (US $41 063) for imazapyr-resistant maize enterprise were attractive. However, its adoption rate was low, whereby about 28% of the surveyed households adopted the technology. The results from tobit model estimation indicate that farming experience, education of the household head, gap between maize production and consumption, farmer's risk-taking, number of extension visits, lack of seeds, membership to social groups and imazapyr-resistant maize's effective dissemination pathway were found to be significant (P<0.05) in influencing the adoption decision. The results of impact assessment indicated that its adoption increased significantly (P<0.01) the frontier maize output. Imazapyr-resistant maize had succeeded in reducing *Striga* seed-bank hence significantly (P<0.05) raising productivity from 2.2 ton/ha (non- imazapyr-resistant maize) to 2.8 ton/ha (imazapyr-resistant maize) with significant returns to land (US $173/hectare) and labour (US $8/man-day).

Two main conclusions can be drawn from this study. First and foremost, is that the use of imazapyr-resistant maize is a promising option for farmers since this technology has been shown to be profitable compared with other maize varieties and, secondly, it has the potential to impact positively on poverty reduction in western Kenya. Therefore, its adoption deserves attention from policy makers who should: (a) Initiate new awareness campaign, improve the seed supply chain in order to broaden its adoption and (b) provide significant positive public investment for technology transfer to improve its effectiveness and efficiency.

DECLARATION

I, Djana Babatima Mignouna, hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work and has neither been submitted for a degree award in any other university.

Djana Babatima Mignouna (PhD Candidate)	Date

The above declaration is confirmed

Prof. E.M. Senkondo (Supervisor)	Date
Dr. K.D. Mutabazi (Supervisor)	Date
Dr. V. M. Manyong (Supervisor)	Date

COPYRIGHT

ACKNOWLEDGEMENTS

Several institutions and individuals have directly and indirectly contributed towards a successful completion of this study. I wish to express my special thanks to the International Institute of Tropical Agriculture (IITA) for the financial support throughout the course of the study; my particular thanks go to Sokoine University of Agriculture (SUA) and my sincere appreciation goes to all the people as individuals or organisations who assisted me in one way or another in the completion of this thesis.

My sincere gratitude goes to my supervisors, Prof. E.M. Senkondo, Dr. K.D. Mutabazi and Dr. V.M. Manyong for their professional guidance, encouragement and constructive criticism during the course of the study without forgetting of my main supervisor the late Prof. G.C. Ashimogo, who died during my data collection.

Special thanks should go to all academicians who contributed in a certain way to the successful completion of this work. In particular I wish to thank Dr. A. Mwakalobo, Dr. S.M.M. Simon, Dr. E. Lazaro, and Mr A. Akyoo for their constructive comments during proposal development and on the final thesis draft. Many thanks should also go to all staff and fellow PhD students in the Department of Agricultural Economics and Agribusiness at Sokoine University of Agriculture.

My fieldwork could not have been successful without the help of Dr. G. Omanya under the African Agricultural Technology Foundation (AATF), the cooperation of Mr. E. Okolo from SAGRIC in Kenya, Mr. B. Oyata, lecturer from Great Lakes University in Kenya and Mrs. A. Muchiri from IITA-Kenya who provided their help for the success of the data collection planning and implementation. I am also indebted to the support given by districts leaders, extension staff, other professionals and enumerators in the surveyed districts in western Kenya.

Last but not least, contribution by my family has been enormous and encouraging above all from the late Ayaa Philomene Mignouna, Raymond Satena Kouana Mignouna, Jacob Mignouna, Philomene Mignouna, Joseph Ranougo Badombena, Josephine Badombena and Gisele Eklou. Thanks are also due to all my sisters, brothers, and friends all over the world above all to my beloved Aguster Deborah Nzenga for constantly encouraging me to achieve this objective.

DEDICATION

To GOD, be the Glory.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AATF	African Agricultural Technology Foundation
BASF	Badische Anlin-& Soda Fabrik
BCR	Benefit Cost Ratio
CGIAR	Consultative Group on International Agriculture Research
CIMMYT	International Maize and Wheat Improvement Center
DCs	Developing countries
DFID	Department for International Development
FAO	Food and Agriculture Organization
FEWs	front-line extension workers
Freq	Frequency
GDP	Gross Domestic Product
GM	Gross Margin
Ha	Hectare
HIV/AIDS	Human immunodeficiency virus/Acquired immune deficiency syndrome
IA	Intervention area
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IPDET	International Program for Development Evaluation Training
IRM	Imazapyr-resistant maize
IRR	Intenal rate of return
KEPHIS	Kenya Plant Health Inspectorate Services

KFSSG	Kenya Food Security Steering Group
Kg	Kilogram
Ksh	Kenya shillings
MOA	Ministry of Agriculture
NARS	National Agricultural Research Systems
NGO	Non Government Organization
NIA	Non-intervention area
NPK	Nitrogen, phosphorus, and potassium
NPV	Net Present value
OFDA	Office of U.S Foreign Disaster Assistance
SPSS	Statistical Package for Social Science
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
TARP II	Tanzanian Agriculture Research Project Phase Two
Ton	Tonne
URT	United Republic of Tanzania
USA	United States of America
USAID	United States Agency for International Development
WeRATE	Western Regional Alliance for Technology Evolution

CHAPTER ONE

INTRODUCTION

1.1 Background Information

There is increasing needs of adopting new enhanced technologies in developing countries (DCs) to accelerate diversification and intensification of agriculture. The need is induced by several factors of which growing population pressure is the most prominent (Norton *et al*., 2006). The adoption of improved agricultural technologies for staple crop production has become a critical avenue of increasing the productivity of smallholder agriculture in DCs, thereby fostering economic growth and improving well being for millions of poor households. Yet some of the DCs are still lacking information about various agricultural technologies used by farmers making the formulation of policy on increasing productivity a difficult endeavour.

There is a wide range of agricultural technologies which are being used successfully by farmers. However their adoption in Africa still poor. Experience from various researches revealed low adoption rate of new agricultural technologies in the context of smallholder farming (Perret and Stevens, 2003); on average 22% in Sub-Saharan Africa (SSA) as opposed to 78% in South Asia and 84% in East Asia (Evenson and Gollin, 2003). Similar cases are reported in Kenya, where the adoption of promising agricultural technologies has been disappointing (Nyangena, 2004). Low adoption rates have been attributed to be correlated to various factors such as: marginal farming conditions (Stoop, 2002), low socio-economic returns to the farmer (Hatibu *et al*., 2002), low ratio of benefit to costs brought about by inadequate development or complete lack of food trade among the rural areas (Hatibu and Rockstrom, 2005); or agro-ecologic factors (Gabre-Madhin and Haggblade, 2004). To help address this concern, the Consultative Group on International Agricultural Research (CGIAR) and its member centers have been at the forefront of research to encourage the use of new staples crops in risky environment.

Maize is one of the most important staples crops in Africa accounting for almost 40% of all cereals (AATF, 2008). This cereal production is constrained by one of the most important root parasites known as *Striga*. *Striga* is worsening the conditions of farmers who were already food-insecure, and threatening long-term global food, leading to food insecurity for millions of people. *Striga* affects cereals in an area of at least 5 million hectares in SSA (Vurro *et al*., 2010). *Striga* depresses maize grain productivity by 20–100%, often leaving farmers with little or no food grain at harvest (AATF, 2008).

In western Kenya, maize is a crop with high yield potential and thus has the potential in helping to solve the food crisis. There are however several factors which contribute to the reduction of household maize production, these include: poor weather conditions, high price of production inputs such as fertilizer and tractor hire, debility impact of HIV/AIDs among agricultural households around the Lake Victoria and *Striga* parasitic weed. *Striga* parasitic weed is considered as one of the major constraints that impedes the realization of yield potentials of maize. *Striga* is colonizing over 216 000 hectares cropland resulting into maize losses of 182 000 tons per year; in monetary terms, about US$ 29 million per *annum* worth of maize is reportedly lost (Woomer and Savala, 2008).

Traditional *Striga* control methods such as uprooting, burning, and manuring have proven to be ineffective (Manyong *et al*., 2008a, 2008b). The modern methods which were made available to reduce *Striga* infestation include heavy application of fertilizer (Igbinosa *et al*., 1996), crop rotation suggested by Oswald and Ransom (2001), use of trap crops susceptible to parasitism by *Striga* (Gbèhounou and Adango, 2003), herbicide application (Oswald, 2005), and the use of resistant/tolerant crop varieties (Showemimo *et al*., 2002). All these methods were limited by the reluctance of farmers to adopt them for both biological and socioeconomic reasons (Lagoke *et al*., 1991; Gbehounou and Adango, 2003). More attention is therefore being focused on finding efficient technology that would successfully address the problem of *Striga* infestation and thus improving maize productivity. As a response to the persistent *Striga* disaster for improving Africa's domestic production, integrated *Striga* control and the novel imazapyr-resistant maize (IRM) technology which utilizes herbicide resistant maize seed coated with the herbicide imazapyr, have been proposed to farmers. However *Striga* is still affecting maize lands in western Kenya depicting a low use of IRM in spite of early economic analysis which showed IRM success on *Striga* control. Therefore questions still remain on what hinders its adoption and the change processes underlying the adoption itself? Is IRM still profitable? Is it the lack of basic inputs for IRM implementation? Is it the weak information system delivery or farmers' low level of information receptiveness? Or was it related to farmers risk attitude and risk perception? On farmers' rationality and ability to adopt the novel technology: Is IRM technology likely to be accessible and acceptable to the farming families for its adoption? Is IRM technology likely to be economically viable for the farmers to adopt at the levels that will be beneficial to them? And what could be the drivers of IRM use and its resulting influence on farmers' livelihoods?

Status of *Striga* damage and its different control methods, the level of initial uptake and the perceptions of users at the early stages of their exposure to IRM in western Kenya have been documented (Manyong *et al*., 2008a, 2008b; De Groote *et al*., 2007; Woomer and Savala, 2007). However more socio-economic analysis on IRM technology is still necessary to determine the level and factors affecting its current use, economic viability and changes brought aimed at promoting its adoption.

1.2 Problem Statement and Justification

The 2006–2008 food and fuel crises placed millions of people out of access to basic staples. The 2009 financial crisis is estimated to have added 100 million to the number of malnourished people in the world (FAO, 2009) with the developing world bearing almost the entire burden, particularly the South Asia and SSA. By simply boosting agricultural productivity in DCs to ensure reduction of food productivity gap between developed and developing countries should be a priority, providing both an opportunity and a challenge.

The challenges, however, are as substantial as the opportunities and investments in new technology to meet local conditions are minimal in most African countries where for example transportation infrastructures are very weak driving up the costs of inputs and reducing farmers' access to information about new technologies and markets compared to Asia. However, there are signs that governments in Africa and donors are refocusing on agriculture as they recognize its central importance in poverty reduction by helping the farmers to adapt to increasing climate change and to free their land and produce from various diseases and pests. Diseases and pests can develop into unexpected and very serious epidemics, owing to the influence of various characteristics of the pathogen, host and environment. These diseases and pests are causing tremendous crop losses, whose economic and social impact are underestimated in Africa (Vurro *et al.*, 2010). Agricultural technologies are made available for these parasites' control but their transfer to Africa requires location-specific adjustments for a much broader range of crops to realize the potential for yield increases.

Achieving high productivity of DCs' crops has the potential of dramatically improving the livelihoods of many of the poorest people in the world, and ensures better incomes, nutrition, and health. Many African countries also have the potential to move from being net importers of food to being net exporters. In SSA, the fact that the uptake of new technologies is low means that if new technologies are adopted, there is substantial potential for improvement in productivity.

Sub-Saharan Africa's average cereal productivity under rainfed agriculture for instance accounts for 90% of total production which is 0.83 ton/ha (Rosegrant, 2002). Food insecurity is greatest in SSA and is defined in relation to the availability of maize (Phiri *et al.*, 2003). Therefore the adoption of productivity-enhancing technologies is particularly necessary in SSA for increasing maize productivity. In order to meet the demand for maize, maize production is expected to increase from 27 million metric tons to 52 million metric tons by year 2020 (SACRED Africa, 2009). As the primary staple crop and a fundamental part of people's livelihood systems, maize is culturally and politically important and has already been the focus of major research and development efforts (McCann, 2005).

In Kenya, maize is the primary staple food for not only rural households but also composes a great share in the food basket of middle-income and urban poor and the crop is associated with household food security. Root parasite, disease, pest and flooding have led to deteriorating food security conditions throughout Kenya, straining coping mechanisms, exacerbating existing chronic poverty in the country (USAID/OFDA, 2009). Between September 2009 and February 2010 the Kenya Food Security Steering Group (KFSSG) increased the projected number of people requiring emergency food assistance to 3.8 million individuals, representing a 32% increase since February 2009. Losses from root parasites, particularly *Striga* alone account for about 60% of Kenya's chronic deficit in maize (Woomer and Savala, 2007). From as early as 1936, *Striga* was described as a serious problem in Kenya (Kanampiu *et al.*, 2006). In Nyanza and Western provinces in particularly *Striga* infestation occurs under maize with high frequency (Manyong *et al.*, 2008a). Therefore maize is seen as the crop most likely to take advantage of new productivity-enhancing technologies and contribute to food security.

In response to the above problem, organisations such as CIMMYT, BASF, AATF, IITA and other stakeholders have made efforts in bringing IRM technology to farmers as assistance for *Striga* control for better maize productivity. Despite the benefits stemming out of new technologies, their adoption by farmers seem to be low and estimated to be on average about 10% for improved crop seeds (AATF, 2008). Information is still lacking on the level of adoption of IRM in western Kenya since its introduction, its economic viability, the determinate factors affecting its adoption and its impact on farmers' livelihoods.

The study intended therefore to fill these gaps established from past studies in order to enhance faster and sustainable adoption of improved agricultural technologies in Kenya and other developing countries as well, to accelerate gains in productivity and achieve the poverty targets of the MDGs. The findings of this study would help various policy responses to encourage use of IRM and other improved technologies to reverse the slide in agriculture and help boost production and enhance food security. Also the findings would provide some opportunities and challenges in galvanizing the government in considering partnership between private and public sectors as visible options in poverty reduction and sustainable development.

The study adds to the present knowledge on how smallholder farmers change their decisions to adopt certain innovation over time given specific conditions. This study provides information on the adoption pattern of IRM and its dynamics in the study area and therefore giving clues to farmers' adoption behaviour when faced with a particular set of conditions being biophysical, socio-economical and institutional. So understanding these conditions will help the decision and policy makers to embed them when planning for any intervention in this or any other area with similar or more or less similar environment. Technology generators, extension agents and policy makers will benefit from the research output since they require micro-level information to formulate and revise policies and strategies. Empirical information for enhanced IRM adoption is lacking particularly on the current adoption processes and dynamics, and micro-level economics as a driver of technology uptake.

Finally, the knowledge generated from these analyses will inform the design of effective IRM scaling-out activities in terms of enhanced adoption and diffusion of the technology, not only in Kenya but possibly in other African countries affected by *Striga*.

1.3 Objectives of the Study

1.3.1 General objective

Generally the study intends to investigate the adoption and impact of IRM technology for *Striga* control to inform change agents for scaling-out IRM technology in western Kenya. To meet the general objective the study is governed by three specific objectives.

1.3.2 Specific objectives

1. To analyse the adoption rate of IRM technology for *Striga* control in the study area
2. To assess the micro-level drivers of adoption of IRM technology.
3. To assess the impacts of IRM technology on farmers' livelihoods in the study area.

1.3.3 Research hypothesis

1. IRM adoption rate is higher in the intervention than in the non-intervention areas.
2. The adoption of the novel IRM technology in the study area has been driven by most influential household, farm, institutional and technological factors.
3. Changes on farmers' livelihoods can be attributed to the use of IRM package in the study area.

1.4 The Conceptual Framework

The conceptual framework for this study is depicted in fig. 1. Agriculture has been central to development in Dcs for decades and agricultural technology development, transfer and adoption is fundamental in contributing to poverty reduction and economic growth. Agricultural production growth would be realized if the majority of farmers adopt more productive technologies. Each new technology has certain biophysical as well as socio-economic requirements and, similarly, each farmer and his/her farm has specific biophysical and socio-economic attributes. Factors influencing the rate of adoption of novel technologies such IRM include the characteristics of the technology; the farmers; and the economy of the society. The framework (Fig. 1) shows that the adoption of IRM technology is influenced by these characteristics which have either fostering or hampering effects categorized in this study into household, farm, institutional, and technological factors.

Illustrating attitudes in farm decision making towards a new technology understands the importance of its economic viability (the practice has lasting benefits for the family and village / community, economy, and is financially advantageous – or at least bearable – for the adopting farmers) and conditions to its adoption. Adoption requires consideration of different characteristics especially characteristics of farmers (including their general knowledge, perception of the new technology and other social variables) and the technology (including, simplicity and quality of the technology). With favorable conditions, IRM package was expected to be adopted and once adopted, it impacts at household and community-level through increase of maize productivity, contribution to maize producers' technical efficiency, reduction of striga seed-bank in the soil and change of the cropping patterns with these impacts contributing for more adoption. In the long term, the complete reduction of *Striga* seed bank can contribute to increased and sustainable food security.

The cause-effect relationship involves two main parts. The first part is a decision to grow the new IRM (adoption). The second is the realization of outcomes on livelihoods from planting the new variety (impact).

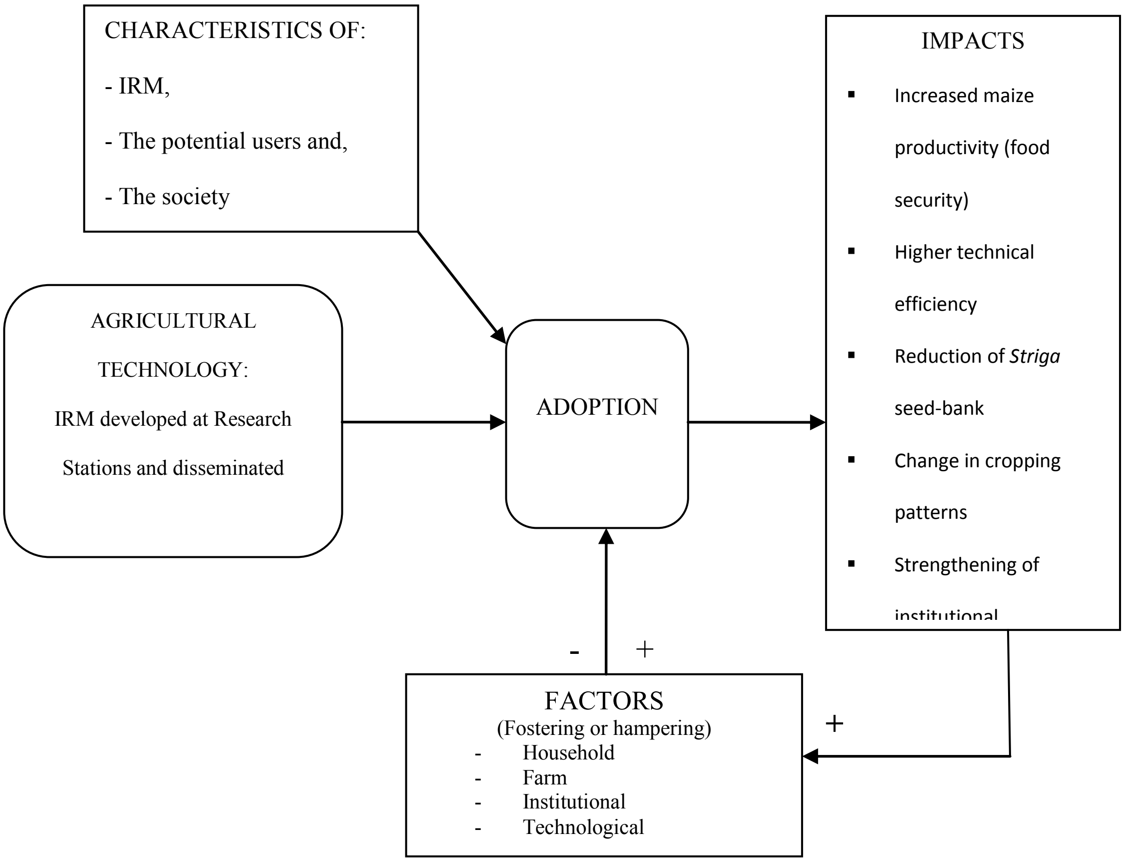

Figure 1: **Conceptual framework for examining adoption and impact of IRM Technology**

1.5 Organisation of the Study

This thesis is organised into five chapters. Chapter One explains the introduction and backgrounds of the study. Also, presented in Chapter One are the problem statement, justification, objectives and conceptual framework. Chapter Two presents literature review where definitions of important terms used in this study are presented. This chapter also discusses issues associated with technology adoption and *Striga* problem in maize. Chapter Three describes the methodology of the study. In this chapter the description of the study area, survey instruments, and definitions of dependent and independent variables used in the study are discussed. Chapter Four presents and discusses the results of the study. Conclusion and recommendations emanating from the major findings of the study are presented in Chapter Five. Lastly, literature cited and appendices are presented at the end.

CHAPTER TWO

LITERATURE REVIEW

2.1 An Overview of the Adoption Concept

Adoption and diffusion are two interrelated concepts depicting the decision to use or not to use and the spread of a given technology among economic units over a period of time. Adoption can have several definitions and in this study, adopt is to bring a given technology like IRM under use in order to control *Striga* and contribute to growth in maize productivity. The adoption of the new technologies, particularly in subsistence farming is governed by a complex set of factors such as household specific, farm, institutional and technological.

The dynamic nature of adoption decisions involves a change as information is progressively collected. Adoption is conceptualised as a multi-stage decision process involving information acquisition and learning by doing by growers who vary in their risk preferences and their perceptions of riskiness of an innovation (Feder *et al*., 1985).

In DCs, adoption studies started about four decades ago following the Green Revolution in Asian countries. In Africa, new agricultural technologies have been introduced in the mid 1970 and the success story achieved in Asia was not exactly the same in african countries except for hybrid maize in Kenya (Byerlee, 1994). The Kenya maize seed industry, especially the hybrid seed development of the 1960s and 1970s, has been hailed as one of the success stories of agricultural development in Africa but for the past

15 years, maize seed sales have stagnated (Doss *et al.*, 2003). During and shortly after the colonial period, maize-based hybridization technologies spread from Kenya over the sub-continent. However, after independence most African governments did not perceive food self-sufficiency as a problem and the improved agricultural technologies were left behind.

A number of non-governmental and public institutions have been attempting to generate and disseminate improved agricultural technologies to smallholders in western Kenya since the end of 1960. Some of these studies were carried out to determine the adoption and factors affecting it (Doss *et al.*, 2003; Ouma *et al.*, 2002), also to analyse the performance of various technologies controlling *Striga* (Khan *et al.*, 2008; De Groote *et al.*, 2008). Adoption studies provide useful background information about farmers who are adopters of a technology and those who are not (Doss, 2003), also about the diffusion pathways.

2.2 Technology Diffusion Pathways

An innovation is an idea, method or object which is regarded as new by an individual, but which is not always the result of recent research (Van den Ban and Hawkins, 1998). Diffusion and adoption are thus closely interrelated even though they are conceptually distinct (Dasgupta, 1989; Diagne, 2010). Not all innovations diffuse at the same rate. The differences in the diffusion rates of innovations in a community can be largely explained by the differences in the characteristics of innovation, as perceived by potential adopters such as: relative advantage, compatibility, complexity, trial ability and observability of its benefits (Dasgupta, 1989).

The adoption pattern of a technological change in agriculture is a complex process with five stages: (a) awareness or the initial knowledge of the innovation, (b) interest and persuasion toward the innovation, (c) evaluation or the decision to adopt or otherwise, (d) trial and confirmation sought about the decision made, and (e) adoption. These stages in the diffusion process imply a time lag between awareness and adoption.

Awareness of *Striga* problem is one of the significant predictors of the decision to adopt *Striga* control measures and awareness of the technology available for its control is a crucial step to adoption. However, researchers have come up with a novel IRM technology which is more effective than the previous methods intended to increase farm production and/or income (Kanampiu *et al.*, 2003). Under such circumstances, farmers must be educated thoroughly on the purpose of this newly introduced innovation if any adoption is to take place. Adesina *et al.* (2000) suggest that to achieve increased impact from new technologies, effective targeting is required. This effective targeting of technologies can be achieved through in-depth analysis of household and its surroundings characteristics, and socio-economic and institutional variables. Awareness is one of the main dynamic elements of technology adoption process and which has a great impact on adoption decision making.

2.3 Technology Adoption Rate

Rogers (2003) defines a rate of adoption as the relative speed with which an innovation is adopted by members of a social system. The rate of adoption is the percentage of farmers who have adopted a given technology (Nkonya *et al.*, 1997). According to Van den Ban and Hawkins (1988), the rate and pattern of adoption of innovations vary according to the type of crop, the location and the specific innovation. The rate of adoption of a new technology is then subject to its awareness and also the profitability and the degree of risk and uncertainty associated with it, and is highly influenced by the capital requirement, agricultural policies, and the socio-economic characteristics of farmers. The rate of adoption of an innovation is greatly enhanced when the proposed technology holds potential to solve perceived problems in a particular location (Raintree, 1983). A study by Byerlee and Hesse de Polanco (1986) examining the relationship between rates (speed) of adoption of technologies and various economic factors showed that the adoption pattern of a particular technology is a function of some characteristics such as profitability, riskiness.

For example in the mid 60s, Kenya recorded one of the highest hybrid maize seed adoption rate in Africa, which was about 88% in the high maize potential zones and also about the same in the western and central highlands (Nyoro *et al*., 2004). The adoption of maize seed in Kenya has been reduced over the last 10 years despite the entry of more seed companies (Appendix 5) into the seed market following the liberalization of the seed industry and the introduction of Kenya Plant Health Inspectorate Services (KEPHIS) as an independent seed inspection authority in 1996. It is the confidence of the seed quality that affects their adoption and not entirely the lack of information of their existence. The challenge in increasing maize productivity therefore is to encourage a wider use of hybrid and other certified seeds (Appendix 5) through improving their quality in order to overcome the sinister diseases and pests.

2.4 Adopters and Non-adopters

There are several definitions of an adopter which vary widely across studies depending on the complexity of the technology concerned. An adopter in this study as already defined by Doss (2003) is someone who is found to be growing any of the introduced improved crop varieties, here IRM package.

2.5 Factors Influencing Adoption of Technologies

This literature explores the determinants of technology choice to explain why rates of technology diffusion frequently seem slower than expected. A number of previous studies have reported issues related to adoption of agricultural technologies and have analyzed the effects of factors in the decision by farmers to adopt agricultural technologies (Fernandez-Cornejo *et al.*, 2002; Gouse *et al.*, 2004; Jera, 2004; Marra *et al.*, 2004; Abdulai and Huffman, 2005; Lemchi *et al*, 2006; Qaim *et al.*, 2006; Nkamleu *et al.*, 2007). For ease of clarity the factors identified as having relationship with adoption are categorized as household specific factors, farm specific factors, institutional factors and technological factors.

2.5.1 Household specific factors

These factors are the most common household characteristics which are mostly related with farmers' adoption behaviour. Among household specific factors, age, education and gender have been reviewed in this study. Each of the above factors influences adoption of agricultural technologies in different ways.

Farmer's age can increase or decrease the likelihood of adopting technologies. Older farmers are likely to adopt a technology because of their accumulated knowledge, capital and experience (See for example studies from Lapar and Pandey, 1999; Abdulai and Huffman, 2005). However, young farmers exhibit a lower risk aversion and being at an earlier stage of a life cycle, are more likely to adopt new technologies that have long lags between investments and yield of benefits (Featherstone and Goodwin, 1993; Million and Belay, 2004; Sidibe, 2005). On the contrary, the study conducted by Tiamiyu *et al*. (2009) on factors affecting the adoption of new rice in Savanna Zone of Nigeria, indicated that farmer's age did not significantly influence improved technology adoption.

On the other hand education may make a farmer more receptive to the advice from an extension agency or more able to deal with technical recommendations that require a certain level of literacy (Simon, 2006). Educated farmers are rational in the choice of technologies instead of developing negative attitudes towards new innovations (Anandajayasekeram *et al.*, 1996; Abdulai and Huffman, 2005) and are earlier adopters of modern technologies (Abdelmagid and Hassan, 1996). The findings of Habtemariam (2004), Million and Belay (2004) indicate that farmer's education has a positive and significant influence on adoption. Each additional year of education increases the probability of the adoption of improved seed. As reports Degnet (1999) cited by Mihiretu (2008) though education plays a significant role in the adoption decision, this variable was not found to be significant in affecting the decision to adopt improved technology.

Gender of the household head also affects the adoption of agricultural technologies. Due to long lasted cultural and social grounds in many societies of DCs, women have less access to household resources and institutional services. Any innovation has different implications to different gender groups depending on their responsibilities and ownership of resources (Adesina *et al.*, 2000). Also due to many socio-cultural values and norms, males have the freedom of mobility and participation in different extension programs and consequently have a greater access to information about new technologies (Asfaw and Admassie, 2004). Regarding the relationship of household's sex with the adoption of agricultural technologies, many previous studies reported that household's gender has a positive effect on adoption in favour of males. Techane (2002) in his study on determinants of fertilizer adoption in Ethiopia found out that male headed households are more likely to adopt fertilizer than female headed households. Similarly, Mulugeta *et al.* (2001) reported that gender differentials among the farm households positively influenced adoption and intensity of adoption of fertilizer use at 5% significance level. They further mentioned that being a male headed household increases the probability of adoption by 5.9%.

2.5.2 Farm specific factors

Farm specific factors such as farm size, farm experience, labour availability and off-farm activities influence farmers' adoption behaviour.

Farm size is often hypothesized as a determinant of technology adoption. Having a large land contributes to perceived security and increased willingness to invest in new varieties. The findings of Nkonya *et al*. (1997) and Gecho (2005) reveal that farm size exerts a positive influence on the adoption of improved technologies. Contrary to this study, Negash (2007) reported that land holding was not significant in the adoption of improved bean and onion technology packages respectively.

Concerning the farming experience, Tiamiyu *et al*. (2009) reported that the more the experience of growing new rice, the higher its adoption. Such a pattern is expected because more experienced farmers may have better skills and access to information about improved technologies. Habtemariam (2004) found that the most efficient farmers appear to have less farming experience than the least efficient ones. More experience is negatively related to adoption at older age. The results of Chilot *et al*. (1996) also indicate that farming experience does not matter in the adoption of improved wheat and coffee technologies.

Labour availability is the other important variable which in most cases has an effect on household's decision to adopt or not to adopt new technologies. Several studies reported positive effect of household labour availability on the adoption of improved agricultural technologies. For instance, Million and Belay (2004) in their study on factors influencing adoption of soil conservation measures in southern Ethiopia found positive effect of household's labour availability on the adoption of soil conservation measures.

Off-farm and non-farm activities are the other important activities through which rural households get additional income. The income obtained from such activities helps farmers to purchase farm inputs. A review of some of the past empirical studies shows that the findings regarding the influence of off-farm/ non-farm income on adoption vary from one study to another. Off-farm income may compensate for missing and imperfect credit markets by providing ready cash for input purchases and could also be used to spread the risk of using improved technologies (Mathenge and Tschirley, 2007). However, off-farm income earners may decide not to invest their financial resources in new agricultural technology but instead invest in more profitable off-farm enterprises (Shiferaw and Holden, 1998; Gebremedhin and Swinton, 2003). Thus the effect of off-farm is difficult to determine a priori.

2.5.3 Institutional factors

The institutional setting of the farm system has a profound influence on the adoption of technologies. Institutional factors like frequent extension contacts are positively related to the adoption decision of farmers (Tesfaye *et al*., 2001; Habtemariam, 2004; and Kansana *et al*., 1996), or they may merely create social pressure for farmers to use inputs and methods the agents advocate (Moser and Barrett 2006). These contacts illustrating that the availability of reliable information sources will enhance communication process and had significant associations with the adoption of improved technologies. Membership to groups may enable farmers learn about a technology via other farmers and from other development agencies (Nkamleu, 2007). Information flow between members of farmer groups is usually very rapid and important. Farmer groups give their members a wider opportunity for educating each other. Higher interactions between members of a group increase chances to widen understanding of new technologies and their advantages. Akinola (1987) cited by Simon (2006) observes that the farmers' habit of attending society meetings regularly is one of the factors, of having positive and significant effects on farmers' adoption decisions. Likewise Adesina *et al.* (2000) found that the probability of adoption is also higher for farmers organized in groups. In some cases, however, an innovation well popularised by extension services may not be adopted if there is no access to it. This is illustrated by Akinola and Young (1985) cited by Simon (2006) which shows that an increase in the distance to the chemical buying stations affects negatively the adoption of cocoa spraying chemical use in Nigeria. Therefore, availability of the innovation to the target farmers is an important determinant of adoption. For scientists to attain higher pay off for their efforts it is important for them to take greater responsibility for ensuring the release of improved varieties and cultivars available to farmers. Manyong *et al.* (1999) show that to increase the probability that successful technologies are more rapidly adopted; there is a need for strengthening links between research, extension, seed companies and non-governmental organizations.

Kansana *et al*. (1996); Tesfaye *et al*. (2001) and Adunni Sanni (2008) reported that access to credit has a significant and positive influence on the adoption of improved technologies. To the contrary, Jabbar and Alam (1993) found that access to credit is not significant in the adoption of rice technology.

Degnet (1999) cited by Mihiretu (2008) in a study conducted in south Gondar, Ethiopia, showed that the number of oxen owned by a farmer determines maize technology adoption. The study revealed that availability of off- farm income opportunity and wealth status of the head of a household affects the adoption of maize technology significantly.

Asfaw *et al*. (1997) in Bako area reported that participation of farmers in extension activities which is represented by farmers attendance to the field days is the only variable which is found to significantly influence the adoption of improved maize variety. Participation in extension training would enable farmers to get more information and improve their understanding about the available packages, which may in turn lead to a change in their knowledge, attitude, and behavior. According to Kansana *et al*. (1996) and Tesfaye *et al*. (2001), attendance of agricultural training is positively and significantly related to the adoption of improved maize technologies. Tesfaye *et al*. (2001) conducted a study on the adoption of high yielding maize technology in major maize growing regions of Ethiopia and the results reveal that even the distance to the nearest market centre significantly and positively influence the adoption decision of improved maize. The study conducted by Negash (2007) on the adoption of bean technology has shown a significant relationship from farms to nearest market distance. However Shivani *et al*. (2000) reported that the distance to the market is negatively related to chickpea adoption.

2.5.4 Technological factors

Farmers' decisions to adopt a new technology in preference to other alternative technologies depend on complex factors. Farmers have subjective preference for technology characteristics which could play a major role in technology adoption. Adoption or rejection of technologies by farmers may reflect rational decision making based on farmers' perceptions of the appropriateness of the characteristics of the technology under investigation (Adesina and Zinnah, 1993). According to Rogers (1983), five major technology characteristics are associated with high rate of adoption of technologies; these include the relative perceived advantage, compatibility with the local culture, low technical complexity, trainability and observability.

The most important advantage of IRM in western Kenya is the eradication of *Striga* from maize fields and the promotion of yield. The more serious the *Striga* infestation to maize is, the greater the relative advantage. Hence, it is easier to mobilize resources in the fight against it. Economic considerations are also important. One should ask the following questions: Does the new technology increase revenue or lower costs? How expensive is it to adopt? Does it reduce efforts or save time? The results from a study by Bartz *et al.* (1999) indicate that technologies with short-term benefits are more preferred by majority of farmers. This can be because farmers lack capability to perceive long-term benefits of technologies. Lapar and Pandey (1999) further show that the relatively longer time period required for realization of benefits makes them more uncertain. Therefore, technologies that take a long time for their benefits to be realised may not be affordable to subsistence farmers (Alavalapati *et al.*, 1995).

Regarding compatibility, Rogers cautioned against committing what he calls the empty vessels fallacy. Those who fall into this trap mistakenly suppose that potential adopters are simply blank slates whose preexisting ideas, practices, and equipment have nothing to do with the proposed innovation. In fact, it is impossible to deal with any new idea except in terms of past knowledge and experience.

The complexity of innovations is a multifaceted subject. On one hand, it is likely to be problematic if a new technology is difficult for potential adopters to understand and use. More precisely, it is problematic if they perceive it to be difficult to understand and use. In other words, the perception is just as important as reality when it comes to the adoption of new technology. From some viewpoints, complexity can be beneficial. It may be advantageous to early adopters if late adopters see a new technology as highly complex, thus prolonging the period during which the innovation confers a competitive advantage for those who have adopted it.

Likewise, trainability may be more important to early adopters than late adopters. When a technology is completely new and has not been adopted, the risks associated with its adoption seem particularly high. It is at this point that making the innovation easily trainable with low risk may be especially important. Once most people are using the technology, trainability becomes less important.

Observability, by contrast, remains important at all phases in the adoption of an innovation because people will not be aware of a given technology unless they learn about it from others. Advertising is often especially important for innovations with low observability, such as products that are used only in private or out of the view of potential adopters, because otherwise few people will learn about these innovations.

2.6 Review of Selected Agricultural Technology Adoption Studies in Kenya

Several adoption studies have been conducted in Kenya and most of them aimed at gathering basic information about the use of modern crop varieties and inputs. A large number of these studies concentrate on cross-sectional analysis of the determinants of agricultural adoption at the farm level. The dynamics of the adoption process are not taken into consideration in cross-sectional analysis and the adoption process is represented as a snapshot in time. The coefficients may be biased since there may be a time-dependent element in the adoption decision. This section reviews some of these studies undertaken in the past.

The CIMMYT studies in Kenya and other East African countries (Mwangi *et al*., 1998; and Doss, 2003) examined adoption decision processes for maize seed and fertilizer technologies and showed that farmer characteristics such as age, gender, and wealth are keys to adoption decisions. Using a Tobit model on cross-sectional data to assess determinants of fertilizer adoption and use in Kenya, Karanja *et al*. (1998) indicated that fertilizer adoption and intensity of use was adversely affected by fertiliser price and the distance to the fertilizer market. Farmers closer to the market tended to use more fertilizer. Farmers using hybrid maize seed used more fertilizer with the effect varying with agro-ecological zones. This indicates existing complementarities between fertilizer and hybrid seed use. The study further noted that education, at post-secondary level, price of maize and extension positively influenced the use of fertilizer on maize. Farmers with higher education tended to adopt and use more fertilizer on maize. This could be because they were able to use recommendations better or had a better ability to evaluate the difference fertilizer makes to productivity.

Ouma *et al*. (2002), in their study using cross-sectional data, found agro-ecological differences, gender, manure use, hiring of labour and extension as statistically significant factors in explaining the adoption of fertilizer and hybrid seed on maize production in Embu district.

Suri (2005) in her study provided a succinct overview of factors affecting maize technology adoption in Kenya. She showed that technology profitability, farmers' training as well as observed and unobserved differences among farmers and across farming systems were the major determinants of adoption

A study by Jayne *et al*. (2006) determined the national-level, region-specific, and household specific factors associated with smallholders' use of improved maize technologies in Kenya where over 25% of the farms use improved maize technology. The study revealed critical factors of which household characteristics such as education of the head, distance to the market, and regional differences lead to fertilizer and hybrid seed adoption on maize production.

Mwabu *et al*. (2006) in their study on the adoption of improved maize varieties and their impact on poverty in Laikipia and Suba districts found that the price of maize, education level, and distance to the roads are the main determinants of hybrid maize adoption by farmers. In their study, De Groote *et al*. (2006) analyzed factors influencing the adoption of maize technologies and fertilizer. Their study found that the proportion of farmers using improved varieties of maize had not changed but there was a positive tendency for the proportion of farmers using fertilizer on maize. They found that education, access to credit, access to extension and agro-ecological differences had a significant influence on fertilizer adoption on maize. The results of the researcher-managed trials with De Groote *et al*. (2007) clearly show that the coating of IRM seeds with imazapyr suppressed the development of *Striga*, and more than doubled productivity, with a spectacular increase of 2.39 tons/ha.

Using household panel survey data to examine trends in fertilizer use on maize by smallholder maize growers in Kenya, Ariga *et al*. (2008) through probit and tobit models to identify factors that affect the decisions by maize farmers to participate in fertilizer markets and conditional on participation and their level of purchases, found location as the dominant factor influencing smallholders' decisions to use fertilizer on maize. The decision of households to purchase fertilizer for maize production was slightly related to land, and unrelated to household wealth. Proximity to fertilizer retailer was found to be an important influence on households' decision to purchase fertilizer for maize production in the relatively low-potential areas. Proximity to fertilizer seller, however, had a very little influence on the quantity of fertilizer purchased. This study considered only fertilizer use on maize and excluded crops such as tea, coffee and sugar cane which, in Kenya, are important drivers of growth in fertilizer use.

2.7 Issues on Technological Impact

A technological innovation usually presents some benefits for its potential adopters but not always to the intended adopters, a new technology has always more advantages than the previous practice that it would replace, at least when there is availability and access to information about it. Technological innovation and adoption were the major contributors to the spectacular increases in agricultural productivity during the twentieth century (Gardner, 2002). The contribution of new technology to economic growth can only be realized when and if the new technology is widely diffused and used. A number of authors have indicated that such results begin to occur only when there is a behavioural change among the potential users. Anandajayasekeram *et al*. (1996) stressed that the impact of any technology or project cannot be assessed without information about the number of users (extent) and the degree (intensity) of adoption of improved technologies. An impact is interpreted differently. DFID defines impact assessment as a process of identifying the anticipated or actual impacts of a development intervention on those social, economic and environmental factors which the intervention is designed to affect or may inadvertently affect. Impact assessment in agricultural research is the effort to measure its social, economic, environmental, and other benefits (La Rovere and Dixon, 2007). According to Baker (2000) and Prennushi *et al.* (2000), an impact is the extent to which interventions or programmes cause changes in the well-being of target populations, such as individuals, households, organisations, communities, or other identifiable units to which interventions are directed in social programmes. The changes can be directly or indirectly by the project or programme. In this context, an impact is conceived as outputs/benefits which are generated from the introduced technologies and which have effects to the beneficiary. The effect may be in the form of economic, social, institutional or environmental nature (Moshi *et al.*, 1997; Anandajayasekaram, 2000;

Anandajayasekaram *et al.*, 2001; URT, 2001a). An impact refers to the broad, long-term economic, social, and environmental effects resulting from an intervention. Impact assessment can be undertaken before initiating the project (ex-ante) or during the project period (mid-term) or after the completion (ex-post) of the project or activity (Anandajayasekeram and Martella, 1996). Impact assessment examines also differences between outcomes for project participants and non-participants. However, it is difficult to evaluate impacts for broad objectives like poverty alleviation or environmental sustainability. Thus FAO (2000) found that it is necessary to use intermediate goals such as increased sustainable agricultural productivity through development of improved technologies. For improved varieties which are not complexe like IRM, they need simple learning and adaptation process. Hence simple linear models adoption process and impact assessment have been used (Douthwaite *et al.*, 2002). Impact assessment has no one best method; the method chosen depends on the availability of data, the economic environment and the type of results required. The conventional-assessment approaches are focused on tangible impacts such as income, productivity, cost-benefit ratio, the rate of return and failed to capture important benefits accruing to people as a result of the project because they tended to create a certain distance between those assessing impacts and programme beneficiaries (Ashley and Hussein, 2000). The participatory approaches involve all project actors, all different categories of stakeholders in all stages and without restriction of predetermined set of variables or outcomes (Bellon *et al.*, 2001; Lilja and Bellon, 2006; Lilja *et al.*, 2006; Hellin *et al.*, 2006, 2008; Lilja and Dixon, 2008). The success of this type of approaches relies to a great extent on qualitative judgments made by beneficiaries and project staff rather than on the interpretation of quantitative data by outside experts.

Mathematical models are appropriate for some tasks. However, to assess impacts on poverty, livelihood approaches have become more widespread. Impact assessment studies require a combination of methods (Adato and Meinzen-Dick, 2007) because projects, data, cost, time constraints, and country circumstances vary. Quantitative or qualitative methods and often integrating quantitative and qualitative methods are used for impact assessment. Four commonly used quantitative methods for measuring impact could be employed: "before and after" comparisons, "with and without" comparisons, "target versus achievement" comparisons and "case study" approach. For more details on these methods, an interested reader is referred to La Rovere and Dixon (2007). Any impact evaluation must estimate the counterfactual that is what would have happened had the project never taken place (Baker, 2000). Thus, counterfactual evidence is at the core of impact evaluation analysis techniques. With/without counterfactuals are normally made of participants in innovations versus non-participants, or of adopters (beneficiaries, for instance of a new variety) versus non-adopters (non-beneficiaries). Therefore this is accomplished in this study through the use of "with and without" comparison. Such analysis was conducted easily by comparing the differences in means or percentages of outcome variables between IRM adopters and non-adopters. However, outcome differences may reflect factors other than impact of the technology, especially systematic differences due to the selection of the two groups (DFID, 2002). There is a need to determine whether a causal relationship exist between outcome and introduction of IRM technology as the following four factors outlined in IPDET (2004) could be used:

a) A logical theory expressing a causal relationship which should exist between the technology introduction and outcome. For instance, new IRM is likely to increase maize production;

b) Time order, IRM intervention should come before outcomes;

c) Co-variation, both IRM intervention and the outcome should have the ability to change meaning that we would be able to identify changes in maize production if we compare IRM adopters against non-adopters;

d) Elimination of rival explanations, there is a need to establish that the changes are real from IRM introduction rather than other factors.

The literature about impact assessment emphasizes the importance of establishing the appropriate counterfactual evidence in order to establish a correct causal relationship between IRM technology and the outcomes being measured, since other confounding factors could also have influenced the outcome (Ravallion, 1994; Doss, 2003). Ravallion (1994) and Baker (2000) suggest other methods available for evaluating intervention impacts:

- Randomization (experimental), a method of creating treatment and control groups statistically equivalent to one another. Treatment and control groups should be sufficiently large to establish statistical inferences with minimal attrition. Randomly generated control groups are the counterfactual. Subjects are randomly assigned to treatment or control groups.
- Matching methods are a second-best to randomization. They pick an ideal control group to match the treatment group from a larger survey.
- Propensity score matching matches control groups to treatment groups on the basis of observed characteristics or by a propensity (to participate) score; the closer this score, the better the match.
- Double difference compares a treatment and control group (first difference) before and after a program (second difference). This can be an effective approach if the

interaction between the adopter/beneficiary group and the non-adopter/non-beneficiary control group is small, and the groups are under reasonably similar conditions.

Qualitative techniques are also used to determine impact without depending on the counterfactual to make a causal inference. The focus is on processes, behaviors, and conditions as perceived by individuals or groups; for example, how a community perceives a project and how they are affected by it. Open-ended methods are used during design, data collection, and analysis. Qualitative data can also be quantified. The types of methods that could be used are: key informant interviews, focus group discussion, community group discussion, direct observation, stakeholder analysis, beneficiary assessment, participatory poverty assessment, participatory rural appraisal, scenario analysis.

The livelihoods approach focuses on people's lives rather than on resources or defined project outputs (Ashley and Hussein, 2000; DFID, 2001). This approach is based upon a prior definition of people's objectives, livelihoods and essential related causes and manifestations of their situation.

2.8 Constraint Faced by Maize Farmers: the Genus *Striga*

This genus of parasite therefore has a bigger impact on humans and agro-ecosystems worldwide than any other of the estimated 4100 parasitic plant species (Nickrent and Musselman, 2004). *Striga* spp. parasitise the root systems of their hosts and discoloured growth of affected plants hence called witchweed (Fig. 2). Its local names are: Buta (Kiswahili, kayongo (Luo), oluyongo (Luyha), imoto (Teso), wublum (Gushiegu), rooiblom (Africaans) an onime (Oshiwambu). All *Striga* species except *Striga* *angustifolia* (Don.) Saldanha are dependent on a host to establish themselves, which makes them obligate parasites. Most *Striga* species are annuals but some are perennials (Parker & Riches, 1993). The genus *Striga*, family Orobanchacecae, contains about 41 species that are found on the African continent and parts of Asia; Africa is the presumed region of origin (Wolfe *et al*., 2005). By parasitising crop species, they can cause substantial productivity losses and are therefore considered agricultural pests. To date there are three species as having a significant impact on agriculture in tropical and subtropical areas which are S. hermonthica (Del.) Benth., S. asiatica (L.) Kuntze and S. gesneroides (Willd.) Vatke. Among the 23 species of *Striga* prevalent in Africa, *Striga* hermonthica is the most socio-economically important weed in eastern Africa (Gressel *et al*., 2004; Gethi *et al*., 2005). *Striga* hermonthica seeds are very small (0.2 × 0.3 mm), light weight (0.4–0.5 × 10^{-2} mg) and one plant can produce up to 200 000 seeds (Parker and Riches, 1993). The estimates of average seed bank densities of *Striga* species range from 1800 to 414 600 seeds m^{-2}, taken from a field in Kenya (Oswald and Ransom, 2001) and Ghana (Sauerborn *et al*., 2003), respectively. Recent studies have tried to explain the variability in the size of seed banks and determine, to what extent, densities can be reduced by control options (Van Delft *et al*., 1997; Abunyewa and Padi, 2003; Sauerborn *et al*., 2003; Schulz *et al*., 2003; Franke *et al*., 2006). The effects of S. hermonthica on its host are diverse. The parasite competes with the host for resources, it changes host plant architecture and it reduces the photosynthetic rate and the water use efficiency of the host (Cechin and Press, 1994; Van Ast *et al*., 2000; Watling and Press, 2001). *Striga* induced reduction in host photosynthesis has been reported as the most important mechanism of growth reduction of the host (Graves *et al*., 1989; Gurney *et al*., 1995; Smith *et al*., 1995; Watling and Press, 2001). Its occurrence is associated with poor soil fertility and hence it is prevalent among the poorest of farmers. Farmers around the Victoria Lake Zone in Eastern Africa (Kenya, Tanzania, and Uganda), parts of Ethiopia, Malawi and several countries in West Africa prioritize *Striga* as a major pest.

The estimates of the area affected by *Striga* spp. in the world suggest that approximately 44 million hectares of arable land are under threat; that the livelihoods of more than 100 million farmers are affected (Press and Gurney, 2000); and that cereal grain losses due to *Striga* spp. stand at an estimated four million tons per annum (Sauerborn, 1991).

2.9 Imazapyr-resistant Maize Technology

Imazapyr-resistant maize comprises 2 main elements: an herbicide-resistant maize seed and imazapyr. As the StrigAway maize germinates, it absorbs some of the herbicide used in coating it. The germinating maize stimulates Striga to germinate and as it attaches to the maize root, it is killed before it can cause any damage. Herbicide that is not absorbed by the maize plant diffuses into the soil and kills Striga seeds that have not germinated. The herbicide used is derived from a naturally occurring gene in maize originally identified by BASF and made available to CIMMYT. Herbicide resistance would integrate well and augment the bio-control strategies being developed for *Striga* (Venne *et al*., 2009).

To control *Striga,* IRM technology has been incorporated in several varieties adapted in western Kenya, and by the beginning of 2006 several seed companies had started producing the seed on a commercial basis. Field trials and tests were organized for farmers to evaluate the technology in order to see how the varieties perform in fields before its release. In the first stage, which took place in 2002, trials were organized in farmers' fields but these were researcher-managed. The field trials in 2002, 2004 under researchers' and farmers' management and other surveys have proved that the approach of coating maize seed with imazapyr was efficient on *Striga* suppression, compatible and effective with traditional farming systems, giving up to more than two-fold maize yield increase under farmers' conditions (De Groote *et al.*, 2007). For better diffusion of IRM technology, a partnership among CIMMYT, NARS, BASF, and AATF, local seed companies, NGOs and farmers has resulted in more than 15 000 demonstrations, five cultivars registered for commercialization, with certified seeds of one of the hybrids being marketed in Kenya since 2006.

Figure 2: *Striga* (witchweed)

2.10 Economic Viability of IRM Technology

Research undertaken by CIMMYT has resulted in the development of a new and promising IRM technology which is highly effective in increasing yields (De Groote *et al.*, 2007). Chemical control of weeds especially using imazapyr reduces and suppresses *Striga* weed densities. This method has gained considerable attention in recent years and appears to be promising as a viable supplement to other control methods.

Studies have particularly proven and confirmed the efficiency in the field and the efficacy under farmers' conditions of IRM technology for *Striga* control (De Groote *et al.*, 2007; Kanampiu *et al.*, 2003). While these present the economic analysis of IRM adoption, empirical analysis of the economic viability of IRM as a strategy for promoting its adoption which is already low is not clearly explained. The results of the researcher-managed trials clearly showed that the coating of IRM seeds with imazapyr suppresses the development of *Striga*, especially in the early stages. Economic analysis showed a high profitability for the IRM technology, the use of IRM technology to control *Striga* leads to yields increase ranging from 38-82% higher than those currently obtained from traditional maize varieties (De Groote *et al.*, 2007). In Kenya, IRM increased yields in farmers' field by 500 kg ha^{-1} (US\$100 ha^{-1}). The benefit from the improved (stress tolerant) germplasm was estimated at 370 kg ha^{-1} or US\$ 74 ha^{-1}, while the benefit due to the herbicide and reduced *Striga* was estimated at 130 kg ha-1 (dependent on *Striga* infestation: 49 kg ha^{-1} of *Striga* m^{-2}). The overall marginal rate of return was 2.4 with 1.9 (respectable) for germplasm, and 5.6 (very good) for IRM (De Groote *et al.,* 2007). Therefore exclusively, the past studies concentrated on analysing and comparing the magnitude of farm outputs (yield and returns) of IRM enterprise with the conventional ones. The most popular methods used in economic analysis are internal rate of return (IRR); benefit cost ratio (BCR) and net present value (NPV).

CHAPTER THREE

METHODOLOGY

3.1 The Study Area

In Kenya, agriculture is very important sector as 80% of the Kenyan population is dependent on it for food and income. Agriculture contributes about 26% of the Gross Domestic Product in Kenya (RoK, 2006; Brooks *et al*., 2009) and 60% of foreign exchange earnings. Maize is the most important food crop in the country covering nearly 80% of the total cereal area of the country and the average Kenyan citizen consumes well over 90 kg/year of maize, one of the highest levels in Africa (Brooks *et al*., 2009).

The current study was carried out in Kenya for being the country where IRM has been first introduced, particularly in Nyanza and Western provinces (Fig. 3). Nyanza province with 12 districts occupies a total area of 12 547 km^2 and a population density of 350 persons/ km^2 with about 968 014 households (Republic of Kenya, 2001). Western province with 9 districts has also a high population density of 406 persons/ km^2 on a total area of 8264 km^2 with about 701 323 households (Republic of Kenya, 2001). These two provinces were selected because of their importance in maize production and their high level of *Striga* infestation. *Striga* accounts for more than 50% of yield losses amounting to more than 182 000 tons per year.

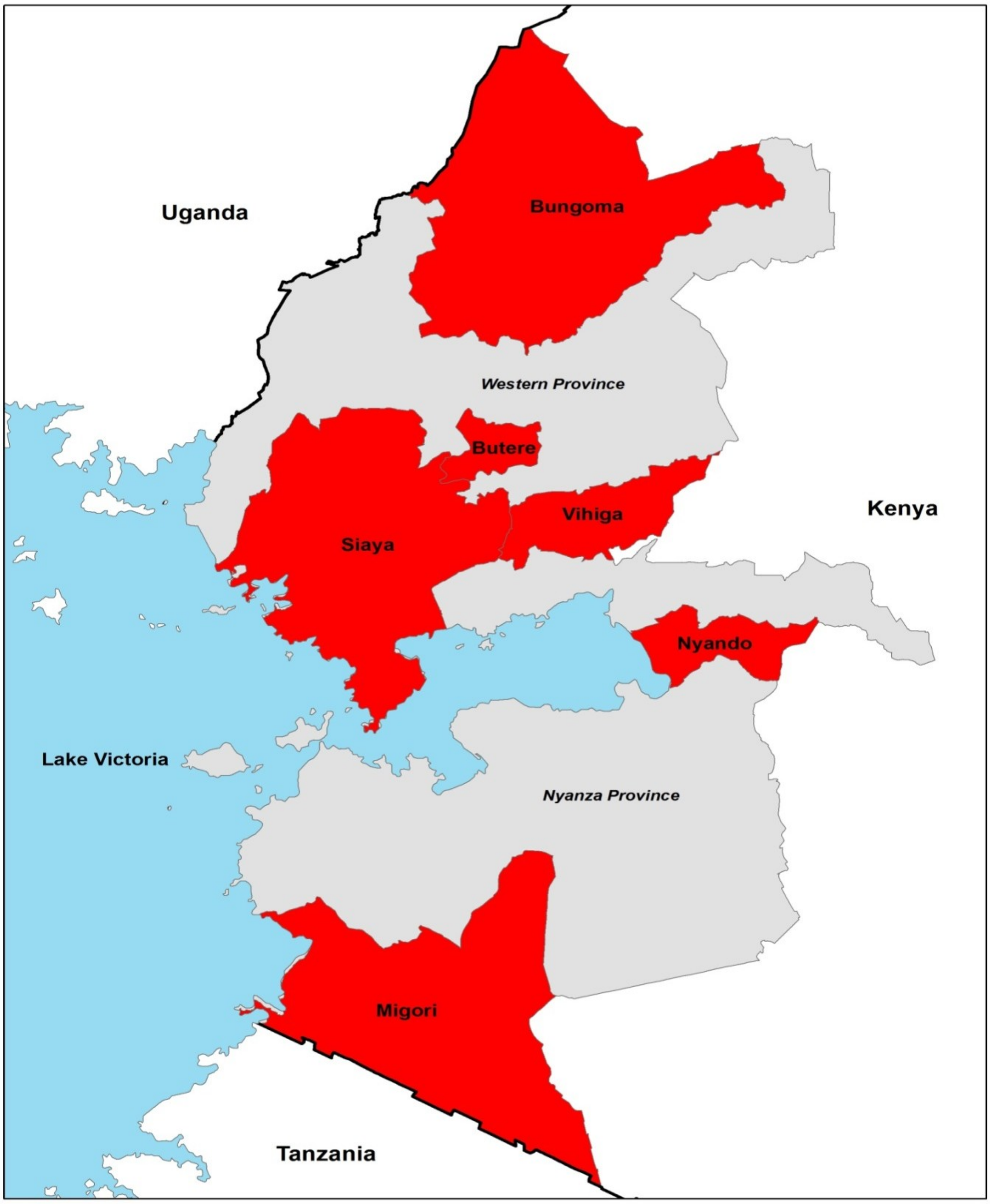

Figure 3: Map showing the surveyed districts (in red) in Nyanza and Western provinces in Kenya (digitised from the study area)

3.1.1 Geography, climate and vegetation

Western Kenya is the region bordering Uganda to the west and Tanzania to the south as shown in Fig. 3. It comprises of Nyanza and Western provinces. Western Kenya lies between latitude 1^o 8’ N and 1^o 24’ S and between longitude 34^o and 35^o E. The elevation ranges from 1000 to 1600 m. It occupies an area of 20 811 km^2 (Republic of Kenya, 2001), which consists of gently undulating landscapes with slopes between 2 and 8%. Poorly drained land makes up about 30% of the total area and occurs in bottomlands, minor valleys, plains, swamps and floodplains. The highest densities of *Striga* hermonthica were reported in Kenya in bimodal climate zones with two cropping seasons in which crops are cultivated two times per year (Oswald and Ransom, 2001).

The mean annual rainfall which ranges from less than 1000 mm near the shores of Lake Victoria to 2000 mm away from the lakeshore is suitable to *Striga* as it grows well in areas receiving less than 1500 mm rainfall per annum (Oswald, 2005). This partially explains severe infestation of *Striga* in the area. Furthermore, rainfall occurs in two seasons: from March to June (long rainy season) and from September to November (short rainy season), thus constituting a bi- modal rainfall pattern.

Temperatures are mostly warm. The average maximum temperature is 29^oC and the average minimum is 15^oC. The coolest period is July and August while the hottest months are December and January. Most of the natural vegetation of western Kenya has disappeared because of intensive agricultural activities. In areas unsuitable for crop cultivation, there are various plants, tree species including eucalyptus and cypress which are the predominant species.

The agro-ecological zones (AEZs) found in western Kenya are the lower midlands (LM), the upper midlands (UM), the lower highlands (LH), and the tropical alpine (TA).

The zones depend on area meeting the temperature and water requirements of the major crops.

3.1.2 Population and socio-economic characteristics

Western Kenya is the home of over 8 million people and one of Kenya's most densely populated regions (Republic of Kenya, 2001). Population densities range from 300 to 500 persons per km^2. Farm sizes are small, ranging from 0.2 to 2.5 ha and most of them infested by *Striga* which seriously constrains the productivity maize driving farmers into extreme poverty (AATF, 2006).

3.1.3 Agriculture

3.1.3.1 Crops

Agriculture in western Kenya is dominated by subsistence farming of which maize, the preferred staple and main crop. Other crops such as banana, cassava, cowpea, groundnut sorghum and sweet potato have been grown on a small scale but are important supplements. Cash crops in the area include tea, sugarcane, cotton and pyrethrum (Amadalo *et al.*, 2003). The production of these crops is limited to a few areas, and coffee has virtually disappeared because the marketing infrastructure has been poor (Amadalo *et al.*, 2003). Local vegetables and fruits are also grown for home consumption and for sale.

3.1.3.2 Livestock

Because the amount of land is limited, livestock numbers are small. Most farmers own chickens and local zebu cattle (1–4 per household), which they keep mostly as liquid capital, by selling them when necessary. Only 5% to 7% of the farmers possess a cow of an improved breed, although its number is increasing (Amadalo *et al.*, 2003). Goats and sheep are much less compared to cattle. While free grazing is a common practice in the drier zones within the Lake Victoria Basin, controlled grazing using tethering and zero-grazing systems are common in the high densely populated zones of the region.

3.1.3.3 Soils and *Striga* distribution

For continuous land cultivation for production, often without fertilizer or with very little use of it, the soils in many areas are infertile. Their lack of nutrients such as nitrogen, phosphorus and potassium catalyze *Striga* development especially with respect to nitrogen (Parker and Riches, 1993). *Striga* favours soils with a low-organic content (Mullen *et al*., 2003). *Striga* is most commonly found in heavy soils particularly in the densely populated parts of the Lake Victoria region of western Kenya (Kiriro, 1991; Frost, 1994). Hassan and Ransom (1998) confirmed that *Striga* incidence in maize is increasing in the moist transitional zone in Kenya with a total affected area of about 300 000-500 000 ha. The problem is also considered to be growing in terms of both the area covered and intensity (Ransom, 2000; Oswald, 2005).

3.2 Sampling

The need for quantitative and qualitative information about households related to IRM use in Kenya requires a statistically plausible sample of the target population. Accurate sampling is important to minimise the risk of sampling bias and to be able to draw inference about the population with statistically estimatable level of confidence.

3.2.1 Sample size

- Four hundred (400) households, from districts which have been accessed by Western Regional Alliance for Technology Evaluation (WeRATE) and seed companies for spearheading and facilitating IRM package dissemination, areas named "Intervention areas" (IAs). This sample size was determined through the approach based on precision rate and confidence level (Kothari, 2004) and the estimation formula for the sample size was:

$$n_{IAs} = z^2.\ p.\ q / d^2$$

Where,

n_{IAs} = sample size from IAs;

z = value of the standard variate at a given confidence level and to be worked out from the table showing the area under normal curve, at 1.96 (in simple at 2.0) corresponding to 95% confidence level;

p = sample proportion in the target population estimate to have a particular characteristic, if not known 50% is used and $q = 1-p$;

d = accuracy desired, set at 0.05.

Substituting these recommended values gives

$$n_{IAs} = (2.0^2)(0.5)(0.5) / 0.05^2$$

The formula equals to:

$$n_{IAs} = 400$$

Taking into account the competing needs, so that costs and efforts to minimize sampling error are optimally balanced, half of the previous sample size was drawn in the same region where no organized programme has been designed by WeRATE and other stakeholders for IRM transfer but where some farmers could have got it indirectly. These are termed as “Non-Intervention areas” (NIAs) and are considered as “wild cards” districts. These NIAs did not host any demonstrations nor did they attend any field days and therefore served as the control group that provided background information explaining IRM. Therefore, the sample size for NIAs was 200 households.

The sampling strategy was implemented as follows:

a) Stage 1 involved the choice of two provinces: Nyanza and Western which were purposely selected for their importance in maize production and high levels of *Striga* infestation. Purpose selection based on previous related studies (Manyong *et al*., 2008a, 2008b)
b) Stage 2 involved purposive selection of two districts in each province based on their high ratings of *Striga* infestation on maize and access by WeRATE and seed companies. The districts retained as IAs in the study area on the one hand, selected in Nyanza province were: Nyando (IA_1), Siaya (IA_2) and on the other hand those selected in Western province were: Bungoma (IA_3), Vihiga (IA_4)
c) Stage 3 involved purposive selection of one district in each province based on its high rating of *Striga* infestation on maize and lack of access by WeRATE and seed companies. The sampled districts under NIAs were: Migori (NI_{A1}) in Nyanza province and Butere (NI_{A2}) in Western province.
d) Stage 4 involved the overall sample of 100 respondents (adopters and non-adopters) randomly picked from each of the six districts using a table of

random numbers generated in Excel sheet. The total sample size for the study was 600 households including 169 adopters and 431 non-adopters.

The lists of households used as sampling frames (from the project site and outside target area) were obtained from the extension agents of the Ministry of Agriculture, known as front-line extension workers (FEWs) in Kenya. The principle respondent was the household head and in his/her absence, the next most senior member of the household aged above 18 years was interviewed. The farm household was the main focus in sampling. Casley and Lury (1987) define a household as a unit which comprises of a person or a group of persons generally bound by ties of kinship that live together under a single roof or within a single compound sharing a community life with a same head and sharing a common source of food. In this study, a household is defined as a unit which comprises of a husband/wife, spouse, children and dependants living together within a single compound producing and consuming together. Other individuals who are not bound by ties of kinship but live under the same roof and pool their resources with the rest of the household members and participate in the production processes and ultimately consume with other members were also considered as members of the household.

3.3 Preliminary Survey

Prior to the operationalization of the main fieldwork, a preliminary survey was conducted in September 2008. The objectives of the survey were to: (a) solicit background information about the study areas, (b) familiarize with the areas where the main survey was to be conducted, (c) establish sampling frames and units, (d) find out the most efficient way of carrying out the main survey and to validate the relevance of the questions to the intended respondents.

3.4. Recruitment and Training of Enumerators

3.4.1 Recruitment of enumerators

The process of recruitment of enumerators took seven days, from 10th to 16th October 2008 after the preliminary survey with the help of District agricultural officers. Three enumerators per district were chosen, thus in total 18 enumerators were identified for the whole survey. The process was guided by such factors as: (a) academic qualifications and minimum level of experience in data collection. (b) Willingness to work for long period of time, (c) ability to speak English and *Kiswahili*/*Dholuo*/*Luhya Luo* fluently as well as the ability to interact with people of different ethnic groups in the same environment and (d) familiarity with places where the fieldwork was to be conducted.

3.4.2 Training of enumerators

Training was conducted from 21st to 22nd October with 18 enumerators covering: instrument administration, interview techniques, procedures and skills, importance of the survey and research process. The training took two days and focused on specific objectives including: (a) Familiarization of enumerators with the questionnaire format, (b) Ensure understanding of all questions, (c) Understanding of probing options, (d) Relevance of questions to the general objectives of the survey, (e) How to record information, and (f) Good behavior to adopt in the field.

3.5 Questionnaire Pre-testing

The pre-testing was carried out by interviewing 10 households at Maseno, Kadibo, Ugunja, Suba and Bumala villages in western Kenya from 06th to 08th October 2008. Pre-testing formed an important part of the survey process. Its objective was to evaluate the validity of the questionnaire as an instrument for collecting data, to verify the clarity of pre-coded responses included in the questionnaire and to check the suitability of the questions in addressing the research objectives. The pre-test called for some modifications to the wording of the questions and removing some questions that appeared to be unnecessary. After the pre-testing, the questionnaire redrafting was done on 09th October 2008 and was adopted for enumeration. It was also noted that the most efficient way of carrying out the main survey was to fix appointments with the respondents before visiting them.

3.6 Data Collection

Both qualitative and quantitative data were collected because of the nature of the existence of data in the surveyed area. To obtain qualitative and quantitative information, both primary and secondary data will be collected for the problem under analysis.

Primary data were obtained from direct observations and general interviews in the field and administration of structured questionnaire to farmers. The structured questionnaire was the main tool for data collection from households.

Secondary data were obtained by consulting various relevant documents, both published and unpublished data. Most of the secondary data were obtained from libraries, various organizations' documents, and internet.

The process of long rains' data of 2008 collection started immediately after training of enumerators. The enumerators administered questionnaires using face-to-face interviews in the households; they filled the questions and completed the questionnaires themselves.

The administration of the questionnaire was conducted within a period of 14 days between 23rd October and 07th November 2008.

The enumerators were closely supervised on the field during the data collection to make sure that only quality data were collected. The questionnaire was formulated in English but the interviews were carried out in the local languages such as *Kiswahili, Dholuo* or *Luhya.*

Besides questionnaires, informal discussions guided by checklists were held to farmers' group leaders and other stakeholders such as agro-dealers and functional heads of different organizations for their opinions on IRM use.

3.7 Data Analysis

3.7.1 Descriptive statistics

A substantial part of the analysis was based on descriptive statistics such as frequencies, cross-tabulations; means and correlation were used to give insights into the magnitude of some critical variables. Under descriptive statistics all the different variables were calculated. Apart from the afore-mentioned descriptive statistics, other analyses such as computations and regressions were performed using EXCEL, SPSS, FRONTIER 4.1 and STATA computer packages.

3.7.2 Adoption of IRM technology

According to Rogers (2003), the rate of adoption is usually measured by the length of time required for a certain percentage of the members of a system to adopt an innovation and therefore the dynamics of innovations adoption were assessed on the basis of innovativeness with the adopters differing in their predisposition to adopt. The resulting distribution of the adoption times is usually described as being a normal curve (Rogers, 2003). Based on these Rogers' innovation adoption curves, practitioners subdivide by convention adopters into five groups: innovators, early adopters, early majority, late majority and laggards. The adoption of innovation was measured in this study in terms of rate of adoption which was analysed using frequency counts and percentages.

3.7.2.1 Adoption rate and related indices of IRM technology

There are many ways of measuring the rate of adoption of technologies. The common procedure for assessing the rate of adoption is through the logistic curve, which captures the historical trend of adoption over a given time. The logistic curve is constructed using data on the proportion of farmers who have adopted an improved technical innovation over a given period. According to CIMMYT (1993), the basic assumption is that adoption increases slowly at first but then increases rapidly to approach a maximum level. The logistic function model operates in the form of non-linear regression method where natural logarithm is used (CIMMYT, 1993; Gujarati, 1995). The second method is computing percentages of adopters without considering the time period. This is more preferred as it does not require time but gives immediate results on the measured innovations.

The adoption rate shows the number of households adopting IRM practice out of the total target number of households (Casley and Lury, 1982). In this study the adoption rate was calculated, by dividing the number of IRM adopters by the total number of surveyed participants in the project as shown below (Objective 1 and Hypothesis 1):

$$A_i = (N/T) * 100$$

Where,

A_i= percentage of adopters

N = number of adopters

T = number total of participants in the project

Adoption could be estimated also as a function of performance and penetration indices as shown in the equation below:

$$A_i = (P_\alpha * P_i) * 100$$

Where,

P_α = performance index,

P_i = penetration index

The performance and penetration indices (explained below in sections 3.7.2.1.1 and 3.7.2.1.2) were used as indicators to assess the success or acceptability levels of messages which have been communicated to farmers before the adoption decision.

3.7.2.1.1 Performance index

Performance Index P_α shows the actual number of households reached against the target number that should be reached (here the total sampled households) (Casley and Lury, 1982). The mathematical expression of P_α is as shown:

$$P_\alpha = (A/T) * 100$$

Where,

A= Actual Number Reached and T= Target Number to be Reached.

3.7.2.1.2 Penetration index

Penetration index (P_i) shows the number of households accepting to adopt IRM practice out of the actual number reached (Casley and Lury, 1982). The mathematical expression of P_i is as shown:

$$P_i = (D/A) * 100$$

Where:

D = Number adopting IRM technology

3.7.2.1.3 Performance difference between IAs and NIAs

Measuring of performance difference is through the difference in the adoption rates between IAs and NIAs of IRM technology. The most common ways of measuring performance difference is by using a Contingency Table or 2x2 Table (Table 1) as shown below (Msambichaka, 1992).

Table 1: Contingency Table

	Adoption		**Total**
	Yes	No	
IAs	a	b	(a + b)
NIAs	c	d	(c + d)
Total	(a + c)	(b + d)	n = (a + b + c + d)

The difference (*D*) in performance between those farmers in IAs (*P*1) and those in NIAs (*P*2) is given in the following equation:

$$D = P1 - P2 = [a / (a + b)] - [c / (c + d)]$$

A smaller figure (*D*) indicates that the diffusion rate of the new technology is to a smaller segment of the population in the two cases and vice versa.

3.7.2.2 Factors affecting adoption of IRM technology

The adoption could be measured as a discrete state with binary variables (adopt or not adopt) or as a continuous measure at a specific time depending on the given technology (Doss, 2003). Much empirical adoption of agricultural technologies studies generally divide a population into adopters and non-adopters and analyse the reasons for adoption or non-adoption at a point in time principally in terms of socio-economic characteristics of the adopters and non-adopters (Feder and Umali, 1993).

To analyse the factors affecting the adoption of IRM in western Kenya, the tobit model originally developed by Tobin (1958) was used. In this study of adoption the variable consists of zero values for those households that have not adopted IRM at all and continuous positive values for those that have adopted it. Since there are zero values for the dependent variable, using Ordinary Least Squares (OLS) would generate negative fitted values (i.e., negative predictions for the dependent variable). Moreover, because the distribution of the dependent variable is “left-censored” at zero, this clearly cannot have a conditional normal distribution (Wooldridge, 2002). Even if the sample is restricted to only those observations with positive values of the dependent variable, the expected value of the dependent variables cannot have a linear relationship with the independent variables (Wooldridge, 2002). Coefficients should not be estimated by the sub-sample of observations with yi>0, for two reasons. First, the observations with yi=0 contain relevant information on the parameters and standard errors; and, second, because in the sub-sample of observations with yi>0 the error terms do not have a zero mean as they come from a truncated distribution (Heij *et al*., 2004). Consequently, OLS - or any kind of linear regression - is not appropriate with a dependent variable of this type, because the coefficient estimates would be biased and inconsistent. With this structure of the dependent variable, what is required a "corner solution model", of which the tobit model is the 'canonical form' (Wooldridge, 2002 and Greene, 2003). The maximum likelihood (ML) estimation for tobit model involves dividing observations into two sets. The first set contains uncensored observations, which is in the same way as any linear regression model (LRM); and the second set contains censored observations. The tobit model provides unconditional marginal effects explaining two effects: first, the probability of a positive response i.e. the probability of households using IRM; and second, for positive responses the impact of explanatory variables, in our case, on the extent of adoption. Tobin (1958) argues that because an explanatory variable may be expected to influence both the probability of a positive response and the observed value, it would be inefficient to throw away information on the value of the dependent variable. Since taking into account both of these effects with the tobit model, this model was used for empirical work. A few recent examples of studies which use tobit model include Doss and Morris (2001), Ransom *et al*. (2003), Nkamleu (2004), Holloway *et al*. (2004), Kristjason *et al*. (2005), James *et al*. (2006), Nkamleu and Tsafack (2007). While other estimation approaches, such as the Heckman's model, could also generate unbiased results, the tobit approach conserved degrees of freedom and is relevant in cases such as this one, where the independent variables had a continuous effect on the dependent variable.

3.7.2.2.1 Specification of the tobit regression model

It is important to understand the factors that affect adoption of IRM so that IRM scaling-out is tailored to fit those traits. In this study, tobit regression model was applied to investigate the determinant factors where the ratio of land under IRM package was used as a dependent variable. The tobit model is appropriate in this study since the dependent variable is the share of land cropped with maize under IRM; thus the dependent variable must be between 0 limit, and continuous levels of adoption above the limit. Censoring captures the binary nature and the extent of adoption i.e. not only 0/1 but the extent of adoption among adopters, those in "1" bracket. Direct application of the tobit estimation sufficiently provides the needed information on adoption probability and the extent of adoption of IRM technology. To avoid the censoring bias that OLS could generate, a tobit censored at zero was used because share of maize land under IRM smaller than zero was not observed and many respondents reported a zero share of land under IRM technology. Generally, the tobit model uses Maximum Likelihood Estimation (MLE) method to estimate the parameters assuming normality and homoskedasticity conditions. According to Greene (2003), the general formulation of the censored regression (tobit) is an index function shown below:

$$Y_i^* = \beta' X_i + \varepsilon_i, \qquad Y_i = y_i^* \text{ If } y_i^* > 0$$

$$Y_i = 0 \quad \text{If } y_i^* \leq 0$$

Where,

The index variable, Y_i^* defines an underlying unobservable tendency where the adoption is a choice rather than a technical outcome. βX_i is a vector of unknown parameters and ε_i is a random error term.

The equation above means that the adoption (y_i) of IRM package will be observed only when the latent tendency is above the unobservable threshold ($y_i^*>0$). If y_i^* is less than or equal to zero, then y_i becomes zero, meaning that there is no adoption. To estimate the probability and the level of adoption of IRM, tobit model using the STATA computer package was applied on the equation above. The dependent variable Y_i i.e. the adoption of IRM was expected give a value ranging between 0 and 1, signifying that certain a proportion of maize area is planted to IRM. The model combines aspects of the binomial probit for distinction of $Y_i = 0$ versus $Y_i > 0$ and the regression model for E [$Y_i \mid Y_i > 1, X_i$] where:

Y = the proportion of area cropped with maize under IRM

β = vector of parameters to be estimated; and ε_i = error term

The empirical model of the effects of a set of explanatory variables on the adoption of IRM applying the maximum likelihood estimation (MLE) technique is specified using the following linear relationship:

$$Y_i = \beta_0 + \beta_1X_1 + \beta_2X_2 + \cdots + \beta_iX_i + u$$

Where,

Y_i= share of maize land under IRM;

β_0 = constant.

X_1 = AGE: age of household head (years), X_2 = EXP: farming experience of household head (years), X_3 = GEN: gender (dummy: 1=female and 0=male), X_4 = EDU: education in years of schooling (years), X_5 = HSIZE: household size (number), X_6 = FSIZE: total farm size in hectares owned by a household (number), X_7 = GAPPC: gap between maize production and consumption (1=deficit in kilogram and 0=otherwise), X_8 = RISKT: risk-taking (dummy: 1= risk-taker and 0=otherwise), X_9 = NEXT: number of contact farmer had with extension agents, X_{10} = LSEED: lack of IRM seeds, X_{11} = MBER: Membership in social group (dummy: 1=existence and 0=otherwise), X_{12} = PATH: pathway in dissemination IRM (dummy: 1=effective and 0=otherwise), X_{13} = COMPL: complexity of the technology (dummy: 1=simple and 0=otherwise), X_{14} = PBEN: perceived benefit (dummy: 1=positive and 0=otherwise).

3.7.2.2.2 Definition of dependent and explanatory variables

The formation of the model was influenced by a number of working hypotheses. It was hypothesized that a farmer's decision to adopt or reject a new technology at any time is influenced by the combined effects of a number of factors related to the farmer's goals and means of achieving them. The following variables in the model were hypothesized to influence the adoption of IRM in different directions, that is positively, negatively, or indeterminately positive, and negative:

a) The characteristics of the household head such as age and farming experience imply farming knowledge gained over time and are important in evaluating technology information (Feder *et al.*, 1985; Belknap and Saupe, 1988). The age of household head

(AGE): it has been documented that young people are more likely to take risks associated with innovation (Rogers, 1983; Alavalapati *et al.*, 1995) and the study by Gockowski and Ndoumbé (2004) has revealed that young farmers are more likely to adopt new agricultural technologies. Farmers' age is related to the adoption of technology. As the farmer's age increases, it was expected that the more the farmer becomes conservative. Therefore it was hypothesized that farmer's age and adoption are expected to relate negatively. Also older farmers with better farm experience are more likely to use IRM package.

b) Farming experience (EXP): measured in terms of the number of years since a respondent started farming on his own. The experience of the farmer is likely to have a range of influences on adoption. Experience would improve the farmer's skills in the production operations. Farmers' experience increases the likelihood of understanding the benefits of IRM package, therefore older farmers are expected to use their farming experience to make informed decisions on the adoption of the new technology.

c) Gender of the household head (GEN): the assumption made was that the head of the household is the primary decision maker and gender difference is found to be one of the factors influencing the adoption of new technologies. Due to many socio-cultural values and norms, males have the freedom of mobility and participation in different extension programs and consequently have a greater access to information about new technologies (Asfaw and Admassie, 2004). Therefore, it was hypothesized that gender is positively related to the adoption of IRM package.

d) Years of schooling of the household head (EDU): literacy level will increase a farmer's ability to obtain, process, and use information relevant to the adoption of IRM. Hence education would increase the probability of a farmer adopting an improved maize technology package. Educated farmers have been found to be more likely to adopt innovations (Nkamleu and Adesina, 2000; Asfaw and Admassie, 2004). It was hypothesized that education is positively related to IRM package adoption.

e) Household size (HSIZE): this can be as an incentive to produce more to meet the needs hence looks for more producing varieties in the *Striga* environment. Therefore positive relationship was hypothesized between IRM and household size considered as major source of labour for farm activities (Adesina *et al*., 2000). Large households have higher demands that motivate the adoption of new farm technologies in order to increase the farmers' income as a means for meeting those demands (Akinola, 1987).

f) Farm size (FSIZE): the influence of farm size holding the adoption decision may be both ways. Farm size was therefore hypothesized to have a positive relation on having a large land contributes to perceived security and increased willingness to invest in IRM (Caveness and Kurtz, 1993). Furthermore, as land availability becomes more inelastic, farmers facing land scarcity may be unwilling to sacrifice croplands for maize not well known. As a result, positive relationship was hypothesized between land and IRM adoption on the one hand; and on the other hand, households endowed with more land may diversify into crops that are not prone to *Striga* hence reduce the urgency of adopting new technology. Therefore a negative relationship was hypothesized between land and IRM adoption.

g) Gap between maize production and consumption per capita (GAPPC): this was hypothesized to be a stimulant of IRM adoption or non-adoption The difference between maize production and consumption which can result into deficit can stimulate the demand for high yielded varieties and surplus can hinder farmers' need for superior varieties like with smallholder maize producers in western Kenya where development of markets is still very poor discouraging production of substantial crop surpluses (Mukhwana, 2003).

h) Risk-taking (RISKT): Risk-taking is defined as the action or activity in which individuals take risks (possibility of loss) to achieve a benefit. Therefore, willingness to take risks was hypothesized as being positively related to technology adoption. The focus of this study was on risk related to technology and on the fact that farm households base their investment and production decisions, in part; on the perceived risk of failure, this study used a simplified way to assess risk by estimating it through the size of land farmers could allocate for IRM cultivation. The assumption made was that all farmers who used more than the median value of land under IRM technology (0.20 ha) can show how farmers are dedicated to it and these farmers are then considered as risk-takers. Risk-taking is fundamental for stimulating farmers to adopt a new variety. On the other hand, farmers who are risk-averse, are therefore very cautious in their willingness to devote some portions of their fields to an untried new variety. Consequently, the proportion of area devoted to the new varieties would be little or completely nothing. This argument presumes that new crop varieties cultivation involves greater risk compared to traditional cultivation.

i) Number of extension visits (NEXT): it was hypothesized that contacts with extension agents received by a farm would increase farmers' likelihood of accepting improved maize varieties after increasing farmers' exposure to awareness. Therefore, extension contact was hypothesized to have a positively influence on farmer's adoption of IRM package.

j) Lack of IRM seeds (LSEED): absence of basic input would hinder farmers from adopting IRM.

k) Membership to a social group (MBER): belonging to a social group enhances social capital allowing trust, idea and information exchange. Better social relations and communication among farmers are crucial for technology diffusion and adoption. Thus membership to a group could increase the technology adoption.

l) Effectiveness of IRM dissemination pathway (PATHW): effective pathway of dissemination was captured based of farmers' perception and was expected to raise farmers' awareness and knowledge about the new technology hence a likelihood of adopting the technology.

m) IRM complexity (COMP): Rogers (2003) defines complexity as the degree to which an innovation is perceived as difficult to use. If IRM package is viewed as a difficult technology, farmers would adopt such a technology. The complexity of a technology is negatively related to adoption and IRM adopters would perceive it as less complex than would non-adopters. Perceived complexity has been proposed to be negatively related to adoption. Complexity was measured here through farmers' perception of IRM.

n) Perceived benefit of IRM (PBEN): any new technology perceived to have positive benefits is likely to be highly adopted.

All these hypothesized explanatory variables cited above were checked for the existence of multicollinearity problem before running the tobit model. There are two measures that are often suggested to test the existence of multicollinearity. These are: Variance Inflation Factor (VIF) for association among the continuous explanatory variables and contingency coefficients for dummy variables. In this study, VIF and contingency coefficients (cc) were used to test multicollinearity problem for continuous and dummy variables respectively. According to Maddala (1992), VIF can be defined as:

$VIF\ (X_i) = 1 / (1 - R_i^2)$

With: $(1 - R_i^2) = TOL\ (X)$ where,

> R_i^2 is the squared multiple correlation coefficient between X_i and the other explanatory variables; *TOL* is Tolerance. The larger the value of VIF, the more troublesome it is.

A statistical package known as Statistical package for Social Sciences (SPSS) was employed to compute the VIF values. To avoid the problem of multicollinearity, it was essential to exclude the variables with the TOL of less than 0.20 or a VIF of 5 and above (O’Brien, 2007).

Similarly, there might also be an association between dummy variables. In order to test multicollinearity problem between discrete variables, contingency coefficient (CC) which is χ^2 -chi-square based measure of the relation between two categorical variables (proposed by Pearson, the originator of the *Chi-square* test) was computed. The values of contingency coefficient range between 0 and 1, with zero indicating no association between the variables and values close to 1 indicating a high degree of association. If the value of contingency coefficient is greater than 0.75, the variable is said to be collinear. The contingency coefficient can be defined as:

$$CC = [\chi^2 / (n + \chi^2)]^{1/2}$$

Where,

CC = Contingency coefficient, n= sample size, χ^2 =Chi-square value.

3.7.3 Economic impact of IRM technology

The analysis of the factors affecting adoption was followed by the estimation of the impact outcomes of the adoption of IRM technology. The economic impact of IRM technology on farmers' livelihoods was investigated through the analysis of the survey data, direct observation, and key informant interviews. Impact assessment of IRM technology in western Kenya was carried out using stochastic frontier function analysis, economic analysis and farmers' perceptions. In this way, a combination of quantitative and qualitative methods quantifies the impacts of IRM package and explains the outcomes. Adato and Meizen-Dick (2007) outline the advantages and disadvantages of integrating these two methods and give examples from case studies. While quantitative data from samples that are statistically representative provide better assessments of causality by means of econometrics, qualitative methods are better for studying selected issues or events, provide critical insights into beneficiaries' perspectives and illuminate quantitative analyses. Additional benefits from integrating quantitative and qualitative methods include: (a) Consistency checks can be built in by triangulations that can independently estimate key variables (e.g., income, opinions about projects, reasons, or specific impacts); (b) Different perspectives can be obtained (e.g., in terms of gender differences); (c) Analysis on different levels. Surveys can give estimates of individual, household, or community level welfare; qualitative tools are more effective for analyzing social processes (e.g., conflicts) or institutions (e.g., effectiveness of services); (d) More options for interpreting findings. Surveys often lead to inconsistencies that cannot be explained by the data. Qualitative methods can be used to check on outliers (responses that diverge from a general pattern) and for rapid field check of such cases.

3.7.3.1 Stochastic frontier production function analysis

In order to analyse the effect of IRM adoption on maize production and to identify as well the sources of inefficiency, the stochastic frontier production function was used as an econometric method of efficiency measurement in production systems. It was estimated around the premise that a production system is bounded by a set of smooth and continuously differentiable concave production transformation functions for which the frontier offers the limit to the range of all production possibilities. Stochastic frontier approach has found wide acceptance within the agricultural economics literature and industrial settings (Battese and Coelli, 1992; Coelli and Battese, 1996), because of their consistency with theory, versatility and relative ease of estimation. It also has the advantage of allowing simultaneous estimation of individual technical efficiency of the respondent farmers as well as determinants of technical efficiency (Farrell, 1957;

Ajibefun and Abdulkadri, 2004; Oyekale and Idjesa, 2009). Many researchers have so far utilized the stochastic frontier approach to examine technical efficiency in various productions (Aigner *et al*., 1977; Battese and Coelli, 1995; Battese *et al*., 1996; Awudu and Huffman, 2000; Awudu and Eberlin, 2001; Gautam and Alwang, 2003; Khairo and Battese, 2005); also in Kenya's maize production (Kibaara, 2005; Manyong *et al*., 2008a). Understanding the levels of inefficiency/efficiency can help address productivity gains if there are opportunities to improve socio-economic characteristics and management practices.

The assessment of farmers' efficiency in maize production resulting from IRM adoption through stochastic frontier production function analysis is therefore considered as the ability to isolate its impact and that of a household to generate maximum output that would contribute to household food security and income generation. To avoid linearity biaises, this study used the translog stochastic frontier production function which can be given by:

$$\ln Y_i = \beta_0 + \sum_{k=1}^{K} \beta_k \ln(X_{ki}) + \frac{1}{2}\sum_{k=1}^{K}\sum_{j=1}^{K} \beta_{kj} \ln(X_{ki}) \ln(X_{ji}) + v_i - u_i$$

Where,

ln denotes the natural logarithms; Y_i is the quantity (or value) of maize output of the i-th farmer; X is a vector of the input quantities; β is a vector of parameters; $k=j=1,\ldots,K$ are input variables; v is a random error term, assumed to be independently and identically distributed as N (0, σ_u^2), independent of u, which represents technical inefficiency and is identically and independently distributed as a truncated normal, with truncations at zero of the normal distribution (Battese and Coelli, 1995). The maximum likelihood estimation of the production frontier yields estimators for β and γ, where $\gamma = \frac{\sigma_u^2}{\sigma^2}$ and $\sigma^2 = \sigma_u^2 + \sigma_v^2$. The parameter γ represents a total variation of the output from the frontier that is attributed to technical inefficiency and it lies between zero and one, that is $0 \leq \gamma \leq 1$. The closer γ is to 1 the greater the deviations of the actual output from the frontier and hence the greater the technical inefficiencies. The Maximum Likelihood Estimates (MLE) Method using the computer package FRONTIER version 4.1 was used to estimate the parameters of the SFPF (Coelli, 1996).

Battese and Coelli (1995), proposed a model in which the technical inefficiency effects in a stochastic production frontier are the function of other explanatory variables. In their model, the technical inefficiency effects, *u*, are obtained by truncation (at zero) of the normal distribution with mean, μ_i, and variance, σ_u^2 such that:

$$\mu_i = \mathbf{Z}_j' \boldsymbol{\delta}$$

Where,

Z is a vector of farm-specific explanatory variables, and δ is a vector of unknown coefficients of the farm-specific inefficiency variables.

For the investigation of the farm-specific technical efficiencies of maize producers in western Kenya, the following translog stochastic frontier production function was estimated:

$$
\begin{aligned}
Ln\ (maize\ output_i) = {} & \beta_0 + \beta_1\ ln(Land_i\ ) + \beta_2\ ln(Labour_i) + \beta_3\ ln(Seed_i) \\
& + \beta_4\ ln(Fertilizer_i) + \beta_5\ ln(Manure_i)\ + \beta_{12}\ ln(Land_i)\ ln(Labour_i) \\
& + \beta_{13}\ ln(Land_i)\ ln(Seed_i) + \beta_{14}\ ln(Land_i)\ ln(Fertilizer_i) \\
& + \beta_{15}\ ln(Land_i)\ ln(Manure_i) + \beta_{23}\ ln(Labour_i)\ ln(Seed_i) \\
& + \beta_{24}\ ln(Labour_i)\ ln(Fertilizer_i) + \beta_{25}\ ln(Labour_i)\ ln(Manure_i) \\
& + \beta_{34}\ ln(Seed_i)\ ln(Fertilizer_i) + \beta_{35}\ ln(Seed_i)\ ln(Manure_i) \\
& + \beta_{45}\ ln(Fertilizer_i)\ ln(Manure_i) + \beta_{11}\ 1/2\ ln(Land_i)^2 \\
& + \beta_{22}\ 1/2\ ln(Labour_i)^2 + \beta_{33}\ 1/2\ ln(Seed_i)^2 + \beta_{44}\ 1/2\ ln(Fertilizer_i)^2 \\
& + \beta_{55}\ 1/2\ ln(Manure_i)^2 + \alpha_1(Mechd_i) + \alpha_2\ (IRM\ adoption_i) \\
& + \lambda_1\ (Nyanza_i) + \lambda_2\ (Western_i) + v_i - u_i
\end{aligned}
$$

The dependent variable is (log of) maize output in kilograms. There are three categories of independent variables. The first category includes conventional factors of production: land planted with maize in hectares, labour in man-days, seed planted in kg, fertiliser in kg, and manure. The second category includes mechanization dummy (1= mechanized and 0= otherwise) and the extent of IRM (share of maize land under IRM) which were to account for the intercept shifts in the production frontier due to IRM technology. In order to account for possible gender yield differentials in frontier maize output in the form of an intercept shift of the frontier. The third category includes province dummies which were to account for the influence of land quality and agro-climatic variations on maize production. The error term, *v*, is the symmetric random variable associated with disturbances in production; and *u* is a non-negative random variable associated with technical inefficiency and is obtained by truncation (at zero) of the normal distribution with mean, μ_i and variance σ_u^2, such that:

$$\mu_i = \delta_0 + \delta_1\ (Education_i) + \delta_2\ (Farm\ experience_i) + \delta_3\ (Farm\ experience\text{-}squared_i) + \delta_4\ (Household\ size_i) + \delta_5\ (Household\ size\text{-}squared_i) + \delta_6\ (Farm\ size_i) + \delta_7\ (Farm\ size\text{-}squared_i) + \delta_8\ (Gender_i)$$

Where,

δ_i, *'s* are unknown parameters to be estimated. Education and age are important human capital variables that determine the efficiency with which farmers use available resources. The effect of age is usually non-linear, and to account for this effect, both age and age-squared were included in the inefficiency model. Farm size and household size were included to account for possible inverse relationships on one hand between farm size and technical efficiency and on the other hand between household size and technical efficiency.

It was hypothesized in this study that the effect of farm size and household size could be non-linear, and hence both farm size and household size and their variables-squared respectively were included. In view of considerable involvement of the sample farmers in terms of gender, a gender dummy variable was included to test its effect on maize production.

Also it is believed that technological changes in production systems can increase productivity in agriculture as well as production and employment in other sectors

(Ogunsumi *et al.*, 2003; Saka and Lawal, 2009). It is therefore important to investigate whether a particular technology had actually brought any changes in production. The magnitude of the upward shift in the maize production function resulting from the introduction of IRM was estimated through its yield advantage over the non-IRM varieties (here for other hybrid and local maize varieties). Pair wise comparison of the values given by the farmers for both IRM and non-IRM varieties, was done as obtained using t-statistic.

3.7.3.2 Gross margin and returns from maize enterprise

There are numerous studies on agricultural productivity/efficiency which simply means maximising output per unit of input. Some studies have focused on physical productivity (yield) to measure efficiency arising from the inputs used while others have focused on profit arising from the cost of inputs. The yield for a maize crop enterprise means the total farm output per unit of land. The equation for calculating average yield is as follows:

$$\mathbf{Y_{ij} = \frac{1}{n}\sum_{i=1}^{n}\frac{O_{ij}}{P_{ij}}}$$

Where,

Y_{ij} = average yield by i^{th} household for j^{th} maize crop enterprise in kg/ha,

O_{ij} = output for i^{th} household from j^{th} maize crop enterprise in kg,

P_{ij} = plot of land for i^{th} household for j^{th} maize crop enterprise in ha,

n = number of households involved in j^{th} maize crop enterprise.

Assessing the adoption potential of IRM technology involves determining its economic viability to farmers. Economic viability is used to determine if the farmer will receive a greater economic and more stable return from adopting the technology. Economic viability generally means profitability but with an ambiguity which comes in the definition of profitability about assumptions such as: (a) Short term versus long term, (b) competitive actions or lack of them, (c) The extent to which the sales model is good enough for prediction, and (d) Good estimate for the costs. Given a set of assumptions, one can then provide the analysis of the economic viability of a product or technology. Economic viability is the assessment that increases in the output produced by using the least cost effective method that would recover costs, provide an additional required rate of return, and sustain effective production in the face of uncertainty and risk. In knowing the benefits and costs of different maize enterprises in western Kenya throughout a period of time, profitability analyses were carried out to show economic viability of the various maize enterprises. Profitability can be assessed using different methods including benefit cost ratio, economic surplus models, economic efficiency estimation and gross margin analysis.

In this study, Gross margin (GM) was used as a proxy for profitability (Castle *et al*., 1987; Senkondo *et al*., 2004). Profitability analysis allows verifying the viability of the maize enterprises and helps in the selection of the most efficient maize enterprise, having some influence in the resources allocation. The merit of GM includes enabling the assessment of profitability of most economic activities. An added advantage of GM is that it can easily be understood and it has logical interrelationship between economic and technological parameters. Despite having the advantages, GM also encompasses several shortcomings; these include inability to accommodate or account variation in fixed costs structure within or among businesses and a failure in making allowances for complementary and supplementary relationship between enterprises. As stated in the literature review, fixed costs have not been included because for the most of poor rural people fixed costs are not reliable. In most cases, farmers do not have permanent working tools. Tools such as pangas, hoes, machetes, buckets and utensils that farmers possess and use in the production process are not properly recorded in terms of money value and purpose of purchase. GM was therefore done to establish whether the adoption is economically profitable.

According to Mutabazi (2007), despite GM analysis being static and not considering the time value of money compared to investment analysis, the GM analysis can still assist in enhancing the overall management as it addresses resource productivity in a given period. For more details on the theoretical shortcomings and strengths of GM analysis among other economic analysis, an interested reader is referred to Kunze (2000), Senkondo *et al*. (2004) and Fox *et al*. (2005). The basic equation for GM computation is presented as follows in equation:

$$\mathbf{GM_{ij}} = \frac{1}{n}\sum_{i=1}^{n}(P_{ij}Q_{ij} - TVC_{1j})$$

Where,

GM_{ij} = average gross margins earned by i^{th} household for j^{th} maize crop enterprise in Ksh;

P_{ij} = unit output price received by i^{th} household for j^{th} maize crop enterprise in Ksh/kg;

Q_{ij} = quantity marketed/valued by i^{th} household for j^{th} maize crop enterprise in kg; TVC_{ij} = total variable costs incurred by i^{th} household for j^{th} maize crop enterprise in Ksh;

n = number of households involved in j^{th} crop maize enterprise.

Gross margins are generally quoted per unit of the most limiting resource, which is usually land, on a per hectare basis (Malcolm *et al*., 2005).

In the case of maize, revenue was obtained by calculating the value of maize produced by using the annual 2008 average market price (mean of prices immediately after harvest and at the end of the season). Prices that farmers receive for their products and pay for inputs and services are also subject to considerable variability resulting from market forces (supply and demand) and policies that modify farmers' economic environment. Prices consequently represent an important source of uncertainty for the farmers' household income.

Total variable costs for IRM production were labour costs on land preparation, cultivation, sowing, weeding, transport and inputs application, harvesting costs and costs of inputs: seeds, fertilizers, pesticides and other field operation during the 2008 long rains season. Valuation of rural family labour has been an area of economic debate. Anyone interested in understanding different views on how to handle valuation of family labour in rural context can read Senkondo *et al*. (2004), Kunze (2000) and Fox *et al*. (2005). Some studies tend to ignore the value of labour. While the opportunity costs of labour may be low in subsistence agriculture in SSA, it is unlikely that the cost is zero. Labour is arguably the most significant investment in subsistence agriculture and failing to introduce labour as an input may not allow for an accurate representation of agricultural production. Therefore, taking into account of the inadequat development of the labour markets in most rural areas like western Kenya and the complexity surrounding valuation of family labour, the family labour was retained as man-days and not valued in monetary terms in this study. Man-day is the work one person would normally do in one working day of 8 hours (official work hours) to carry out specific activity (Oduor, 2002). In farming activities, the number of working hours in a day varies depending on the area and activity. The labour cost of various activities may also vary, not only from place to place, but also from season to season, depending on the demand for labour and its availability (Oduor, 2002). However for the development agent to survey and establish the actual unit cost for different activities in a particular area, we consider the wage rate in the community as the basis for estimating labour cost (Oduor, 2002).

Parameters used along with GM to express the profitability of IRM crop enterprise under *Striga* infestation included productivity (tons per hectare), returns to land (gross margin per hectare) and returns to labour (gross margin per man-day). Gross margins (returns) were computed by subtracting the variable costs from the gross revenue. Returns to labour were expressed as the gross margins divided by the number of man-days of the family labour employed in the production process. So in this study, the monetary unit used in this report is the US $ at an exchange rate of Ksh 72 to US $1.

3.7.3.3 Analysis of long-term economic viability of IRM

The analysis of long-term economic viability of community IRM design was pertinent to inform community targeting policy interventions. As said before, *Striga* causes yield losses ranging from 20% to 100% (AATF, 2008). The novel IRM has been introduced to about 5 000 farmers in the same study area and the data collected from on farm trials and farmer fields indicate that maize productivity has increased on average from 1.5 to over 3 ton/ha (AATF, 2006). Some plausible assumptions made in this analysis include: (a) The time horizon of 10 years was chosen, (b) Maize productivity doubles every year, (c) Fixed costs were not considered because the components of what could have been part of such cost structure are either provided by nature or were done once forever, (d) As reported by farmers, the average maize productivity for the 2007 short rain season was about 65% of that long rain season, (e) The discount rate of 10% (see Pagiola, 1996; Senkondo *et al*., 2004) was assumed. The financial streams of revenues and costs were discounted to determine the net present value (NPV) and Benefit/Cost Ratio (BCR). The discounted budgeting technique was used in this study despite the criticisms vested in its underlying static production economics theory which ignores dynamics practically facing farm firms in real world. According to Bradford and Debertis (1985), the problem of static assumption is that budgeting cannot address the problem of future inflationary shifts or market prices of inputs and outputs. However, budgeting has remained a useful planning tool in farm production and management (Mutabazi, 2007). Net present value is the present value of a series of future net benefits that will result from an investment. The criterion for the acceptance of a project is that the NPV must be positive and BCR must be greater than 1 (see Stutely, 2002; Mullins *et al.*, 2002). The computation of present value of the stream revenues and costs was done in the Excel worksheet using built-in command. Mathematical Equations underlying the computation of NPV and BCR are as follows:

$$\mathbf{NPV_s} = \sum_{t=1}^{n} \mathbf{R_t}\left(\frac{1}{(1+r)^t}\right) - \sum_{t=1}^{n} \mathbf{C_t}\left(\frac{1}{(1+r)^t}\right) \qquad \mathbf{BCR_s} = \sum_{t=1}^{n} \frac{\mathbf{R_t}\left(\frac{1}{(1+r)^t}\right)}{\sum_{t=1}^{n} \mathbf{C_t}\left(\frac{1}{(1+r)^t}\right)}$$

Where,

NPV_s = Net Present Value of the scheme (Ksh), BCR_s = Discounted BCR of the scheme, R_t = revenue in year t (Ksh), C_t = costs in year t (Ksh), r = discount rate (10%), $t…n$ = year t to nth of the project time horizon, $\sum$ = the sum of each of the years' discounted net benefit stream

When a farmer undertakes a new technology like novel IRM crop enterprise, there is always a risk of failure and loss of time, cash, or other inputs invested in the enterprise to be considered. With a new technology, farmers are concerned about the risk involved as opposed to the risk of their present technology. Measuring risk is difficult and of somewhat limited value, because different farmers look at risk differently. Risk analysis needs to be kept as simple as possible. Some indications of risk can be obtained from doing sensitivity analysis, stochastic dominance analysis which assumes that farmers prefer more profit to less, and modified safety-fret analysis which provides information on the likelihood of returns from a technology falling below a minimum acceptable level. Furthermore, sensitivity analysis was done to portray changes in the magnitude of net benefit streams with positive yield impacts of using IRM in successive years by certain proportion (25%, 50% and 75%). In western Kenya, IRM improves maize productivity while reducing *Striga* biomass and seed bank in the soil. Therefore, the major effect of IRM is expected from an increase in productivity through a reduction of *Striga* parasitism.

The net returns or benefits per capita expressed the project entire benefits to the beneficiary population. The population of farmers served by the project was computed by multiplying the region average household size and the total of beneficiary households. The challenge is that for a 10-year time horizon the household size is not static it keeps on changing over the years. Mathematical equation underlying the computation of net benefits per capita is as follows:

$$NBC_t = NB_t / N_t$$

Where,

NBC_t = net benefits per capita in year t (US $)

NB_t = net benefits in year t (US $)

N_t = number of project beneficiaries in year t

3.7.3.4 Development impact of IRM project at the community level

Many studies have used economic approach to determine the impact of development projects (Moshi *et al.*, 1997; TARP II-SUA Project, 2001). The economic approach is important because it measures poverty or welfare changes through the use of consumption or income variables. The majority of rural households depend on agricultural production as their main source of income and this study used income as a welfare measure because it is strongly correlated with the capacity to acquire many things that are associated with an improved standard of living, such as food, clothing, shelter, health care, education, and recreation. This study used the NPV analysis with counterfactual evidence by comparing the long term benefits of IRM and local maize enterprises. To establish that the changes are really from IRM introduction rather than from other factors, other hybrid maize enterprises have been excluded because of the elimination of rival explanations that could have occurred with some hybrid (e.g. H 513) known as reducing *Striga*.

3.7.3.5 Farmers' perceptions of the impacts of IRM on their livelihoods

The impacts of IRM technology on farmers' livelihoods were also investigated through a series of open-ended interviews using the interview checklists of topics or questions (Appendix 2) with some of the key informants (members of farmers' groups, members of women's groups, community organizations and leaders). Also recording of observations of facts seen and heard at the study area was taken into consideration.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Overview

This chapter presents the results of the study analysis. The chapter is divided into two main sections. The first section discusses the adoption rate of IRM technology along with the determinate factors influencing its adoption while the second section presents the impact of adopting IRM technology at household and community-level. The general households' characteristics are presented in the Appendix 1.

4.2 Results of Adoption of IRM Technology

The level of achievement reached in the adoption process is the adoption rate and in this case the adoption rate showed the proportion of the total target number which has adopted IRM technology. To capture the impact of information in technology generation and development, the adoption rate was a function of the performance and penetration indices.

4.2.1 Adoption of IRM technology

Adoption studies are being carried out in many different countries and they have indicated that there is a great variation in the rate of technology adoption. In western Kenya as shown in Table 2, the adoption of IRM was illustrated by the adoption rate as a result of performance and penetration indices. The adoption rate of IRM in the whole sample was 28% meaning that the adoption of technology had not made an appreciable headway, and local and other hybrid maize varieties are still dominating the production system. The proportion of 28% of households have adopted IRM technology after 64% of the total sampled households (performance index) have actively shown interest in receiving information about IRM technology in the two provinces and 44% (penetration index) involved themselves in the adoption process after thus have been reached. As shown in the Table 2, the adoption rate of IRM package is 37% and 12% in the IAs and NIAs respectively depicting a difference likely due to the intervention. Performance and penetration indices were used as proxies for explaining the success of technology transfer.

Table 2: Performance and penetration indices and IRM adoption rate

Adoption items	Unit	IA_S	NIA_S	Total
Target number to be reached (T)	n	400	200	600
Population aware (A)	n	252	130	382
Number of IRM adopters (D)	n	146	23	169
Performance index (Pα= A/T * 100)	%	63	65	64
Penetration index (Pi= D/A * 100)	%	58	18	44
Adoption rate (A=Pα*Pi)/100 or A=D/T	%	37	12	28

n: number

The adoption rate of IRM is still low and the perception of farmers gave an insight into the factors likely to limit the adoption of IRM– such constraints include lack of seeds, unawareness, cash constraints and risk aversion as summarized in Table 3. Fifty percent (50%) of the responses for non-adoption are related to lack of IRM seeds in the marketplaces. This is due to slow commercialization of the IRM in the seed supply chain in the local marketplaces accessible to farmers. Also, slightly more than a quarter of all the responses were still gathering more information about the new IRM technology. Other reasons for non adoption are as shown in Table 3 below:

Table 3: Reasons for non-adoption of IRM technology

Reasons	Counts*	Percent
Lack of IRM seeds	388	50
Gathering more information about it	220	28
Cash constraints to buy IRM seeds and related inputs	99	13
Traditional control practices are better	55	7
Too risky to adopt	14	2
Total	776	100

**The total for counts exceeds the sample size due to multiple responses*

Low adoption of IRM is attributed to lack of seed and information as underlined in the following quotes from a respondent farmer and a seed company:

"…After having received a kit of IRM *as a trial, it helped me to get an unexpected yield, I appreciated but the following year (2006), I got hardly 2 kg from our only stockist and this year (2008) while I planned to buy a lot for my whole farm, unfortunately I did get anything around. I complained to the stockists who also complained to have not received the seed from the supplier company"* (Quoted from Mrs Janet Wanyama, a farmer from Ugunja, Siaya - translated from Dholuo version).

"I can only produce IRM *seeds if I get a certain and specific order. AATF asked me to produce seeds for them and I did. There is no extra demand except from AATF and the market has become small. I am willing to bring the technology to farmers but not at my own risk".* (Quoted from Mr. Salima, Western Seed Company Director, Kitali).

Presumably, the low adoption rate of IRM was due to lack of seeds and farmers' unawareness about IRM. In addition, farmers have showed a preference for more experienced individuals when learning IRM package and a better communication between farmers and extension agents could lead to more adoption. The adoption rate of 28% of IRM observed in the study in Western Kenya has decreased by 10% compared to that of 2005/2006 reported by AATF (2006). Such a decline in the adoption rate could be attributed to among other things a slow rate of promoting IRM technology widely in the *Striga* affected areas. The adoption rate is very low to a tune of one digit in Migori district, a non-intervention area. Exceptionally, the adoption rate is also low in Nyando district, an intervention area justified this time by a low level of awareness (27%) and thus Nyando fared poorly in terms of the adoption rate as compared to other intervention districts including even Butere where there was no intervention at all.

By splitting the adoption items from Table 2 into six studied locations the computed adoption rates are presented in Fig. 4 where location disaggregated results inform about specific adoption status of the area. In these six areas, the achievement index or adoption rate was highest for Siaya district (IA_2) but lowest for Nyando district (IA_1), both in the Nyanza province. The penetration index reveals that among the four intervention areas, Vihiga district (IA_4) had more households which were sensitized about IRM technology and at the same time have responded positively than any other district.

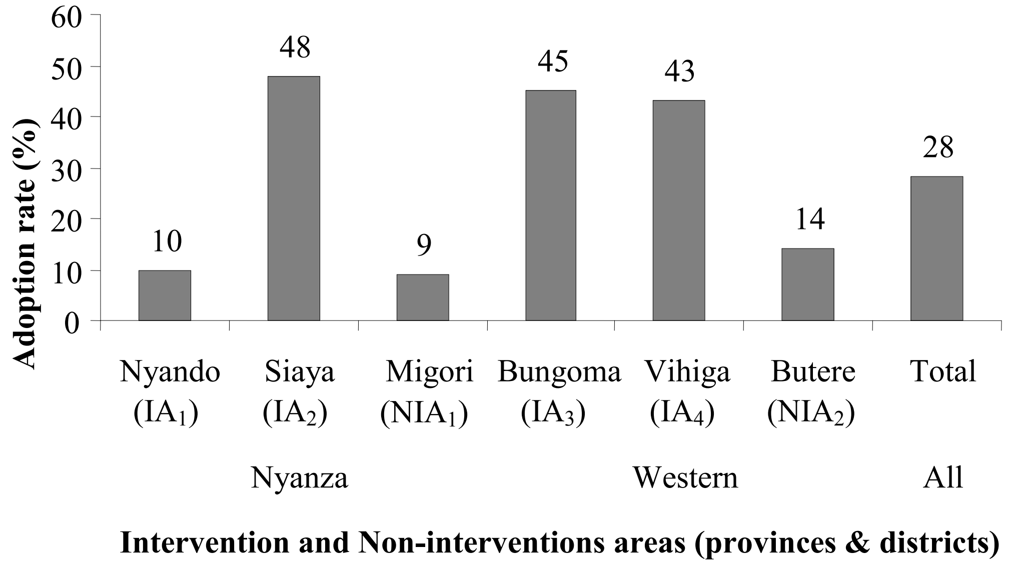

Figure 4: Adoption rate per area of intervention

Awareness is often achieved through prudent use of certain communication channels. In the study area, information regarding IRM reaches farmers through several diffusion mechanisms, including field days, meetings, exhibitions, exposure to other farmers, and written media (e.g. pamphlets and booklets). Awareness creation was therefore an initial stage in the IRM adoption process which requires time to be realized in the mindsets of potential adopters. Awareness determines the performance and penetration indices which influence the adoption rate.

4.2.1.1 Performance index

The performance index was obtained from equation in the section 3.7.2.1.1 and is equal to 0.63 in IAs as shown in Table 2 meaning that 63% of farmers in the target population have been reached by IRM. This index is a bit less than that in the NIAs (0.65) describing the high motivation in NIAs. Through questions and statements coming from majority of farmers in both areas, we could noticed their eagerness in seeking information on new technologies or practices that could help them to control *Striga* which has been damaging their crops for many years. At that early stage of learning about IRM package, farmers felt motivated in rushing to more information and knowledge about it for new possible decision.

4.2.1.2 Penetration index

Some of the farmers after being reached manifested their desire to go for IRM and thus leading to the penetration index. The penetration index was obtained from equation in section 3.7.2.1.2 and is equal in IAs to 0.58 (Table 2). This implies that 58% of the farmers in IAs who received the information about IRM technology adopted the technology; this rate is higher than that in NIAs (18%). This difference denotes the effect of diffusion agents (here WeRATE and other stakeholders) and extension services on the adoption decision process which devoted more visits to households in IAs than in NIAs. This penetration index here underscores the essence of creating awareness over spontaneous spread of information about the technology which might not equip potential adopters in NIAs with the right information for enhanced adoption.

According to innovation decision process theory of Rogers (2003), once farmers reach this stage of persuasion, they must be persuaded to see the value of the innovation. This was the case in IAs, where the persuasion has come from WeRATE and other stakeholders involved for IRM technology dissemination. The penetration index was much lower in NIAs mainly due to poorly informed persuasion from neighbours, relatives and friends in NIAs. After quantifying the number of IRM technology users, the study considered the effect of the user's zone by using the performance difference between user's group and non-user's.

4.2.1.3 Performance difference between IAs and NIAs

The results from the contingency Table 4 indicate that in IAs 37% of the households (146 out of 400) adopted IRM technology after 63% of the households have been made aware about it. In contrast, only 12% of the households (23 out of 200) in NIAs adopted IRM technology after 65% of households have been made aware about it through farmers' interactions with their peers from IAs. This fact depicted the importance of farmer-to-farmer spread of IRM which occurs between IAs and NIAs, areas close to each other in the same *Striga* zone. But only few of farmers from NIAs who were aware about IRM technology from the neighbourhoods adopted it. This situation might be due to the source of awareness in a sense that farmers could have not trusted much their peers.

Table 4: Contingency table for calculating performance difference

Adopters/Non-adopters	Adopters	Non-adopters	Total	P_1, P_2
IAs Households	146	254	400	37
NIAs Households	23	177	200	12
Performance Difference (*D=P₁-P₂*)				25

χ^2 = 41.19, df=1, P<0.05)

The performance difference of 25% as shown in Table 4 is relatively small denoting a low performance difference between farmers' adoption rates in IAs and NIAs. Also the Table 4 has shown that adopters and their localization area are associated meaning that being an adopter or non-adopter, depends significantly (P<0.05) on the area where the farmers are located. Different areas under *Striga* infestation in western Kenya receive different treatments from stakeholders involved in IRM technology transfer.

The performance difference between IAs and NIAs denotes a positive effect of change agents. So far, efforts have been made by change agents in increasing awareness among the farmers regarding a rational decision making in adopting IRM. However the efforts are insufficient to effect important change, reason why the gap between IAs and NIAs has been narrowed to 25%. Therefore more efforts in technology transfer initiatives and incentives should be made to create and reinforce awareness in the NIAs where households unaware have been reduced already by their own initiative to 35%. Awareness should also be strengthened in IAs where 37% of households are still unaware. Policy makers should involve more themselves in technology transfer decisions and understand the effectiveness of farmer networks in facilitating the spread of information. This understanding can help promote better technology transfer and, in so doing, effectively help sustain maize production in western Kenya.

As found above, 37% of farmers in IAs against 12% in NIAs adopted IRM showing that there was strong evidence to accept the first hypothesis of the study i.e., IRM adoption rate is higher in IAs than NIAs.

4.2.1.4 IRM technology diffusion

Plotting the percentages of IRM adopters against years of IRM establishment was done to produce the technology diffusion curve. The resulting Fig. 5 is an S-shaped curve which complies with the adoption theory. According to the theory, the adoption rate is normally low at the beginning but increases with time as more and more beneficiaries get full knowledge of the technology. From the slope of Fig. 5, the adoption rate of IRM was higher between 2005 and 2006 seasons. According to the secondary information gathered during this study, such high adoption rate would have resulted from a series of dissemination activities including: launching of IRM technology in June 2005 at Kisumu in western Kenya, over 1300 on-farm testing during long rains season of 2005 carried out in 12 districts covering a total of 50 hectares in western Kenya and more than 120 tons of IRM production by CIMMYT in collaboration with Western Seed Company for commercialization in March 2006.

The shape of "S" in Fig. 5 is almost flat indicating a more gradual slope denoting a slower rate of adoption of IRM. IRM dissemination measures and strategies remain to be accomplished and could be enhanced for the IRM technology to diffuse rapidly so as to create a steeper S-curve.

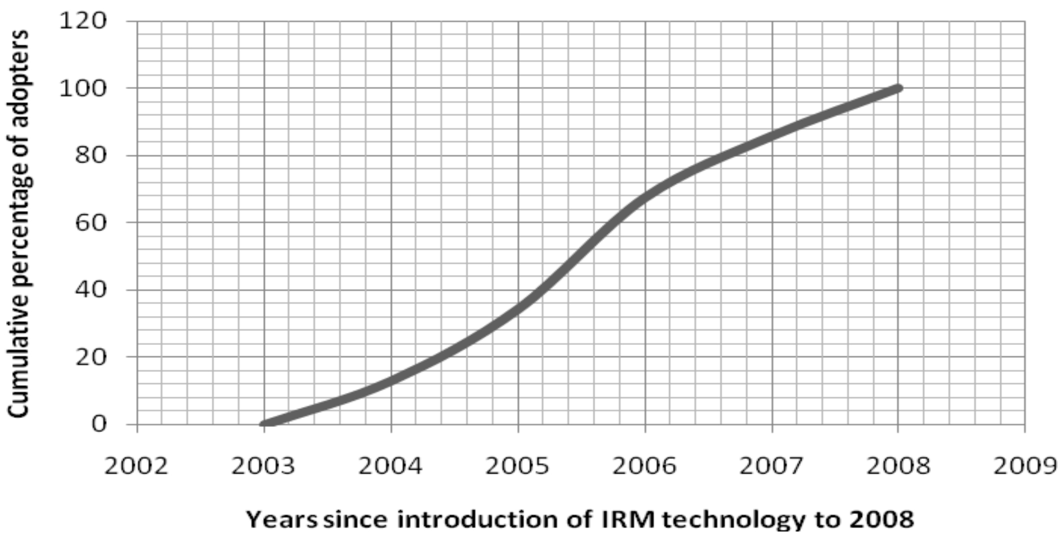

Figure 5: Cumulative distribution of IRM adopters from 2004 to 2008

4.2.2 Factors influencing adoption of IRM technology

The results for all VIF values were ranging from 1.007 to 2.163 (Table 5). Likewise, the values of contingency coefficients were also low and ranging from 0.000 to 0.383 (Table

6). Hence, multicollinearity was not a serious problem both among the continuous and discrete variables.

Table 5: Multicollinearity test result for continuous variables (N = 600)

Variables	Collinearity Statistics	
	TOL	VIF
1. AGE	0.462	2.163
2. EXP	0.560	1.786
3. EDU	0.529	1.891
4. HSIZE	0.723	1.384
5. FSIZE	0.993	1.007
6. MPGAP	0.805	1.242
7. NEXT	0.631	1.586

Table 6: Contingency coefficient for dummy variables

Variables	GEN	RISKT	LSEED	MBER	PATHW	COMPL	PBEN
1. GEN	1						
2. RISKT	0.023	1					
3. LSEED	0.076	0.383	1				
4. MBER	0.036	0.160	0.192	1			
5. PATHW	0.069	0.153	0.288	0.121	1		
6. COMPL	0.017	0.168	0.176	0.085	0.200	1	
7. PBEN	0.035	0.140	0.123	0.000	0.132	0.310	1

The results from the tobit model are presented in Table 7. The model is appropriate given its significant chi-square (P<0.001), Log Likelihood ratio as well as Goodness of fit, which is generally measured by Pseudo R^2 in such model was 0.92, suggesting a strong explanatory power of the included regressors (Table 7). The results from the study showed that the coefficients of most of the variables hypothesized to influence the extent of adoption of IRM have the expected signs.

The results in Table 7 show that excluding the constant term, eight out of 14 explanatory variables, namely farming experience, education, gap between maize production and consumption, risk-taking, number of extension visits, lack of IRM seeds, membership to a social group, and pathway in dissemination were IRM statistically significant at 5% and 10% in affecting the adoption of IRM by households.

The variables such as age, gender, household size, farm size, complexity, and the perceived benefit of the technology, which were expected to influence the adoption of IRM and were included in the model, were found to be insignificant regarding their influence on the adoption of IRM.

Experienced farmers tended to adopt more IRM as witnessed by the positive and highly significant coefficient of EXP of household head ($P<0.01$). This may be explained by the fact that farmers with accumulated experiences from maize cultivation in *Striga* infestation environment over years could easily make a difference between past technologies used for its control and IRM. Farmers' experience has increased the likelihood of understanding the benefits of IRM.

The same high significant relationship has been observed between education (EDU) in years of schooling and the adoption of IRM ($P<0.01$) revealing that formal literacy increases farmer's ability to obtain, process and use information relevant for the adoption of IRM. Moreover, education may lower the risk aversion behaviour and thus increasing the likelihood of adopting a new technology like IRM.

The coefficient of lack of IRM seeds for planting (LSEED) was significant ($P<0.01$) and negatively related with the adoption of IRM. This is in line with the *a priori* expectation and suggests that households lacking IRM seeds for planting had a lower probability of adopting IRM, IRM seed being *sine qua' non* for its adoption.

The coefficient of gap between maize production and consumption per capita (GAPPC) was statistically significantly (P<0.05) and supports the hypothesized sign that the deficit of maize production per capita influences positively the adoption of technology. Any household with maize deficit has to seek for high-yielding maize varieties to increase its production and therefore they are likely to adopt IRM. This result confirms the scientific studies which have shown the existence of substantial opportunities of increasing food production per capita through the use of improved technologies (Sen, 1996).

The number of extension visits (NEXT) to farmers was found to be significantly (P<0.01) and positively correlated to the decision to adopt IRM. The extension contact was an important determinant of technology adoption because; any newly developed technology like IRM was introduced to farmers through the activities of extension agents. A farmer whose contact with the extension agents is very high is expected to be more familiar and more knowledgeable about the use of IRM.

Risk-taking (RISKT) or positive attitude towards risk correlates positively and significantly (P<0.01) with the adoption of IRM and vice versa. This finding is in harmony with the studies reported in 1967 by Popielarz (1967) and Arndt (1967) who admitted that willingness to take risks tend to lead to more innovativeness.

Effective pathway of IR dissemination is an important factor influencing the adoption of IRM. As expected, its coefficient was positive and highly significant at P<0.01. The positive coefficient suggests that the use of effective way to disseminate IRM has a higher likelihood of adopting it. IRM dissemination is one of the most prearranged conditions for creating awareness and building the necessary knowledge for using the innovation following the approach which is most convenient to farmers.

Membership of association is expected to assist farmers to enhance access to technological information. Membership had a significant (P<0.01) positive influence on the extent of adoption. It improved social interactions and exchange of information among farmers and which in turn enhances technology adoption. Earlier results have shown that 65% of farmers in NIAs have known IRM through farmer-to-farmer channel. Membership or farmers association led to farmers' increased awareness of IRM.

Table 7: Tobit model estimates for determinants of share of IRM

Variable	Coef.	Std. Err.	t	P>|t|	dy/dx
Household specific factors					
AGE	-0.002	0.003	-0.910	0.364	-0.002
EXP	0.020	0.002	9.820	0.000***	0.020
GEN	-0.036	0.036	-1.010	0.313	-0.036
EDU	0.037	0.006	5.660	0.000***	0.037
HSIZE	-0.010	0.010	-1.020	0.309	-0.010
Farm specific factors					
FSIZE	-0.103	0.055	-1.880	0.061	-0.103
GAPPC	0.001	0.002	-2.420	0.016**	0.001
RISKT	0.306	0.052	5.890	0.000***	0.306
Institutional factors					
NEXT	0.030	0.006	4.620	0.000***	0.030
LSEED	-0.252	0.039	-6.410	0.000***	-0.252
MBER	0.135	0.043	3.170	0.002***	0.135
PATHW	0.193	0.037	5.250	0.000***	0.193
Technological factors					
COMPL	0.017	0.036	0.470	0.636	0.017
PBEN	0.063	0.047	1.350	0.178	0.063
constant	-0.688	0.143	-4.800	0.000	

Significance levels: *, ** and *** are P<0.1, P<0.05 and P<0.01, respectively.

Model summary	
Model and estimation	Tobit (censored) and Maximum Likelihood Estimation
Dependent variable	Share of maize land under IRM
Number of observations	572
Software used	STATA
LR chi^2 (df)	739.18 (14)
Prob > chi^2	0.0000
Pseudo R^2	0.9240
Log likelihood function	-30.38
Sigma coef	0.23
Censoring Obs	Left-censored = 403, uncensored =169 and right-censored=0

The tobit regression analysis supports by 90% and/or 95% the third hypothesis of the study that the adoption of IRM has been influenced by household, farm, institutional and technological factors surrounding the farmers and the technology.

To estimate the effects of each independent variable on the IRM adoption, marginal effect of the explanatory variable were estimated (Table 7 above). The coefficients of marginal effect of the explanatory variables showed changes in the intensity of adoption with respect to a unit change of an independent variable among IRM farmers. Among different factors influencing the adoption of IRM, risk-taking has the largest positive effect followed by effective pathway dissemination, membership in social group, education in years of schooling, the number of visits of extension agents to farmers, farming experience, the gap between maize production and consumption, and lack of seeds.

4.3 Results of Impact Analysis

4.3.1 Maize production efficiency

A stochastic frontier production function (SFPF) model is applied to cross sectional data to examine whether IRM adoption enhances maize production via efficiency gains. The model specified was estimated in this study by the Maximum Likelihood (ML) Method using FRONTIER 4.1 software. The results on Table 8 show ML estimates and inefficiency determinants. The sigma squared (σ^2) 941.53, is statistically significant ($P<0.01$) and different from zero. This result indicates a good fit and the correctness of the specified distribution assumption of the composite error term. The value of Gamma (γ) is close to 1 and significant at 1%; meaning that the systematic effects that are unaccounted for, by the production frontier function, are the dominant sources of stochastic random errors. That is about 90% variation in the output level of maize could be attributed to the presence of technical inefficiency in resource use. The results of the diagnostic statistics therefore confirm the relevance of stochastic parametric production function and the maximum likelihood estimation. The result of production function estimates is quite revealing and adequate to explain the descriptive statistics pertaining to the sample characteristics of the variables examined as presented in Table 9. The relative relevance of resource input is shown in the production estimates; the mean technical efficiency (TE) of the farmers' maize production is 70% implying that the farmers are efficient as the observed output is 30% which is less than the maximum output.

The estimated coefficient for the adoption of IRM was positive, conforms to a priori expectation, which was highly significant at 1% and showed the strongest positive effect on gross value of maize output per hectare. This clearly shows that the adoption of IRM led to higher technical efficiency in the study area. The adoption of IRM comes as the most important factor of maize production and its positive effect is consistent with the concept of new enhancing-agricultural technologies. The inference drawn from our analysis is that IRM adoption exerts a positive impact on maize production in western Kenya. The novel IRM package has helped farmers to maximise the maize output affected by *Striga* for so long time. Hence, in such a risky environment, if farmers want to increase technical efficiency in maize production, shifting to IRM adoption offers ample opportunities. IRM use increased significantly the frontier of maize output along with other factors in the production process.

There is a positive and significant relationship ($P<0.01$) between land and maize output in the study area even with an increase of land factor. Land is therefore, a significant factor associated with changes in the output especially in western Kenya where there is a growing population pressure on land. There is a negative and significant relationship ($P<0.01$) between fertiliser and maize output even with an increase of fertiliser factor. In this regard, maize output is more responsive to land and less responsive to fertiliser, low responsiveness of yield to fertilizer was unexpected. This could probably be explained partly by the inappropriate and non-optimal use of fertilizer due to lack of knowledge and low purchasing power experienced by the producers. This has been noticed also by Kibaara (2005) who reported the tendency by some maize farmers in the tea-growing region applying tea fertilizer (such as NPK) to maize. Such fertilizer does not benefit maize plants since the nutritional requirement is different. In addition, incorrect timing of the topdressing fertilizer may reduce the effectiveness of the applied fertilizer. The use of top-dressing fertilizer as a basal fertilizer may be another problem. Low adoption and intensity of use of fertiliser could be associated with the high price of fertiliser as opposed to that of maize as reported by Manyong *et al.* (2008a). Manure correlated significantly ($P<0.01$) with low maize output, however an increased use of manure increased significantly ($P<0.01$) the maize frontier output. This means the rate of application of manure is suboptimal and there is a room of improving productivity by increasing the amount of manure applied in maize farming. Low fertility has been recognized as one of the major biophysical constraints affecting agriculture in western Kenya. Intensive and continuous cropping with low application of fertilizer and manure cause a negative balance between nutrient supply and extraction. Furthermore, the interaction between fertilizer and manure appeared to have a negative impact on the maize frontier output. As reported by some farmers, due to lack of the means, they did apply more manure in their plots and reduced the application of fertilizer rendering the application rates of both manure and fertiliser sub-optimal leading to non-maximization of output. This is confirmed by the negative and significant ($P<0.01$) coefficient of the variable “fertilizer-manure”.

Labour is found to be a significant ($P<0.01$) factor influencing changes in maize output, however, it is negative. This implies that the more the labour that is been employed, the maize output will be reduced.

Maize seed per unit land was found to be a significant ($P<0.01$) factor that correlated negatively with maize output. By increasing the factor seeds, the maize output was increased but insignificantly. Most of the maize seeds planted are not certified and thus have poor germination rate. This confirms the observation that few farmers (21%) in western Kenya used certified seeds, a situation which may have contributed to low productivity.

The coefficients of the province dummy variables are highly significant ($P<0.01$) indicating substantial maize productivity difference with Western province being more productive than Nyanza province. The difference is probably due to the fact that the population density was lowered by the HIV/AIDS crisis in Nyanza. The population density of the province was already low (350 persons/km^2) compared to that in Western province (406 persons/km^2). Nyanza was unfortunately dogged with a number of socio-economic problems such as poverty, malaria, and a very high prevalence rate of HIV/AIDS destroying the much-needed skills and striking the prime-aged adults. Thus the most productive segment of the economy either fall ill, die or stop productive work.

The sources of inefficiency were examined using the estimated (δ) coefficients associated with the inefficiency effects in Table 8, the inefficiency effects are specified as those relating to education, farm experience, household size, farm size and gender. The signs and coefficients in the inefficiency model are interpreted in the opposite way such that a negative sign means the variable increases efficiency and vice versa (Battese et *al*., 1996).

In analyzing the sources of inefficiency, two factors were identified. These were household size and farm size. The coefficient of household size was found to be negative and significant ($P<0.01$) implying in this case that household size, through its presumed positive correlation with the availability of family labour, would have reduced labour constraints on the farm and result into more quality labour available for carrying out farming activities in a timely manner, thus making the production process more efficient.

This result is similar to the findings of Parikh and Shah (1994), that household size has a positive and significant relationship with efficiency.

The coefficient of farm size was found to be negatively significant ($P<0.01$) in explaining farmers' inefficiency. It indicates that every unit increase in land leads to a decrease in technical inefficiency. Coelli and Battese (1996) observed the same phenomena while studying the technical efficiency of Indian farmers. Larger farms tend to be efficient but sometimes the advantage of small farms is thus attributed to their greater technical efficiency. In this study by progressive increase of farm size, farm size-squared becomes positive and significant ($P<0.01$) indicating that as the farm size increases, farmers become more and more unable to maintain the productivity of farm. Efficiency is only assured at a manageable level and not beyond.

The coefficient of education was expected to have a negative sign, assuming that a higher level of education would result in lower inefficiency. Similarly, long years of experience in farming also would have reduced technical inefficiency. As farmers accumulated more years in education level or gained more experience, they became better equipped and more knowledgeable in maize farming. Both variables indeed had a negative sign, but neither of the two was statistically significant.

Table 8: Maximum likelihood estimates of the translog stochastic frontier and efficiency model for maize production in western Kenya

Variable	Parameter	Coefficients	Std-error	T-ratios
Stochastic frontier				
Constant	β_0	-716.230***	0.605	-1183.892
Land	β_1	1.906***	0.194	9.844
Labour	β_2	-0.153***	0.044	-3.490
Seed	β_3	-0.646***	0.188	-3.429
Fertilizer	β_4	-0.142***	0.055	-2.598
Manure	β_5	-0.306***	0.039	-7.867
Land X Land	β_{11}	0.118***	0.034	3.432
Labour X Labour	β_{22}	0.015***	0.002	6.725
Seed X Seed	β_{33}	0.039	0.032	1.203
Fertilizer X Fertilizer	β_{44}	-0.009***	0.003	-2.847
Manure X Manure	β_{55}	0.030***	0.003	9.310
Land X Labour	β_{12}	-0.013	0.012	-1.090
Land X Seed	β_{13}	-0.197***	0.067	-2.969
Land X Fertilizer	β_{14}	-0.028*	0.015	-1.787
Land X Manure	β_{15}	-0.039***	0.009	-4.092
Labour X Seed	β_{23}	-0.007	0.009	-0.805
Labour X Fertilizer	β_{24}	0.038***	0.004	9.494
Labour X Manure	β_{25}	-0.006***	0.001	-6.140
Seed X Fertilizer	β_{34}	0.048***	0.014	3.411
Seed X Manure	β_{35}	0.082***	0.008	10.592
Fertilizer X Manure	β_{45}	-0.018***	0.004	-4.316
Mechanization	α_0	0.008	0.010	0.779
IR Adoption	$\boldsymbol{\alpha_1}$	**0.218*** **	**0.012**	**18.841**
Nyanza	λ_1	725.844***	0.584	1242.296
Western	λ_2	725.923***	0.585	1241.936
Inefficiency model				
Constant	δ_0	-29.034***	2.284	-12.710
Education	δ_1	-0.071	0.182	-0.388
Farm experience	δ_2	-0.183	0.358	-0.511
Farm experience-squared	δ_3	0.002	0.006	0.388
Household size	δ_4	-57.382***	1.117	-51.360
Household size-squared	δ_5	3.805***	0.097	39.098
Farm size	δ_6	-9.875***	0.986	-10.018
Farm size-squared	δ_7	4.508***	0.602	7.492
Gender (head female = 1)	δ_8	-0.728	0.985	-0.739
Efficiency parameters				
sigma-squared	σ^2	941.526***	1.468	641.164
gamma	γ	0.999999990***	0.000000007	145766790
log likelihood function	LLF	-901		
Mean technical efficiency		**0.70**		

***Significant at 0.01 level; **Significant at 0.05 level; *Significant at 0.10 level

Table 9: Mean values of output and explanatory variables (N= 573)

Variable	Unit	Mean	Std. Dev.	Min	Max
Output	Kilogram	1016.44	690.10	35.00	3630.00
Land	Hectare	0.48	0.28	0.02	1.22
Labour	Man-day	24.08	24.89	0.00	112.00
Seeds	Kilogram	13.23	7.52	0.25	35.00
Fertilizer	Kilogram	24.28	21.22	0.00	127.00
Manure	Kilogram	33.32	75.74	0.00	600.00
Education	Year	5.13	3.44	0.00	18.00
Farm experience	Year	23.08	13.55	4.00	70.00
Farm size	Hectare	0.99	0.53	0.08	4.41

The results show that the overall mean technical efficiency is estimated at 70% (Table 8). Therefore, there is a 30% scope for increasing maize production. The analysis of TE of the whole sample (Fig. 6) indicates that 45% of farmers in western Kenya operate at over 75% mean technical efficiency and less than 1% (0.3%) has a mean TE below 25%, which is considered technically inefficient with about 14% and 41% of farmers operating at 25% to 49% and 50% to 74% respectively. These results illustrate that most of the maize producers in western Kenya are technically efficient.

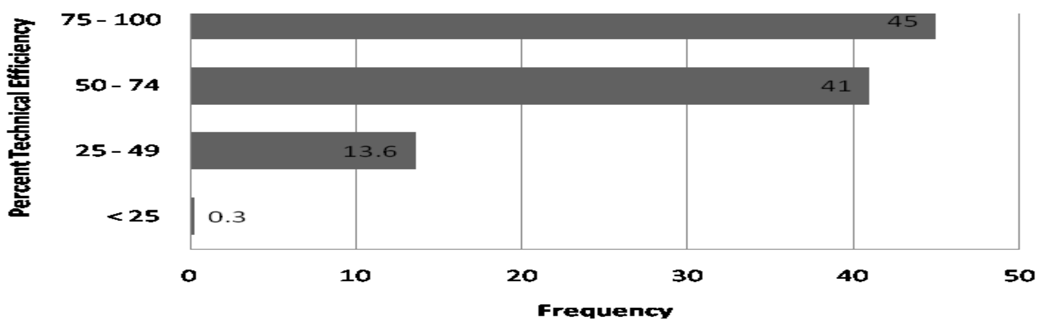

Figure 6: Frequency distribution of technical efficiency for maize production in western Kenya.

The farm-specific technical efficiency is segregated into adopters and non-adopters, Nyanza and Western provinces and also IAs and NIAs (Fig. 7).

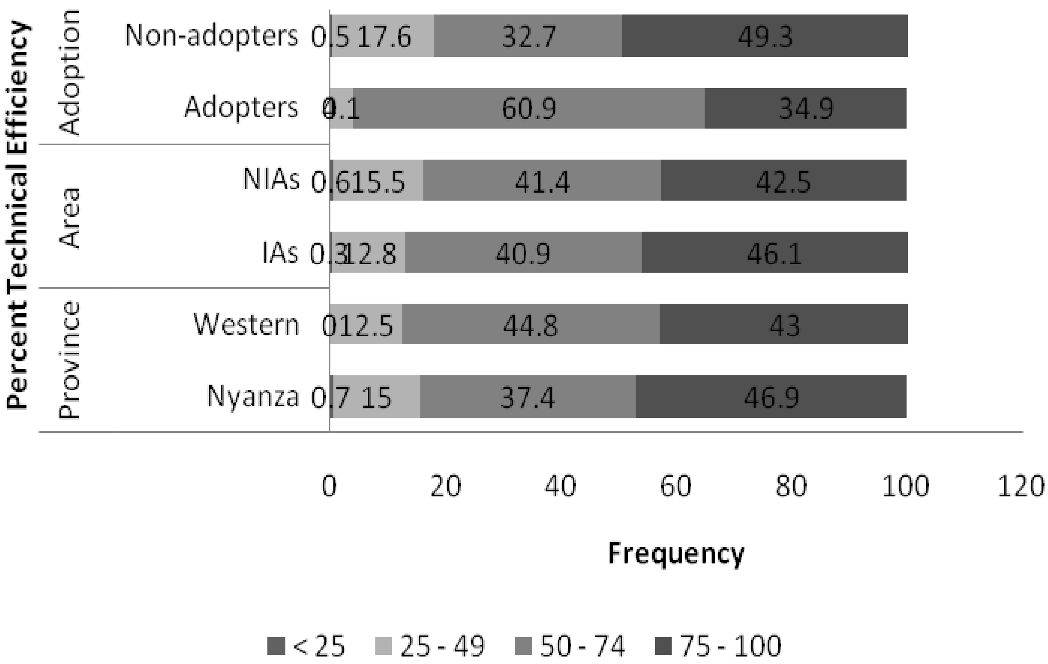

Figure 7: Frequency distribution of technical efficiency by adoption, area of intervention and province

Fig. 7 show that 43% of farmers in the Western province versus about 47% in Nyanza province operate at over 75% mean TE while about 45% of farmers in the Western versus 37% in Nyanza operate at between 50% and 74%. Less farmers in western (12%) compared to Nyanza (15%) operate at between 25% and 49% mean TE and there is no farmer in the Western operates at under 25% mean TE. This observation illustrates the mean TE in maize production which was marginally higher with sampled farmers from Western (71%) than that with sampled farmers from Nyanza (69%) confirming the higher maize productivity of farmers in the Western.

Regarding the intervention area, IAs and NIAs as depicted Fig. 7 indicates that the mean TE in maize production was found to be higher in IAs (71%) than it was in NIAs (69%).

Both in IAs and NIAs would be able to increase their output from the available inputs by about 29% and 31% respectively under perfect technically efficient production condition. Fig. 9 shows that 46% of maize producers in IAs against 43% in NIAs operate at over 75% mean TE while the same percentage of farmers in both IAs and NIAs operate at between 50% and 74% TE. Between 25% and 49%, 13% of farmers in IAs operate at less than they do in NIAs (16%) and at half in IAs (3%) compared to farmers in NIAs (6%) which operate at below TE of 25%. The study reveals that farmers in IAs are more technically efficient than those in NIAs. The effect of comprehensive campaign could have contributed to knowledge thus giving farmers more techniques of counteracting major farming constraints that could interfere with the objective increasing farm production.

Further disaggregation of the whole sample from Fig. 7 into adopters and non-adopters (Fig. 8) indicates that the mean TE in maize production was found to be slightly higher with IRM adopters (71%) than that with non-adopters (69%). Both adopters and non-adopters would be able to increase their output from the available inputs by about 29% and 31% respectively under perfect technically efficient production condition. The range of inefficiency effect is found to be minimum (5%) among non-adopters in maize production. Fig. 8 shows that 35% of maize producers who have adopted IRM against 49% of non-adopters operate at over 75% mean of technical efficient while 61% of adopters versus 33% operate at between 50% and 74% TE. Between 25% and 49% adopters (4%) operate at less than do the non-adopters (18%), and there is no adopter operates below TE of 25%. The study reveals that IRM adopters are more technically efficient than non-adopters. The significant difference between adopters and non-adopters could be attributed to farmers' attempts to adjust their production decisions to cope with the changes in the production by using IRM for *Striga* control whose transfer could have also built and reinforce knowledge component. This could have improved the farming skills of the adopters. In this case, the difference in TE is attributed to IRM, confirming that there is a significant positive impact of IRM package in maize production.

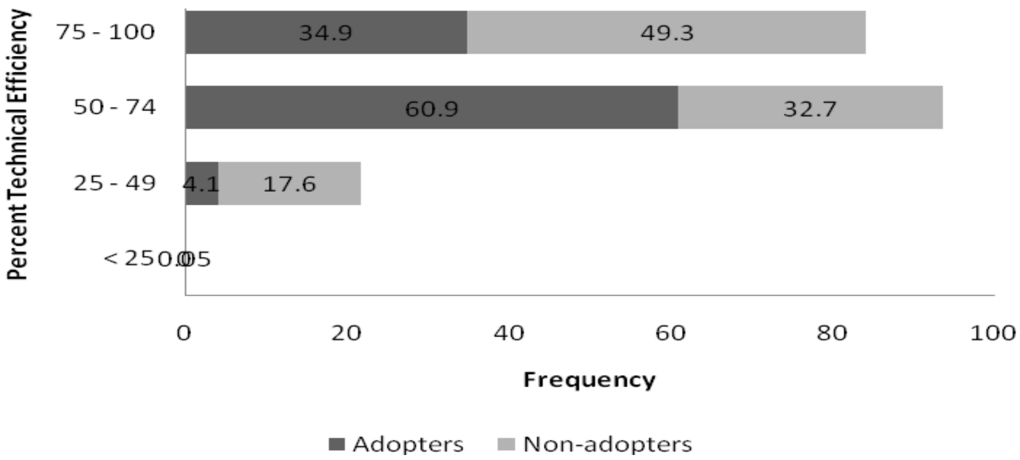

Figure 8: Frequency distribution of technical efficiency by adopters and non-adopters

4.3.2 Economic impact of IRM technology

The data analysis reveals that changes in maize productivity, economic viability, food security, *Striga* seed-bank and cropping patterns were the result of using IRM package.

4.3.2.1 Impact on maize productivity

Several varieties of maize have been used in western Kenya (Appendix 5) and were mainly categorized in three: local maize, IRM, and other hybrid maize. By comparing maize productivity of the three maize varieties in western Kenya as depicted the Table 10, IRM grown resulted into significantly (P<0.01) higher productivity than that of other hybrid. Also the recorded mean IRM productivity was significantly higher (P<0.01) than that obtained with local maize.

The impact of IRM on the total maize productivity was assessed by comparing maize productivity differential between non-IRM and IRM varieties. Because the two types of maize varieties were grown under the same conditions in the same area during the long rainy season of 2008, the likely source of productivity variation was the type of maize grown, a pair-wise comparison of the productivity between maize varieties indicates also that the mean productivity of IRM was significantly (P<0.05) higher than that of the non-IRM (2.2 ton/ha) amounting to a 27.3% productivity advantage (Table 10). This confirms that there is a positive contribution in maize output from adopting IRM as realized in the frontier model estimation in Table 8.

Table 10: Maize productivity and productivity differential by maize variety

Type of maize	Descriptive statistics of productivity (ton/hectare)		
	N	Mean	Standard Deviation
Local maize	291	1.4	0.22
IRM	169	2.8	0.44
Hybrid maize	312	2.5	0.19
Local Vs. IRM: -t = 26.02***	Local Vs. Hybrid: -t = 25.86***		IRM Vs. Hybrid: t =5.88***
	Maize productivity (ton/ha)	**Standard deviation**	**T-Value**
IRM	2.8	0.45	7.92*
Non-IRM	2.2	0.73	

*Significant at P<0.05 *** Significant at P<0.01

4.3.2.2 Economic viability of adopting IRM technology

Striga control technologies are effective through productivity gains. Productivity damage with different varietal typologies of maize cultivated in western Kenya (IRM, other hybrid and local maize) depends on the extent of *Striga* infestation. A more limited average variable cost-and-returns analysis is often used to compare different technologies that used the same fixed inputs. The gross margin for a maize enterprise is a good guide to the profitability of that enterprise under the conditions of crop production costs, yields and prices specified. The maize enterprise should remain viable if the gross margin together with any other farm income must be sufficient to cover the costs.

4.3.2.2.1 Gross margin and returns from maize enterprise

The gross margin (GM) of the different types of maize is shown in Table 11 below and a reader interested in the details of GM calculation is referred to Appendix 2. As shown in Table 11, returns to labour and gross margins vary among different types of maize. A comparison between maize crops shows that in average GM per ha of IRM was significantly ($P<0.01$) higher than that of hybrid (Ksh 51 753 versus Ksh 45 032). Also GM per ha of IRM was significantly ($P<0.01$) almost double that of local maize (Ksh 51 753 versus Ksh 26 566). In terms of variable costs, local maize is the cheapest but its relative low output per unit makes it a disadvantaged crop in terms of returns to land. Therefore, IRM is likely to be the first crop in relative profitability.

Table 11: Gross margins across different maize enterprises, values in Ksh, 2008

Item	Maize farming system typical for		
	Local maize (n=291)	**IRM** (n=169)	**Hybrid maize** (n=312)
Gross revenue in Ksh/ha (Mean)	**28 494**	**55 555**	**49 240**
Gross revenue in Ksh/ha (Median)	29 000	58 000	50 000
Total operational costs in Ksh/ha (Mean)	**1 928**	**3 802**	**4 196**
Total operational costs in Ksh/ha (Median)	1 220	2 673	3 600
Gross margin in Ksh/ha (Mean)	**26 566**	**51 753**	**45 032**
Gross margin in Ksh/ha (Median)	27 350	54 500	45 969
Gross margin in Ksh/ha (St. Deviation)	**4 628**	**9 455**	**4 663**
Gross margin in Ksh/ha (Minimum)	**11 400**	**21 067**	**9 590**
Gross margin in Ksh/ha (Maximum)	**39 450**	**67 967**	**53 330**

Gross revenue		
Local Vs IRM: -t = 26.02***	Local Vs Hybrid: -t = 25.86***	IRM Vs Hybrid: t = 5.88***
Total operational costs		
Local Vs IRM: -t = 7.69***	Local Vs Hybrid: -t = 5.39***	IRM Vs Hybrid: t = 3.93***
Gross margin (Mean)		
Local Vs IRM: -t = 22.26***	Local Vs Hybrid: -t = 20.48***	IRM Vs Hybrid: t = 4.32***

***Significant at $P<0.01$

After taking into account prices and costs of production, the yields of maize realized during the long rainy season of 2008 were expressed in financial returns to land from maize as shown in Table 12. The returns to land realized under IRM were significantly ($P<0.05$) higher to that of local maize. Contrary to physical yields, returns to land realized under IRM were significantly less ($P<0.05$) than those obtained under hybrid maize. Given that IRM recorded high productivity compared to hybrid maize (Table 10 above), lower returns from the former could be resulting from differences in the output prices and costs of production among farmers. Generally, an increased adoption of improved maize would improve crop income even other factors such as better output prices and lower costs of inputs associated with maize are constant.

Table 12: Returns to land from different types of maize

Type of maize	Descriptive statistics of returns to land (Ksh/hectare)		
	n	Mean	Standard Deviation
Local maize	291	9 522	6 572
IRM	169	12 457	9 752
Hybrid maize	312	18 436	11 881
Local Vs. IRM: -t = 8.72***	Local Vs. Hybrid: -t = 8.80***	IRM Vs. Hybrid: t = 3.08***	

*** Significant at P<0.01

The returns to labour reflects the level of reward for each man-day of the household workforce engaged in the production process and the results in Table 13 show that the pattern of returns to labour followed a different trend like returns to land. Financial reward to family labour input of IRM enterprise significantly (P<0.01) exceeded that of hybrid maize which in turn significantly (P<0.05) exceeded that of the local maize. This indicates the possibility that farmers tended to allocate less labour in local maize enterprise than they do in improved maize. Generally, IRM enterprise demonstrated higher mean return to labour than other hybrid and local maize enterprises, indicating the potential of the former in reducing poverty and vulnerability associated with *Striga*.

Table 13: Returns to labour from different types of maize

Type of maize	Descriptive statistics of returns to labour (Ksh/man-day)		
	n	Mean	Standard Deviation
Local maize	107	363	287
IRM	79	600	411
Hybrid maize	144	501	303
Local Vs. IRM: -t = 2.30**	Local Vs. Hybrid: -t = 2.45**	IRM Vs. Hybrid: t = 5.03***	

Significant at P<0.05, * Significant at P<0.01

4.3.2.2.2 Long-term economic viability of IRM project

Table 14 presents the economic viability indicative parameters extracted from Appendices 6, 7, 8 and 9. During the 10-year time horizon projected, the total revenues covered the total costs implying attainment of break-even point. Net present value and BCR reflect the economic viability of community IRM adoption project. The NPVs are all positive. The BCRs are good enough and ranged from 4.77, 6.21, 7.66, and 9.10 under full utilization of the project yield and hypothesised sensitivity analyses. The NPV reflects the economic worthiness and opportunity cost of investment and operating capital. In other words, it is the money that the community is qualified to borrow from the lending commercial institution and invest in the scheme.

Table 14: Economic viability of IRM project under sensitivity analyses on yields

Indicative parameters (in US $)	**Entire scheme yield**	**% increase of the IRM yield**		
		25	50	75
Net benefits	41 062.82	53 480.38	65 897.94	78 315.51
Net benefits/capita	42.26	55.04	67.81	80.59
Benefit/Cost Ratio (BCR)	4.77	6.21	7.66	9.10
Net present value (NPV)	21 680 402	27 113 724	32 547 047	37 980 370

The streams of net benefits per capita are less than the dollar poverty line; it is clear in this study that aggregated project benefits seemed to be high and relatively modest when distributed among beneficiary population. The long-term economic viability indicative parameters of IRM enterprise were good and more interesting along with the hypothesized increase of maize yield due to the level of *Striga* infestation reduced by IRM.

4.3.2.2.3 Development impact of IRM project at the community level

Table 15 presents the relative economic viability indicative parameters extracted this time from Appendices 6 and 11. The net present current worth of 10-year time horizon is US $21.7 million equivalent to more than a hundred times what is obtained from local maize under 20% annual yield decrease; and this illustrates the fruit of investing in IRM. These results indicate that IRM cultivation fetches higher returns whereas benefit cost ratio is reasonably lower than that of local maize.

Table 15: Relative economic viability of IRM project to local maize

Indicative parameters (in US $)	Entire IRM yield	Entire local maize yield
Net benefits	41 062.82	59 191.27
Net benefits/capita	42.26	35.38
Benefit/Cost Ratio (BCR)	4.77	5.60
Net present value (NPV)	21 680 401.78	158089.53

The returns to labour is a good indicator of income and hence poverty reduction as a result of the employment created through farming. In the income poverty analysis, the return to labour indicates the magnitude of a daily income that can be gauged on absolute poverty thresholds to reflect the depth of poverty. During the long rainy season of 2008, farmers with IRM plots as illustrated in section 4.3.2.2.1 realized Ksh 600 (US $8) for each person-day of the household workforce involved in producing maize. This means that return to labour realized by IRM producers in the project is eight times above the global poverty line of US $1 per person-day, reflecting the daily impact of farming on poverty reduction. The same section presents the yields of IRM realized during the long same season. These are expressed in financial returns to land amounting to Ksh 12 457 (US $173) per hectare which is substantial in the context of a rural economy.

4.3.3 Impact on food security as perceived by households

Maize plays a major role in the household's diet in western Kenya and to obtain a picture of the own perception of households in terms of the impact of IRM on food security, questions were addressed to households which adopted IRM and those which did not. To the households who adopted IRM we ask whether its use has changed the daily frequency of maize meals intake and to households who did not adopt the technology whether the non-use of IRM has brought any change on the daily frequency of maize meals intake.

Farmers have recently reported an increase in the productivity due to effective *Striga* control and utilization of some of the land left barren previously because of being invaded by *Striga.* Regarding the frequency of maize meal intake, each farmer approximated his/her consumption to be 250 g maize meal for every meal and eats once to twice in a day. With the introduction of IRM, 74% of IRM adopters reported to have a consumption rate increased to three in a day.

About 65% of non-adopters reported a decline of the maize meals intake from two meals to one meal per day, subject to decrease of maize production due to persistent *Striga* infestation.

Another exceptional and funny event reported by few IRM adopters relates to a biological factor as an indicator of availability of surplus maize grains in the study area where birds which were not used to be a problem in the past were back in big numbers due to migration. Permanent availability of bits of maize grains left behind or those which were delayed to be harvested were consumed by the birds.

4.3.4 Impact on *Striga* seed-bank and cropping patterns

In addition to the immediate benefits, about 26% of farmers realized that in their IRM plots, they noticed and experienced a progressive diminution of *Striga* is reclaiming some plots that were severely infested. Therefore they reported to have increasingly growing less of the local maize variety and other crops by allocating more and more land to IRM package. This has been confirmed by the intensity of IRM adoption (section 1.1.8 in Appendix 1) where the number of hectares planted with improved IRM seed has reached 48% of the total maize land.

4.3.5 Impact on institutional environment

Striga problem has strengthened the institutional collaboration in IRM related research and outreach initiatives (e.g.: agricultural collaborative studies done so far on *Striga* control by AATF and IITA). Therefore, IRM technology has brought hands-on involvement of many public and private organisations such as CIMMYT, AATF, IITA and NGOs in the IRM technology development and transfer. Similarly, impact analysis revealed that there was strong evidence to accept the third hypothesis of this thesis i.e., the use of IRM package brought positive changes on livelihoods of smallholfer farmers in western Kenya by increasing maize production, returns, food security, reducing Striga seed-bank and also strengthening institutional collaboration.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The general objective of the study was to analyse the adoption and impact of IRM technology for *Striga* control. More specifically the study intended to address the following objectives (a) To analyse the adoption rate of IRM technology in western Kenya, (b) To assess critical factors affecting the adoption of IRM technology and (c) To identify the impacts of novel IRM technology on farmers' livelihoods in the study area.

Multi-stage random sampling procedure was employed in selecting a total of 600 households from Nyanza and Western provinces in western Kenya including adopters and non-adopters. Descriptive and quantitative techniques were used to analyze the data. This chapter presents the conclusions and recommendations emerging from the major findings of the study.

5.1 Rates of Adoption of IRM Technology and Factors Affecting its Adoption

Many existing technologies such as IRM that have the potential of improving productivity particularly in *Striga* prone areas in western Kenya have surprisingly shown a low adoption rate amongst poor farmers. There was strong evidence that IRM adoption rate is higher in IAs than NIAs and there were many influential factors on its adoption such as farming experience, education, gap between maize production and consumption, risk-taking, the number of extension visits, lack of seeds, membership in social group and effective pathway for IRM dissemination. The adoption of IRM technology could be maximized by initiating new awareness campaign through the media and other communication channels (religious groups, traditional leaders, etc), and appointing young and better farmers to be trained as community facilitators to complement the role of extension agents particularly for IRM adoption. This farmer-to-farmer extension was particularly useful because some areas have not been serviced by government extension staff in helping to promote the use of IRM seed named by most of its adopters "*peremende"* meaning candy. There is also need to have sound management practices and the expansion of local supervisory capacity. Farmer-to-farmer diffusion would become more effective as a dynamic IRM seed industry to be responsive to farmers' needs hence improve their lives in western Kenya. In order to broaden the adoption of IRM in western Kenya, it would be also necessary for the stakeholders to take the necessary measures to built farmers' knowledge for risk minimization, develop IRM seed chain, intensify the transfer of technology and follow up through extension services as well as getting the required inputs. Policy makers and stakeholders of the maize sector are hereby called upon to develop the sector through taking measures in encouraging the adoption of IRM technology. This is vital for increasing maize productivity through *Striga* control.

5.2 Impact of IRM Technology

The highest gross margins have made IRM to be a viable and potential option in western Kenya which is devastated by *Striga*. The novel IRM guarantee significantly higher yields than local and other hybrid maize. Thus the long-term economic worth indicators have shown that IRM has the potential for poverty reduction and minimizing food security problems. Also its net present value, benefit-cost ratio and net benefits per capita were attractive. The IRM technology was effective for *Striga* control and well appreciated by farmers during 2008 long rainy season in western Kenya. The results show that the adoption of IRM was the major contributing factor to increased technical efficiency in maize productivity. The novel IRM package showed positive outcomes on livelihood indicators by succeeding in meeting its main objectives of reducing *Striga* seed-bank, raising productivity, having significant returns to land and labour, and improving nutrition for resource-poor households that led to acceptance of the third hypothesis of the thesis. In the process, an additional goal of IRM has also been realized: the capacity and cohesion of all institutions involved in IRM projects from the development of IRM seeds to its appreciable deployment has been greatly strengthened.

Therefore, IRM has great potentials for poverty reduction; efforts should therefore be made to enhance its adoption. Promoting the use of certified seeds and particularly IRM should thus be a critical goal for policy makers in Kenya. In this regard, continuous interventions from MoA, KEPHIS and AATF would be of interest to farmers to produce closer to their production frontier and reduce hunger and poverty in western Kenya. IRM technology occupies a central role in the design of comprehensive *Striga* Eradication Initiatives in maize fields and therefore should be prioritized particularly in western Kenya. Hence a significantly positive public investment and technology transfer is needed to improve its efficiency; this would, in turn, improve the adaptive capacity of western Kenya farming households and communities against *Striga*.

Drawing from above, it can be said that the IRM technology is appropriate for the multiple objectives of different actors in the study area due to their initial involvement in different IRM activities. In addition, more consideration should be given on the critical ways to speed up the adoption of IRM technology identified and mentioned by Manyong *et al.* (2008b) that could lead to high success in the technology dissemination programs as to comprise of the strong demand from farmers for *Striga* eradication. The adoption rate is however still low in spite of all the efforts made so far, while farmers continue to develop interest in the IRM package. At this stage, seed companies and stakeholders should have the ability to invest in capital (equipment, seed, stocks) increased and then absorb risks because the technology is still new. It requires a spirit of co-innovation among all the actors involved in the dissemination of IRM package programs because IRM, the novel remedy has to be known and experienced by all farmers in western Kenya as long as they all know about the evil *Striga*.

Since the current study did not use a rigorous assessment to evaluate the impact on food security, it is suggested that further research be carried out to assess the calories consumption per person with and without IRM, also to consider the multiplier effects as increased maize production which will increase maize supply, reduce the price hence benefit anybody around the area even those without IRM.

In order to extrapolate results about adoption and impact of IRM from this study, it is highly recommended that further research should be done in other areas with different agro-ecological conditions where IRM has been introduced.

REFERENCES

AATF (African Agricultural Technology Foundation) (2005). *A New Bridge to Sustainable Agricultural Development in Africa. Inaugural Report May 2002-December 2004*. Nairobi, Kenya: AATF. 44pp.

AATF (African Agricultural Technology Foundation) (2006). *Empowering African farmers to eradicate Striga from maize croplands*. Nairobi, Kenya. 17pp.

AATF (African Agricultural Technology Foundation) (2008). *Delivering the Promise: Impacting Lives with New Technologies. Annual Report 2006.* Nairobi, Kenya: AATF. 39pp.

Abdelmagid, S.A. and Hassan, F.K. (1996). Factors affecting the adoption of wheat production technology in the Sudan: *Quarterly Journal of International Agriculture* 35(4): 325 – 337.

Abdulai, A. and Huffman, W.E. (2005). The Diffusion of New Agricultural Technologies: The Case of Crossbred-cow Technology in Tanzania. *American Journal of Agricultural Economics* 87: 645-659.

Abunyewa, A.A. and Padi, F.K. (2003). Changes in soil fertility and *Striga hermonthica* prevalence associated with legume and cereal cultivation in the Sudan savannah zone of Ghana. *Land Degradation and Development* 14: 335-343.

Adato M. and Meinzen-Dick R. (eds.) (2007). *Agricultural Research, Livelihoods, and Poverty Studies of Economic and Social Impacts in Six Countries*. Published for IFPRI by Johns Hopkins University Press. 416pp.

Adesina, A.A. and Zinnah, M.M. (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone, *Agric. Econ*. 9: 297-311.

Adesina, A.A. and Baidu-Forson, J. (1995). Farmer's perceptions and adoption of new agricultural technology: Evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics* 13: 1 – 9.

Adesina, A.A., Mbila, M., Nkamleu, G.B. and Endamana, D. (2000). Econometric Analysis of the Determinants of Adoption of Alley Farming by farmers in the Forest Zone of South-West Cameroon. *Agricultural Ecosystems and Environment* 80: 255-265.

Adunni Sanni, S. (2008). Animal Traction: An Underused Low External Input Technology among Farming Communities in Kaduna State, Nigeria. *Tropicultura* 26(1): 48-52.

Aigner, D.J., Lovell, C.A.K. and Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics* 6: 21-37.

Ajibefun, I.A. and Abdulkadri, A.O. (2004). Impact of size of farm operation on resource use efficiency in small scale farming: Evidence from southwestern Nigeria, *Food, Agric. Environ*. 2(1): 359-364.

Akinola, A.A. (1987). An Application of Tobit Analysis to the Adoption of Tractor Hiring Services Scheme in Nigeria. *Oxford Agrarian Studies* 16: 70 – 82.

Alavalapati, J.R.R., Luckert, M.K. and Gill, D.S. (1995). Adoption of agroforestry practices: A case study from Andhra Pradesh, India. *Agroforestry Systems* 32: 1–14.

Amadalo, B., Jama, B., Niang, A., Noordin, Q., Nyasimi, M., Place, F., Franzel, S. and Beniest, J. (2003). *Improved fallows for western Kenya: an extension guideline*. Nairobi: World Agroforestry Centre (ICRAF). 56pp.

Amudavi, D.M., Khan, Z.R., Wanyama, J.M., Midega, C.A.O., Pittchar, J., Hassanali, A., Pickett, J.A. (2009). Evaluation of farmers' field days as a dissemination tool for push-pull technology in Western Kenya. *Crop Protection* 28: 225-235.

Anandajayasekeram, P. and Martella, D.R. (1996). Conceptual framework to assess the impact of agricultural research. *Journal of Agricultural Economics and Development* 1(1): 3- 19.

Anandajayasekeram, P., Bouret, I.R. and Corker, K. (1996). *A Training Manual for Biological Scientists on Impact Assessment of Investment in Agricultural and Natural Resources Research*. Southern African Centre for Cooperation in Agricultural and Natural Resources Research and Training. SACCAR. 230pp.

Anandajayasekeram, P., Semgalawe, Z.M., Lema, N., Moshi, A.J., Rugambwa, V., Mwinjaka, S. and Shayo, M. (2001). *Impact Assessment of Selected Research Programmes*. Tanzania Agricultural Research project – Phase Two (TARP II). Ministry of Agriculture and Food Security. Tanzania. 83pp.

Ariga, J., Jayne, T.S., Kibaara, B. and Nyoro, J.K. (2008). *Trends and Patterns in Fertilizer Use by Smallholder Farmers in Kenya, 1997-2007*. Tegemeo Working Paper No.32: Tegemeo Institute, Egerton University. Nairobi. 54pp.

Arndt, J. (1967). Role of product-related conversations in the diffusion of a new product, *J. Marketing Res.* 4: 291–295.

Asfaw, A. and Admassie, A. (2004). The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. *Agricultural Economics* 30: 215–28.

Asfaw N, Gungal, K., Mwangi, W. and Beyene S. (1997). Factors Affecting Adoption of Maize Production Technologies in Ethiopia. *Ethiopian Journal of Agricultural Economics* 2: 52-69

Ashley, C. and Hussein, K. (2000). *Developing Methodologies for Livelihood Impact Assessment: Experience of the African Wildlife Foundation in East Africa*. Working Paper 129. Overseas Development Institute (ODI). London. 78pp.

Awudu, A. and Huffman, W. (2000). Structure Adjustment and Economic Efficiency of Rice Farmers in Northern Ghana. *Economic Development and Cultural Change*. pp. 503-519.

Awudu, A. and Eberlin, R. (2001). Technical Efficiency during Economic Reform in Nicaragua: Evidence from Farm Household Survey Data. *Economic Systems* 25: 113-125.

Baker, J.L. (2000). *Evaluating the impact of development projects on poverty*: A Handbook for Practitioners. World Bank Publication Astract. New York. 240pp.

Battese, G.E. and Coelli, T.J. (1992). Frontier Production Function, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India. *Journal of Productivity Analysis* 3: 153-169.

Battese G.E. and Coelli, T.J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. *Empirical Economics* 20: 325-332.

Battese, G.E., Malik, S.J. and Gill, M.A. (1996). An Investigation of Technical Inefficiencies of Production of Wheat Farmers in Four Districts of Pakistan. *Journal of Agricultural Economics* 47(1): 37-49.

Batz, F.J., Peters, K.J. and Janssen. W. (1999). The influence of technology characteristics on the rate and speed of adoption. *Agricultural Economics* 21: 121–130.

Belknap, J. and Saupe, W.E. (1988). Farm family resources and the adoption of no-plow tillage in Western Wisconsin. *North Central J. Agric. Econ*. 10: 13–23.

Bradford, G.L. and Debertin, D.L. (1985). Establishing Linkages between Economic Theory and Enterprise Budgeting for Teaching and Extension Programs. *Southern Journal of Agricultural Economics* 18: 2.

Brooks, S., Thompson, J., Odame, H., Kibaara, B., Nderitu, S., Karin, F. and Millstone, E. (2009). *Environmental Change and Maize Innovation in Kenya: Exploring Pathways In and Out of Maize,* STEPS Working Paper 36, Brighton: STEPS Centre. 75pp.

Byerlee, D. (1994). *Maize research in Sub-Saharan Africa: An overview of past impacts and future prospects*. CIMMYT Economics Working Paper 94/03. CIMMYT, Mexico City. 36pp.

Byerlee, D., Hesse de Polanco, E. (1986). Farmers' Stepwise Adoption of Technological Packages: Evidence from the Mexican Altiplano. *American Journal of Agricultural Economics* 68(3): 519– 527.

Casley, D.J. and Lury, D.A. (1982). *Monitoring and evaluation of agriculture and rural development projects*. Baltimore, Md. : Published for the World Bank [by the] Johns Hopkins University Press. 145pp.

Casley, D.J. and Lury, D.A. (1987). *Data Collection in Developing Countries*. 2nd ed. Oxford University Press, USA. 240pp.

Castle, E.N., Manning H., Becker, M.H. and Nelson, A.G. (1987). *Farm Business Management: The Decision-Making Process*. New York: Macmillan Publishing Co. pp. 331-335.

Caveness, F.A. and Kurtz, W.B. (1993). Agroforestry Adoption and Risk Perception by Farmers in Senegal. *Agroforestry Systems* 21(1): 11- 25.

Cechin, I. and Press, M.C. (1994). The influence of nitrogen on growth and photosynthesis of sorghum infected with *Striga hermonthica* from different provenances. *Weed Research* 34: 289-298.

Chilot, Y., Shampiro, B.I. and Mula, D. (1996). Factors influencing adoption of new wheat technologies in Wolmera and Addis Alem Areas of Ethiopia. *Ethiopian Journal of Agricultural Economics* 1: 63-83.

CIMMYT (1993). *The Adoption of Agricultural Technology: A guide for survey design.* Mexico, D.F.: CIMMYT Economics Program. 250pp.

Coelli, T. J. (1996). *A Guide to Frontier Version 4.1 Computer Program For Stochastic Frontier Production And Cost Function Estimation*. CEPA Working Papers, 96/07, University of New England, Australia. 135pp.

Coelli, T.J. and Battese, G.E. (1996). Identification of factors which influence the technical inefficiency of Indian farmers. *Australian Journal of Agricultural Economics* 40(2): 103-128.

Dasgupta, S. (1989). *Diffusion of Agricultural Innovations in Village India*. Wiley Eastern Limited, New Delhi. 231pp.

De Groote, H., Kimenju, S., Owuor, G. and Wanyama, J. (2006). Market Liberalization and Agricultural Intensification in Kenya (1992-2002). Contributed paper prepared for presentation at the 26th *Conference of the International Association of Agricultural Economics*, Gold Coast, Australia. [http://www.iaae-agecon.org/]. Site visited on 04/03/2008.

De Groote, H., Wangare, L. and Kanampiu, F. (2007). Evaluating the use of herbicide-coated imidazolinone resistant (IR) maize seeds to control *Striga* in farmers' fields in Kenya, *Crop Protection* 26: 1496-1506.

De Groote, H., Wangare, L., Kanampiu, F., Odendo, M., Diallo, A., Karaya, H. and Friesen, D. (2008). The potential of a herbicide resistant maize technology for *Striga* control in Africa. *Agricultural Systems* 97: 83–94.

DFID (2001). *Evaluation Guidelines*. Evaluation Department for International Development (DFID), London, United Kingdom. 23pp.

DFID (2002). Sustainable Livelihoods Guidelines. [http://www.livelihoods.org/index.html], site visited on 07/04/2008.

Diagne, A. (2010). Technological change in smallholder agriculture: Bridging the adoption gap by understanding its source. *African Journal of Agricultural and Resource Economics* 5: 261- 286.

Doss, C.R. (2003). *Understanding Farm Level Technology Adoption: Lessons Learned from CIMMYT's Micro Surveys in Eastern Africa*. CIMMYT Economics Working Paper 03 – 07. Mexico, D.F.: CIMMYT. 26pp.

Doss, C.R. and Morris M.L. (2001). How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics* 25: 27–39.

Doss, C.R., Mwangi, W., Verkuijl, H. and De Groote, H. (2003). *Adoption of Maize and Wheat Technologies in Eastern Africa: A Synthesis of the Findings of 22 Case Studies.* CIMMYT Economics Working Paper 03-06. Mexico, D.F.: CIMMYT. 32pp.

Douthwaite, B., Schulz, S. and Olanrewaju, A. (2002). Impact Pathway Evaluation: an Approach for Achieving and Attributing Impact in African agriculture.In: *Proceedings of CGIAR Social Science Conference 11- 14 September 2002, in Cali, Colombia*. IITA Ibadan, Nigeria. 71pp.

Evenson, R. and Gollin, D. (2003). Assessing the Impact of the Green Revolution, 1960 to 2000. *Science Magazine* 300(5620): 758 – 762.

FAO (2009). *The State of Food Insecurity in the World: Economic crisis - impacts and lessons learned*. Rome. 56pp.

Farrell, M.J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, Series A (General) 120: 252-281.

Featherstone, A. and Goodwin, B. (1993). Factors Influencing Farmers Decision to Invest in Long Term Conservation in Improvements. *Land Economics* 69: 277-292.

Feder, G. and Umali, D.L. (1993). Adoption of Agricultural Innovations *A Review. Technological Forecasting and Social Change* 43: 215–239.

Feder, G., Just R.E. and Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey, *Econ. Dev. and Cul. Ch.* 33: 255-297.

Fernandez-Cornejo, J., Klotz-Ingram, C. and Jans, S. (2002). Farm-level effects of Adopting herbicide-tolerant soybeans in the USA. *Journal of Agricultural And Applied Economics* 34(1): 149-163.

Fox, P., Rockstrom, J. and Barron, J. (2005). Risk analysis and economic viability of water harvesting for supplemetal irrigation in semi-arid Burkina Faso and Kenya. *Agricultural Systems* 83: 231-250.

Franke, A.C., Ellis-Jones, J., Tarawali, G., Schulz, S., Hussaini, M.A., Kureh, I., White, R., Chikoye, D., Douthwaite, B., Oyewole, B.D. and Olanrewaju, A.S. (2006). Evaluating and scaling-up integrated *Striga hermonthica* control technologies among farmers in northern Nigeria. *Crop Protection* 25: 868-878.

Frost, H.M. (1994). *Striga Research and Survey in Kenya*. National Agricultural Research Project, KARI/ODA Crop Protection Project. Final Report. 61pp.

Gabre-Madhin, E.Z. and Haggblade, S. (2004). Successes in African Agriculture: Results of an Expert Survey, *World Development, Elsevier* 32(5): 745-766.

Gardner, B.L. (2002). *American Agriculture in the Twentieth Century: How It Flourished and What It Cost*. Cambridge, MA: Harvard University Press. 388pp.

Gautam, H. and Alwang, J. (2003). Access to Credit, Plot Size and Cost Inefficiency among Smallholder Tobacco Cultivators in Malawi. *Agricultural Economics* 29: 99-109.

Gbèhounou, G. and Adango, E. (2003). Trap crops of *Striga hermonthica*: in vitro identification and effectiveness in situ. *Crop Prot*. 22: 395–404.

Gebremedhin, B. and Swinton, S.C. (2003). Investment in Soil Conservation in Northern Ethiopia: The Role of Land Tenure Security and Public Programs. *Agricultural Economics* 29: 69-84.

Gecho, Y. (2005). Determinants of Adoption of improved Maize Technology in Damote. Gale Woreda, Wolaita, Ethiopia. Msc.Thesis (Unpublished). 122pp.

Gethi, J.G., Smith, M.E., Mitchell, S.E., Kresovich, S. (2005). Genetic diversity of *Striga* hermonthica and *Striga* asiatica populations in Kenya. *Weed Res.* 45: 64–73.

Gockowski, J. and Ndoumbé, M. (2004). The adoption of intensive monocrop horticulture in southern Cameroon. *Agricultural Economics* 30: 195–202.

Gouse, M., Pray, C. and Schimmelpfennig, D. (2004). The Distribution of Benefits from Bt Cotton Adoption in South Africa. *The Journal of Agrobiotechnology Management and Economics, AgBioForum* 7: 187-194.

Graves, J.D., Press, M.C. and Stewart, G.R. (1989). A carbon balance model of the sorghum-*Striga hermonthica* host-parasite association. *Plant, Cell and Environment* 12: 101-107.

Greene, W.H. (2003). *Econometric Analysis*, New Jersey, Prentice Hall. 778pp.

Gressel, J., Hanafi, A., Head, G., Marasas, W., Obilana, A.B., Ochanda, J., Souissi, T., Tzotzos, G. (2004). Major heretofore intractable biotic constraints to African food security that may be amenable to novel biotechnological solutions. *Crop Prot.* 23: 661–689.

Gujarati, D.N. (1995). *Basic Econometrics*. 3rd edition. McGraw-Hill Inc. New York. 838pp.

Gurney, A.L., Press, M.C. and Ransom, J.K. (1995). The parasitic angiosperm *Striga hermonthica* can reduce photosynthesis of its sorghum and maize hosts in the field. *Journal of Experimental Botany* 46: 1817-1823.

Habtemariam A. (2004). The comparative influence of intervening variables in the adoption behavior of maize and dairy farmers in Shashemene and Debre Zeit, Ethiopia. Thesis for Award of PhD Degree at, University of Pretoria, South Africa, 201pp.

Hassan, R. and Ransom, J.K. (1998). Determinants of the incidence and severity of *Striga* infestation in Maize in Kenya. In: Hassan, R.M. (Ed.), *Maize Technology Development and Transfer. A GIS Application for Research Planning in Kenya.* CAB International, Oxon, UK, pp. 163–174.

Hatibu, N. and Rockström, J. (2005). Green–blue water system innovations for upgrading of smallholder farming systems – a policy framework for development. *Water Science and Technology* 51: 121–131.

Hatibu, N., Young, M. D. B., Gowing, J. W., Mahoo, H. F. and Mzirai, O. B. (2002). Developing improved dry land cropping systems in semi-arid Tanzania. Part One: experimental evidence of the benefits of rainwater harvesting for maize. *Experimental Agriculture* 39: 297 – 292.

Heij, C., Boer, P., Franses, P., Kloek, T. and Dijk, H. (2004). *Econometric methods with applications in business and economics*, New York, Oxford University Press Inc. pp. 495.

Hellin, J., Bellon, M.R. and Badstue, L. (2006). Participatory research: a catalyst for greater impact. *Appropriate Technology* 33(2): 14-16.

Hellin, J., Bellon, M.R., Badstue, L., Dixon, J. and La Rovere, R. (2008). Increasing the impacts of participatory research. *Experimental Agriculture* 44 (1): 81-95.

Holloway, G., Nicholson, C., Delgado, C., Staal, S. and Ehui, S. (2004). A revisited Tobit procedure for mitigating bias in the presence of non-zero censoring with an application to milk-market participation in the Ethiopian highlands. *Agricultural Economics* 31: 97–106.

Hussain, S.S., Byerlee, D. and Heisey, P.W. (1994). Impact of training and visit extension system on farmers' knowledge and adoption of technology: Evidence from Pakistan. *Agricultural Economics* 10: 39–47.

Igbinosa, I., Cardwell, K.F. and Okonkwo, S.N.C. (1996). The effect of nitrogen on the growth and development of giant witchweed, *Striga* hermonthica Benth.: effect on cultured germinated seedlings in host absence. *Eur. J. Plant Pathol*. 102: 77–86.

IPDET (International Program for Development Evaluation Training) (2004). *Skills to Evaluate Development Interventions*. The World Bank. International Programme for Development Evaluation Training. Operations Evaluation Department in Patnership with Carleton University. Faculty of Public Affairs and Management. Ottawa, Canada. 346pp.

Jabbar, M. A. and Alam, M. (1993). Adoption of modern rice varieties in Bangladesh. *Bangladesh Journal of Agricultural Economics* 16 (2): 77-95.

James, O.O., Hugo, D.G. and George, O. (2006). Determinants of Improved Maize Seed and fertilizer use in Kenya. In: *the International Association of Agricultural Economist Conference*, Gold Coast, Australia. August 12 – 18, pp 16.

Jayne, T.S., Govereh, J., Xu, Z. Ariga, J. and Mghenyi, E. (2006). Factors affecting small farmers' use of improved maize technologies: Evidence from Kenya and Zambia. Paper prepared for the *Organized Symposium "Seed/fertilizer Technology, Cereal Productivity and Pro-Poor Growth in Africa: Time for New Thinking?"* Meetings of the International Association of Agricultural Economists (IAAE) 12-18 August 2006 Gold Coast, Queensland, Australia. [http://www.iaae-agecon.org/]. Site visited on 05/03/2008.

Jera, R. (2004). Comparative Socio-economic Evaluation of Alternative Farming Systems with Intergrated *Striga* Management Technologies. *Journal of Agricultural Economics* 20: 231- 239.

Kanampiu, F.K., Ransom, J.K., Friesen, D. and Gressel, J. (2002). Imazapyr and pyrithiobac movement in soil and from maize seed coats to control *Striga* in legume intercropping, *Crop Protection* 21: 611-619.

Kanampiu, F.K., Kabambe, V., Massawe, C., Jasi, L., Friesen, D., Ransom, J.K. and Gressel, J. (2003). Multi-site, multi-season field tests demonstrate that herbicide seed-coating herbicide-resistance maize controls *Striga* spp. and increases yields in several African countries. *Crop Prot*. 22: 697–706.

Kanampiu, F., Omanya, G., Muchiri, N., Nang'ayo, F.,Werehire, P., Tyrell, D. and Sthamer, V. (2006), Launch of *STRIGA*WAY (IR-maize) technology for *Striga* control in Africa, *Proceedings of the launch of the STRIGAWAY (IR-maize) technology*. 5-7 July 2005, Kisumu, Kenya. pp. 5-62.

Kansana, H. S., Sharma, R.P. and Sharma, S.K. (1996). Knowledge and adoption of wheat technology among contact and non-contact farmer. Digest Karnal. *Agricultural Science* 16:154 -156.

Karanja, D.D., Jayne, T.S. and Strasberg, P. (1998). *Maize Productivity and Impact of Market Liberalization in Kenya*. Tegemeo Working Paper: Tegemeo Institute, Egerton University. Nairobi. 28pp.

Khairo, S.A. and Battese, G.E. (2005). A Study of Technical Inefficiencies of Maize Farmers Within and Outside the New Agricultural Extension Program in the Harari Region of Ethiopia. *South African Journal of Agricultural Extension* 34(1): 136- 150.

Khan, Z.R., Midega, C.A.O., Njuguna, E.M., Amudavi, D.M., Wanyama, J.M. and Pickett, J.A. (2008). Economic performance of the 'push–pull' technology for stemborer and *Striga* control in smallholder farming systems in western Kenya. *Crop Protection* 27: 1084–1097.

Kibaara, B.W. (2005). Technical Efficiency in Kenya's Maize Production: An application of the Stochastic Frontier Approach. A Dissertation submitted In partial fulfillment of the requirements For the Degree of Master of Science of Colorado State University Fort Collins, Colorado, 84pp.

Kiriro, F.H. (1991). The *Striga* problem in Kenya. In: Combating *Striga* in Africa. *Proceedings, International Workshop organised by IITA, ICRISAT and IDRC*. Kim, S.K. (ed). 22-24 August 1988. IITA, Ibadan, Nigeria. Pp. 15-17.

Kothari, C.R. (2004). *Research Methodology: Methods and Techniques*. 2nd revised edition. New Age International (P) Ltd, Publishers, New Delhi, India. 418pp.

Kristjanson, P., Okike, I. Tarawali, S., Singh B.B. and Manyong, V.M. (2005). Farmers Perception and benefit and Factors affecting Adoption of improved dual-purpose Cowpea in the dry Savannahs of Nigeria. *Journal of Agricultural Economics* 32: 195-210.

Kunze, D. (2000). Economic Assessment of Water Harvesting Techniques: A demonstration of Various Methods. *Quarterly Journal of International Agriculture* 39 (1): 69-91.

Lagoke, S.T.O., Parkinson, V. and Agunbiade, R.M. (1991). Parasitic weeds and control methods in Africa. In: Kim, S.K. (Ed.), Combating *Striga* in Africa. *Proceedings of an International Workshop organized by IITA, ICRISAT and IDRC*, 22–24 August 1988. IITA, Ibadan, Nigeria. pp. 3–14.

La Rovere, R. and Dixon, J. (2007). *Operational guidelines for assessing impact of agricultural research on livelihoods. Good practices from CIMMYT*. Working Document, Version 2007.1.0. CIMMYT, Mexico, D.F. 74pp.

Lapar, M.A. and Pandey, S. (1999). Adoption of Soil Conservation: The Case of Philipes Lands. *Agricultural Economics* 21(3): 241- 256.

Lemchi J. I., Tshiunza, M., Onyeka, U. and Tenkouano, A. (2006). Factors Driving the Adoption of Cooking Banana Processing and Utilization Methods in Nigeria. *African Journal of Biotechnology* 8(11): 1335 – 1347.

Lilja, N. and Bellon, M. (2006). *Analysis of Participatory Research Projects in the International Maize and Wheat Improvement Center*. Mexico, D.F.: CIMMYT. [www.cimmyt.org/english/docs/impacts/analysisParticipaResProj.pdf] site visited on 6/3/2010.

Lilja, N. and Dixon, J. (2008). Operationalising participatory research and gender analysis: new research and assessment approaches, *Development in Practice* 18 (4): 467 – 478.

Lilja, N., Dixon, J., Manners, G., La Rovere, R., Hellin, J., Feldstein, H.S. (eds) (2006). New avenues in impact assessment of participatory research and gender analysis. *Summary proceedings of the Impact Assessment Workshop*, CIMMYT Headquarters, Texcoco, Mexico, October 19-21, 2005. Cali, Colombia: CGIAR Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation (PRGA); and Texcoco Mexico: International Maize and Wheat Improvement Center (CIMMYT). 63pp.

Maddala, G.S. (1992). *Introduction to Econometrics*. Second Edition. New York: Macmillan Publishing Company. 631pp.

Malcolm, B., Makeham, J.P. and Wright, V. (2005). *The Farming Game: Agricultural Management and Marketing*. 2nd edition: Cambridge University Press. 291pp.

Manyong, V.M., Hounde'kon, V.A., Sanguiga, P.C., Vissoh, P. and Honokaa, A.N. (1999). *Impact: Mucuna Fallow Diffusion in Southern Benin*. IITA and Meg-Comm Network, Ibadan, Nigeria. 68pp.

Manyong, V.M., Alene, A.D., Olanrewaju, A., Ayedun, B., Rweyendela, V., Wesonga, A.S., Omanya, G., Mignouna, H.D. and Bokanga, M. (2008a). *Baseline Study of Striga Control using Imazapyr-Resistant (IR) Maize in Western Kenya*. An agricultural collaborative study on *Striga* control by the African Agricultural Technology Foundation and the International Institute of Tropical Agriculture. 55pp

Manyong, V.M., Nindi, S.J., Alene, A.D., Odhiambo, G.D., Omanya, G., Mignouna, H.D. and Bokanga, M. (2008b). *Farmer Perceptions of Imazapyr-Resistant (IR) Maize Technology on the Control of Striga in Western Kenya*. An agricultural collaborative study on *Striga* control by the African Agricultural Technology Foundation and the International Institute of Tropical Agriculture. Nairobi, Kenya: African Agricultural Technology Foundation. 81pp.

Marra, M.C., Piggot, N.E. and Carlson, G.A. (2004). *The Net Benefits, Including Convenience, of Roundup Ready Soybeans: Results from a National Survey*. NSF Center for IPM Technical Bulletin 2004-3, Raleigh NC, September. 39pp.

Mathenge, M. and Tschirley, D. (2007). Off-farm Work and Farm Production Decisions: Evidence from Maize-Producing Households in Rural Kenya. Paper presented at the Centre for the Study of African Economies (CSAE) Conference 2007 on Economic Development in Africa, St. Catherine's College, University of Oxford, UK, March 18-20. 37pp

McCann, J.C. (2005). *Maize and Grace: Africa's Encounter with a New World Crop, 1500-2000,* Cambridge: Harvard University Press. 289pp.

Mihiretu, T.A. (2008). Farmers' evaluation and adoption of improved onion production package in Fogera district, South Gondar, Ethiopia. M.Sc. Thesis (Unpublished). Haramaya University, Ethiopia. 141pp.

Milimo, J.T. (1987). Women, population, and food in Africa: The Zambian case. *Development* 2/3 (special double issue): 70- 83.

Million, T. and Belay, K. (2004). Determinants of fertilizer use in Gununo area, Ethiopia. In Tesfaye Zegeye, Legesse Dadi and Dawit Alemu (eds) in *Proceedings of agricultural technology evaluation adoption and marketing*. Workshop held to discuss results of 1998-2002, August 6-8, 2002. Pp. 21-31.

Moser, C.M. and Barrett, C.B. (2006). The Dynamics of Smallholder Technology Adoption: The Case of SRI in Madagascar. *Agricultural Economics* 35: 373-388.

Moshi, A., Anandajayasekeram, P., Kaliba, A., Martella, D., Mwangi, W. And Shao, F. (1997). *Economic Impact of Maize Research in Tanzania*. Publishe by SACCAR. Gaborone Botswana. 14pp.

Mukhwana, E.J. (2003). Using Community Based Cereal Banks to Improve Smallholder's Access to Markets in Kenya, *African Crop Science Conference Proceedings* 6: 718-721.

Msambichaka, L.A. (1992). *Methods and Techniques for Agriculture and Rural Development Analysis: A Handbook for Functional Managers*. Economic Research Bureau, University of Dar-Es-Salaam. Printed by The Dar-Es-Salaam University Press. 203pp.

Mullen, J.D., Taylor, D.B., Fofana, M. and Kebe, D. (2003). Integrating long-run biological and economic considerations into *Striga* management programs. *Agricultural Systems* 76: 787–795.

Mullins, D., Gehrig, G., Mokaila, G.E., Mosaka, D., Mulder, L. and van Dijk, E. (2002). *A manual for Cost Benefit Analysis in South Africa with Specific Reference to Water Resource Development*. WRC., Pretoria, 144pp.

Mulugeta, E., Belay, K. and Legesse, D. (2001). Determinants of Adoption of Soil Conservation Measures in Central Highlands of Ethiopia. The Case of Three Districts of North Shoa. *Agrekon* 40 (3): 293- 315.

Mutabazi, K.D.S. (2007). Farmers' Perceptions, attitudes and adaptability to Rainfall variability risks in dry land areas of Tanzania. A thesis submitted in Fulfillment of The Requirements for the Degree of Doctor of Philosophy of Sokoine University of Agriculture, Morogoro, Tanzania. 178pp.

Mwabu, G., Mwangi, W. and Nyangito, H. (2006). Does adoption of improved maize varieties reduce poverty? Evidence from Kenya. *Poster paper prepared for presentation at the International Association of Agricultural Economists Conference*, Gold Coast, Australia, August 12-18, 2006. 15pp.

Mwangi, W.M., Lynam, J. and Hassan, R. (1998). Current Challenges and Strategic Future Choices for Maize Research and Policy in Kenya, In: Hassan, R. (ed.). *Maize Technology Development and Transfer: A GIS Application forResearch Planning in Kenya*, Wallingford: CAB International, UK. [http://www.*escholarship.org/uc/item/9666220j.pdf*]. Site visited on 14/9/2007.

Negash, R. (2007). Determinants of adoption of improved haricot bean production packsge in Alaba Special Woreda, Southern Ethiopia. Thesis for Award of MSc Degree at School of Graduate Studies of Haramaya University, Ethiopia. 154pp.

Nkamleu, G.B. (2004). Productivity growth, technical progress and efficiency change in African agriculture. *Africa Development Review* 16 (1): 203–22.

Nkamleu, G.B. (2007). Modelling Farmers' Decisions on Integrated Soil Nutrient Management in sub-Saharan Africa: A Multinomial Logit Analysis in Cameroon. In: Bationo, A., Waswa, B., Kihara, J. and Kimetu, J. (eds.). *Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities*. Netherlands: Springer Publishers. pp. 891-903.

Nkamleu, G.B. and Adesina, A.A. (2000). Determinants of chemical input use in peri-urban lowland systems: Bivariate probit analysis in Cameroon. *Agricultural Systems* 62: 1–11.

Nkamleu, G.B. and Tsafack, R. (2007). On measuring indebtedness of African countries. *African Finance Journal* 9 (1): 21–38.

Nkamleu, G.B., Keho, Y., Gockowski, J. and S David, S. (2007). Investing in agrochemicals in the cocoa sector of Côte d'Ivoire: Hypotheses, evidence and policy implications. *African Journal of Agricultural and Resource Economics* 1 (2): 261- 286.

Norton, G.W., Alwang, J. and Masters, W.A. (2006). Economics of Agricultural Development: World Food Systems and Resource Use, Routledge, New York. 448pp.

Nyangena, W. (2004). The Effect of Social Capital on Technology Adoption: Empirical evidence from Kenya. *Paper presented at the Thirteen Annual Conference of the European Association of Environmental and Resource Economics*, Budapest, June 25-28, 2004. 23pp.

Nyoro, J.K, Kirimi, L. and Jayne, T.S. (2004). *Competitiveness of Kenyan and Ugandan maize production: challenges for the future* .Draft for Review - Working Paper No 9 .Tegemeo Institute Of Agricultural Policy and Development, Egerton University. 28pp.

O'Brien, R.M. (2007). A Caution Regarding Rules of Thumb for Variance Inflation Factors. *Quality and Quantity* 41(5): 673- 690.

Oduor, A. (2002). Estimating Costs and Benefits on Crop Products. *Journal for A Simplified Guide for Smallholder Farmers* 4: 132- 135.

Ogunsumi, L.O., Saka, J.O., Afolami, C.A., Ojo, D.K. and Fakoya, E.O. (2003). Effect of downy mildew resistance maize technology of farmers yield and income in downy mildew endemic area of Nigeria. *ASSET Series A* 3: 55-22.

Otieno, H., Maina, J., Omare, M.N., Omanya, G. and Woomer, P.L. (2005). Field testing imazapyr-resistant maize to control *Striga* in western Kenya. *African Crop Science Conference Proceedings* 7: 461-465.

Oswald, A. (2005). *Striga* control-technologies and their dissemination. *Crop Protection* 24: 333–342.

Oswald, A. and Ransom, J.K. (2001). *Striga* control and improved farm productivity using crop rotation. *Crop Prot*. 20: 113–120.

Ouma, J., Murithi, F., Mwangi, W., Verkuijl, H., Gethi, M. and De Groote, H. (2002). Adoption of Maize Seed and Fertilizer Technologies in Embu District, Kenya. Mexico, D.F.: CIMMYT. 24pp.

Oyekale, A.S. and Idjesa, E. (2009). Adoption of Improved Maize Seeds and Production Efficiency in Rivers State, Nigeria. *Academic Journal of Plant Sciences* 2(1): 44- 50.

Pagiola, S. (1996). Price Policy and Returns to Soil Conservation in Semi-Arid Kenya. *Environmental and Resource Economics* 8: 255-271.

Parikh, A. and Shah, K. (1994). Measurement of Technical Efficiency in the North-West Frontier Province of Pakistan. *Journal of Agricultural Economics* 45:132-138.

Parker, C. and Riches, C.R. (1993). *Parasitic weeds of the world: Biology and control*. CAB International, Wallingford, UK, 332pp.

Perret, S. and Stevens, J. (2003). Factors affecting the adoption of water-conservation technologies. Key note address and paper to the *International Conference: Water Conservation Technologies for Sustainable Dryland Agriculture in Sub-Saharan Africa*, 8-11/04/2003, Bloemfontein, South Africa. 15pp.

Phiri, M.A.R., Mekuria, M. and Banziger, M. (2003). *Assessment of Smallholder Farmers' Utilization of Improved Maize Seed in the SADC Region*: A Study of Malawi, Tanzania, Zambia and Zimbabwe. CIMMYT, Harare, Zimbabwe. 194pp.

Popielarz, D. (1967). An explanation of perceived risk and willingness to try new products, *J. Marketing Res.*4: 368–372.

Prennushi, G., Rubio, G. and Subbarao, K. (2000). *Monitoring and Evaluation. Source Book for Poverty Reduction Strategies*. Washington, D.C.: World Bank. 41pp.

Press, M. C. and Gurney, A.L. (2000). Plant eats plant: sap-feeding witchweeds and other parasitic angiosperms. *Biologist* 47:189-193.

Qaim, M., Subramanian, A., Naik, G. and Zilberman, D. (2006). Adoption of Bt-Cotton and Impact Variability: Insights from India. *Review of Agricultural Economics* 28(1): 48-58.

Raintree, J.B. (1983). Strategies for Enhancing the Adoptability of Agroforestry Innovations. *Agroforestry Systems* 1(2): 173- 187.

Ransom, J.K. (2000). Long term approaches for the control of *Striga* in cereals: Field management options. *Crop Protection* 19: 759–763.

Ransom, J.K., Paudyal, K. and Adhikari, K. (2003). Adoption of improved maize varieties in the hills of Nepal. *Agricultural Economics* 29: 299–305.

Ravallion, M. (1994). *Poverty Comparisons. Fundamentals in Pure and Applied Economics*. Volume 56. Harwood Academic Publishers. 17pp.

Republic of Kenya (2001). *1999 Population and Housing Census*. Volume 1: Population Distribution by Administrative Areas and Urban Centers. Central Bureau of Statistics, Ministry of Finances and Planning. Nairobi, Kenya. 448pp.

Republic of Kenya (RoK) (2006). Medium Terms Expenditure Framework 2006/2007 2008/2009. Report for the Agriculture and Rural Development (ARD) Sector. Final Draft. February 2006. Nairobi: RoK. [www.treasury.go.ke/Sector_reports/ARD_Sector%20_Report_2007%20_Draft.pdf] site visited on 4/3/2010.

Rogers, E.M. (1983). *Diffusion of Innovations*. Third edition. London: Macmillan. 453pp.

Rogers, E.M. (2003). *Diffusion of Innovations*. The fifth edition. The Free Press, New York, 551pp.

SACRED Africa (2009). Setting the Scene: Poverty and Declining Agriculture in Sub-Saharan Africa. [www.sacredafrica.org/] site visited on 10/2/2010.

Saka, J.O. and Lawal, B.O. (2009). Determinants of adoption and productivity of improved rice varieties in southwestern Nigeria. *African Journal of Biotechnology* 8(19): 4923-4932.

Sauerborn, J. (1991). The economic importance of the phytoparasites *Orobanche* and *Striga.* In: *Proceedings of 5th International Symposium on Parasitic Weeds,* Edited by (Ranson, J. K., Musselman, L. J., Worsham, A. D. and Parker, C.) Nairobi, 1991 CIMMYT, Nairobi, pp. 137-143.

Sauerborn, J., Kranz, B. and Mercer Quarshie, H. (2003). Organic amendments mitigate heterotrophic weed infestation in savannah agriculture. *Applied Soil Ecology* 23: 181-186.

Schulz, S., Hussaini, M.A., Kling, J.G., Berner, D.K. and Ikie, F.O. (2003). Evaluation of integrated *Striga hermonthica* control technologies under farmer management. *Experimental Agriculture* 39: 99-108.

Semgalawe, Z.M. (1998). Household Adoption behaviour and Agricultural sustainability in the North-eastern Mountains of Tanzania: The case of Soil Conservation in North Pare and West Usambara Mountains. Thesis for Award of PhD Degree at Wageningen Agricultural University, Netherlands, pp. 90 – 150.

Sen, A. (1996). Economic Interdependence and the World Food Summit. Paper Presented at *the Seminar on "Global Food Security" Arranged by Swedish FAO-Committee in Stockholm* on 3rd June 1996. Journal of the Society for International Development, available at: [http://www.sidint.org/publications/development/96-4b.htm]

Senkondo, E.M.M., Msangi, A.S.K., Xavery, P., Lazaro, E.A. and Hatibu, N. (2004). Profitability of Rainwater Harvesting for Agricultural Production in Selected Semi-Arid Areas of Tanzania. *Journal of Applied Irrigation Science* 39(1): 65-81.

Shiferaw, S. and Holden, S.T. (1998). Resource Degradation and Adoption of Land Conservation Technologies by Smallholders in the Ethiopian Highlands: A study in Andit Tid, North Shewa. *Agricultural Economics* 18 (3): 233-247.

Shivani, R. L., Jooshi, P.K., Asokan, M. and Bantilan, M.C.S. (2000). Adoption of improved chickpea varieties: Evidences from tribal region of Gujarat. *Indian Journal of Agricultural Economics,* 55 (2).

Showemimo, F.A., Kimbeng, C.A. and Alabi, S.O. (2002). Genotypic response of sorghum cultivars to nitrogen fertilization in the control of *Striga hermonthica*. *Crop Prot*. 21: 867–870.

Sidibe A. (2005). Farm-level Adoption of Soil and Water Conservation Techniques in Northern Burkina Faso. *Agricultural Water Management* 71: 211–224.

Simon, M.M.S. (2006). Adoption of Rotational Woodlot Technology in Semi-arid areas of Tanzania: The case of Tabora Region. Thesis for Award of PhD Degree at Sokoine University of Agriculture, Morogoro, Tanzania, 237pp.

Smith, L.H., Keys, A.J. and Evans, M.C. (1995). *Striga hermonthica* decreases photosynthesis in *Zea mays* through effects on leaf cell structure. *Journal of Experimental Botany* 46: 759-765.

Stern, N., Dethier, J.J. and Rogers, F.H. (2005). *Growth and Empowerment: Making Development Happen*. CES. The MIT Press Cambridge, Massachusetts. London, England. 463pp.

Stoop, I. (2002). Overgehaalde respondenten. In: Averechtse Effecten. Nieuwjaarspocket SCP 2002, Den Haag: Sociaal en Cultureel Planbureau, pp. 46-52.

Stutely, R. (2002). *The Definitive Business Plan*. Pearson Education Limited, U.K. 312pp.

Suri, T. (2009). Selection and comparative advantage in technology adoption. Working Paper 15346. 56pp

Tan, S., Heerink , N., Kuyvenhoven, A. and Qu, F. (2010). Impact of land fragmentation on rice producers' technical efficiency in South-East China. NJAS-*Wageningen Journal of Life Sciences* 57(2): 117- 123.

TARP II-SUA Project (2001). Methodology for Agricultural Reasearch Impact Assessment. In: *Proceeding of a Workshop held under the project Food Security and Household Income for Smallholder Farmers in Tanzania*: Applied Reasearch with Emphasis on Women. TANESCO Training Centre, Morogoro, Tanzania 5-12 December 2000. 57pp.

Techane, A. (2002). Determinants of Fertilizer Adoption in Ethiopia. The Case of Major Cereal producing Areas. Thesis to School of for Award of MSc Degree at Graduate Studies of Alemaya University, Ethiopia, 92pp.

Tesfaye Z., Taye, G,, Tanner, D., Verkuijl, H., Agidie, A. and Mwangi, W. (2001). *Adoption of Improved Bread Wheat Varieties and Inorganic Fertilizer by Small Scale Farmers in Yelma Dansa and Farta Districts of Northern Ethiopia*. Mexico, D.F. Ethiopian Agricultural Research Organization (EARO) and International Maize and Wheat Improvement Center (CIMMYT). 29pp.

Tiamiyu, S.A., Akintola, J.O. and Rahji, M.A.Y. (2009). Technology Adoption and Productivity Difference among Growers of New Rice for Africa in Savanna Zone of Nigeria. *Tropicultura*, 27(4): 193-197.

Tobin, J. (1958). Estimation of Relationships for Limited Dependent Variables. *Econometrica* 26(1): 24 – 36.

URT (2001a). *Impact Study on Water Supply and Health Interventions in Dodoma and Kondoa Districts, Dodoma region Tanzania*. Presidents Office. Regional Administration and Local Governmemt. Volume 1. Project Coordination Unit. WSHPMA. 86pp.

USAID/OFDA (2009). *Kenya – Food Insecurity* [http://www.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/] site visited on 11/09/2009.

Van Ast, A., Bastiaans, L. and Kropff, M.J. (2000). A comparative study on *Striga* hermonthica interaction with a sensitive and a tolerant sorghum cultivar. *Weed Res*. 40: 479–493.

Van Delft, G.J., Graves, J.D., Fitter, A. and Pruiksma, M.A. (1997). Spatial distribution and population dynamics of *Striga hermonthica* seeds in naturally infested farm soils. *Plant and Soil* 195: 1-15.

Van den Ban, A.W. and Hawkins, H.S. (1988). *Agricultural Extension*, Longman, London, U.K. 328pp.

Venne, J., Beed, F. and Watson, A. (2009). Integrating *Fusarium oxysporum* f. sp. *Strigae* into cereal cropping systems in Africa. *Pest Manag Sci* 65: 560–565.

Vurro, M., Bonciani, B. and Vannacci, G. (2010). Emerging infectious diseases of crop plants in developing countries: impact on agriculture and socio-economic consequences. *Food Security* 2(2): 113-132.

Watling, J.R. and Press, M.C. (2001). Impacts of infection by parasitic angiosperms on host photosynthesis. *Plant Biology* 3: 244-250.

Wolfe, A.D., Randle, C.P., Liu, L. and Steiner, K.E. (2005). Phylogeny and biogeography of *Orobanchaceae*. *Folia Geobotanica* 40: 115.

Wooldridge, J. (2002). *Econometric Analysis of Cross Section and Panel Data*, London, The MIT Press. pp. 518-596.

Woomer, P.L. and Savala, C.N. (2007). *Striga* Management through Herbicide Resistance: A Public-Private Partnership in Action. *AAAE Conference Proceedings*.pp. 489-496.

Woomer, P.L. and Savala, C.E.N. (2008). *Striga* Technology Extension Project (STEP). *First Quarter Technical Report and Financial Statement*, 1 February to 30 April 2008 prepared on behalf of the WeRATE Network and submitted to The African Agricultural Technology Foundation. 14pp.

Woomer, P.L., Tungani, J., Odhiambo, G. and Mwaura, F.M. (2005). *Striga* management options in western Kenya. *African Crop Science Conference Proceedings* 7: 479-484.

APPENDICES

Appendix 1: Household characteristics

1.1 Socio-economic and farm characteristics and adoption of IRM technology

A few socio-economic and farm variables of more relevance in adoption decisions were considered.

1.1.1 Gender and age of the head of household

About 74% of households in western Kenya were headed by male as in most sub-Saharan Africa countries and inter-province differences in household headship showed that more female-headed households were found in Western province (about 15%) than in Nyanza province (about 12%). This can be explained possibly by the occupational mobility of men from Western to Nyanza and the incidence of high displacement of women in Nyanza compared to Western due to post-election violence of January and February 2008 in Kenya. Within the small proportion of female-headed households, about 8% were IRM adopters and 18% non-adopters underscoring probably that female-headed households were less risk takers in adoption a new technology. The low involvement of female-headed households in IRM adoption could be as studies have shown that women farmers are less likely to receive agricultural credit, and when they do, the amounts are significantly lower than those for men (Milimo, 1987), implying that female-headed households could not probably afford to support the extra costs of adopting a new technology.

The average age of the heads of households for IRM adopters was significantly higher than that of non-adopters (Table 16). These results are aligning with the findings by

Shiferaw and Holden (1998) that there are some relationships between age and adoption of land conservation technologies in north Shewa, Ethiopia.

Table 16: Average age (Years) and distribution of heads of households by age groups

Statistics	IRM adopters	Non-adopters
Average age	48.9	45.1
Std deviation	11.5	12.6
Minimum	18.0	12.0
Maximum	77.0	81.0
Age group	**% distribution within the group**	**% distribution within the group**
21 – 40	27.8	43.2
41 – 65	64.5	49.7
> 65	7.7	7.2

1.1.2 Household size

Household size determines the availability of household labour supply and Table 17 indicates large household size for both IRM adopters and non-adopters which may be attributed to the propensity of adult sons and daughters (unmarried or married) to remain in the parental household. Moreover, large household size tends to be allied generally with rural areas characterized by pronatalism and extended family relations. Table 17 illustrated that adopters of IRM technology had significantly larger household size than non-adopters ($P < 0.05$). This suggests that, adoption of IRM technology was associated with large household size probably due to higher labour requirements for IRM cultivation. These findings support the idea of Semgalawe (1998) that household size significantly influenced adoption of labour intensive technologies in north Pare and west Usambara mountains, Tanzania. The dependency ratio shows that the number of dependents is higher than the number of adults for adopters and the opposite is depicted with non-adopters illustrating that adoption of IRM might be associated to the dependency ratio which is important because as it increases, there may be an increased cost on the productive part of the population to maintain the upbringing and pensions of the economically dependent.

Table 17: Distribution of age groups within the household and the average household size

Age groups	IRM adopters	Non-adopters
0 – 14	3.27 (52.5)	2.41 (45.6)
15 – 64	2.88 (46.2)	2.82 (53.3)
> 65	0.08 (1.3)	0.06 (1.1)
Statistics	**IRM adopters**	**Non-adopters**
Average household size	6.2 (100)	5.3 (100)
Std deviation	2.4	2.1
Minimum	1.0	1.0
Maximum	13.0	13.0
Dependency ratio	1.16	0.87

Note: Number in the parenthesis indicate percentage of each age group per average household size

1.1.3 Level of education

Education is an important tool for enhancing people's ability to build awareness on various interventions and technologies and Table 18 indicates that, adopters of IRM spent more years in school than non-adopters. The overall average years spent in school by adopters was about 6.8 while non-adopters spent about 4.4 years. The differences in average number of years spent in school were significant ($P < 0.05$). These findings suggest that, IRM adopters were more literate than non-adopters and this could facilitate them enough in the adoption of IRM that required comprehension of technical extension leaflets and/or handbooks. These confirm the positive association between education and adoption of innovations in developing countries (Asfaw & Admassie, 2004).

Table 18: Education of the head of households in years spent in school

Statistics	IRM adopters	Non-adopters
Average	6.8	4.4
Std deviation	3.7	3.1
Minimum	0.0	0.0
Maximum	18.0	12.0
Years in school	**% for IRM adopters**	**% for non-adopters**
Below 1	1.0	13.5
1 - 8	18.5	49.5
9 - 12	6.2	8.8
Above 12	2.5	0.0

1.1.4 Occupation

Table 19 shows the distribution of respondents with respect to their major occupation. Maize cultivation was the major occupation for both IRM adopters and non-adopters. The difference between IRM and non-adopters with respect to maize as a major occupation was minor implying that adoption of IRM was not necessarily associated with maize cultivation as a major occupation.

Table 19: Distribution of respondents by major occupation

Major occupations	IRM adopters		Non-adopters	
	Freq.	%	Freq.	%
Maize farming	110	65.1	209	48.5
Mixed farming	31	18.3	102	23.7
Livestock farming	19	11.2	70	16.2
Wage employment	4	2.4	32	7.4
Self employment in artisan/business	5	3.0	18	4.2
Total	169	100	431	100

1.1.5 Per capita household income

Farmers are engaged in different income generating activities, and the main sources of income is crop and livestock selling, and information on household income was captured for the both seasons and was calculated at an average of Kshs 53,719 per household, with the income indicating that adopters of IRM technology had significantly (P < 0.05) higher household income than non-adopters. This suggests that, adoption of IRM technology was associated with high household income probably due to higher purchasing power to support all the costs requirements for IRM cultivation (Table 20). The per capita household income corresponded to about US$ 0.59/day for IRM adopters and US$ 0.36/day for non-adopters, characteristic of extreme poverty in western Kenya which is defined as under the World Bank poverty line of US$ 1/day/person.

Table 20: Per capita household income

Statistics	IRM adopters	Non-adopters
Observations (n)	169	431
Average HH income (Kshs)	80972	43033
Std deviation	55497	41931
Minimum	10000	3000
Maximum	349000	303000
Median	70000	33000
1st quartile	50000	10000
3rd quartile	108000	65000
	% for IRM adopters	**% for non-adopters**
Per capita HH income (Kshs/year)	15467*	9319*
Per capita/day HH income (US $)	0.589	0.355
Standard deviation	13463	11819
Median	12714	6667
1st quartile	7353	1955
3rd quartile	20700	12500

*Significant at P<0.05

Few respondents reported involvement in off-farm activities. The percentage of IRM adopters who were involved in off-farm activities (18%) was approximately equal to the percentage of non-adopters who were involved in these activities (16%). Table 21 shows the off-farm activities have contributed to total household income in some households with the artisan works which include masonry, carpentry and tailoring.

Table 21: Distribution of households with off-farm activities

Off-farm activities	IRM adopters		Non-adopters	
	Freq.	%	Freq.	%
Petty business	12	40.0	19	27.1
Trading business	8	26.7	9	12.9
Casual labour	4	13.3	9	12.9
Government employment	3	10.0	22	31.4
Artisan	3	10.0	11	15.7
Total	30	100.0	70	100.0

1.1.6 Number of extension visits

Number of extension visits is one of the prime movers of the agricultural sector and have been considered as a major means of technology dissemination. They aim to improve the productivity of agricultural systems, by raising the income of farm families and improving the quality of life of rural farm households. Farmers' contacts with extension agents are cost effective ways of reaching out with IRM technology. Regarding the contact farmers had with extension agents, about 33% of households in western Kenya declared have had a contact and Table 22 indicates that within those visits farmers, adopters of IRM technology had significantly higher number of visits by extension agents (twelve times) than non-adopters ($P < 0.05$). This suggests that, adoption of IRM technology was highly associated to contact with extension agents.

Table 22: Number of extension visits

Statistics	IRM adopters	Non-adopters
Average number of extension visits	3.81	0.30
Std deviation	2.64	0.69
Minimum	0.00	0.00
Maximum	10.00	4.00

1.1.7 Intrahousehold decision making

An understanding of the role of household head or jointly with his/her spouse in making decisions (Table 23) about issues to access resources could help the design of appropriate strategies for the introduction of a new technology especially IRM. There is no difference in average decision making between adopters and non-adopters on IRM adoption implying that adoption of IRM was not associated with Intrahousehold decision making.

Table 23: Intrahousehold decision making

Statistics	IRM adopters	Non-adopters
Average decision making	0.97	0.97
Std deviation	0.17	0.16
Minimum	0.00	0.00
Maximum	1.00	1.00
Decision making	**IRM adopters**	**Non-adopters**
Decision making by HH alone (%)	97.0 (164)	97.2 (419)
Decision making jointly by HH and spouse	3.0 (5)	2.8 (12)
Total	100 (169)	100 (431)

1.1.8 Agricultural land availability and use

Land was by far the major natural capital for smallholders in western Kenya and was a limiting resource for most farmers whose holdings were very small in size, 0.97ha on average of which 49% allocated to maize and 48% of the maize land allocated to IRM production. The total farmland is bigger in Nyanza (1.12ha) than in Western (0.82ha). Table 24 shows the average size of land owned by the sample households. Average farm size was significantly ($P < 0.05$) larger for non-adopters (1.01 ha) than adopters (0.85 ha). Likewise, as shown Table 10, maize cultivated area was larger for non-adopters (0.47 ha) than for adopters (0.41 ha). This implies that adoption of IRM is not likely associated with large sizes of land owned by farmers and farmers with larger farms tended to be less responsive to IRM package because they were most probably more willing to accept the higher risks associated with new varieties. Large landholding farmers were certainly feeling uncertain about IRM and were thinking about the amount of financial loss which will be greater commensurate with their bigger size of lands. Most empirical studies have shown that larger farms are more likely to adopt new technology as they can spread the costs over a wider range of outputs than is possible for small farms (Feder *et al.*, 1987; Hussain *et al.*, 1994); the larger the farm size, the more likely that a farmer can afford to set aside an extra piece of land to grow new variety. Contrary to the pattern observed with most of adoption studies, farmers with larger land holdings made less use of IRM package and more use of other varieties than those with smaller farms and farm size was negatively related to farmers' decision to adopt IRM technology. To solve the problem of land shortage, some farmers did apply improved technologies such as IRM.

Table 24: Total land (ha) owned by respondents

Items	IRM Adopters	Non-adopters	Overall
Mean	0.85	1.01	0.97
St. Deviation	0.50	0.54	0.54
Minimum	0.08	0.10	0.08
Maximum	1.92	4.41	4.41

Table 25 shows that, on average IRM adopters had a total of 0.41 ha of land under maize production, which was significantly lower than the 0.47 ha of maize land cultivated by the non-adopters ($P < 0.05$). These findings suggest that adopters of IRM were relatively smaller scale farmers and therefore have determination to compensate the shortage of the area by cultivating yielding varieties. Large land sizes which offers probability that non-adopters having more land are prone to IRM adoption failed it and most probably because of their risk aversion, stayed then hanging on their local and other hybrid maize.

Table 25: Maize and IRM land (ha) owned by respondents

	Land allocated to maize		
Items	**Adopters (N=169)**	**Non-adopters (N=431)**	**Overall (N=600)**
Mean	0.41	0.47	0.46
St. Deviation	0.27	0.29	0.29
Minimum	0.02	0.05	0.02
Maximum	1.22	1.22	1.22
	Land allocated to local maize		
Mean	0.17	0.42	0.36
St. Deviation	0.10	0.25	0.25
Minimum	0.01	0.05	0.01
Maximum	0.41	1.20	1.20
	Land allocated to IRM		
Mean	0.23		0.23
St. Deviation	0.17		0.17
Minimum	0.02		0.02
Maximum	1.00		1.00
	Land allocated to other hybrid maize		
Mean	0.21	0.49	0.41
St. Deviation	0.14	0.28	0.28
Minimum	0.01	0.10	0.01
Maximum	0.72	1.22	1.22

1.1.9 Use of fertilisers and pesticides

Due to low fertility and maize crop pest, use of fertilisers and pesticides was common among farmers in the study area. Since its use is *sine qua 'non* for IRM use, all IRM adopters used fertilisers compared to 67% of non adopters. The common types of inorganic fertilisers used were DAP and CAN and maize often requires rates of 90 to 120 kg/ha in the study area. Table 26 shows that, IRM adopters used more inorganic fertilisers and some traces of manure than non-adopters although the amount applied was below the recommended rate.

Table 26: DAP and CAN fertilisers (kg/ha) applied in maize crop

Items	**Maize inputs (DAP)**		**Maize inputs (CAN)**	
	IR adopters	Non-adopters	IR adopters	Non-adopters
Mean	55.51	29.53	23.92	7.77
Std deviation	75.37	23.27	37.88	7.75
Minimum	13.11	0.00	6.56	0.00
Maximum	1000.00	75.00	500.00	29.27
Recommended rate	105.00	105.00	105.00	105.00
Rate of use (%)	53	28	23	7

Apart from inorganic fertilisers, use of pesticides like thiodan or pesticides in post harvest to protect the produce was minimal.

1.1.10 Seed use

In the study area, farmers used a higher proportion of seed than 25kg/ha recommended for maize in the region. Table 27 shows that farmers do not sow the quantities of seed required to obtain a maximum of productivity. A higher density in this case leads to overexploitation of the land and competition of crops with IRM adopters who used seed slightly less than non-adopters probably because of their willingness for obtaining good yield.

Table 27: Maize seed planted (kg/ha)

Items	**Maize seed in kg**	
	IR adopters	Non-adopters
Mean	26.57	26.76
Std deviation	5.53	8.07
Minimum	5.00	15.00
Maximum	40.00	60.00
Recommended rate	25.00	25.00
Rate of use (%)	106	107

1.1.11 Variations in labour use

In most land–scare rural areas with high population density like western Kenya, labour is rarely a limiting resource and technological change in agriculture can create competing demands for labour. It may require additional time spent in agricultural production even while it generates an increase in household income resulting in additional demand of labour. In this process, factors external to the household, such as the characteristics of the rural labour market and factors internal to the household such as Intrahousehold decision making and availability of resources can influence the outcomes.

Table 28 shows the labour use per cultivated hectare of different types of maize land and this study observed that in western Kenya, proportion of farm labour is obtained from household members and by hiring because of insufficiency of family labour. The relative higher proportion of farm labour is obtained with IRM cultivation followed by hybrid and local maize. By comparing local and hybrid maize labour use between adopters and non-adopters, on average IRM adopters had more man-days of family and hired labour compared to non-adopters and the mean difference was significant (P < 0.05 level). In the study area, family labour represents the major source of power. These results may imply that, abundant farm labour among IRM adopters might have influenced them to adopt IRM. Use of technologies such as oxen-plough or tractor-plough cultivation is generally expected to reduce the labour requirement for farming and are in this study area minimal.

Table 28: Labour use in western Kenya (man-days/ha)

Type of maize		IRM adopters		Non-adopters		All	
		Family labour	Hired labour	Family labour	Hired labour	Family labour	Hired labour
Local maize	**Mean**	160.43 (33)	37.64 (19)	85.29 (74)	22.57 (83)	108.47 (107)	25.38 (102)
	St. Dev.	68.17	18.44	51.39	14.28	66.61	16.15
	Minimum	10.00	15	29.17	6.25	10.00	6.25
	Maximum	260.00	90	250.00	90.00	260.00	90.00
IRM	**Mean**	122.32 (79)	44.31 (54)	0.00 (0)	0.00 (0)	122.32 (79)	44.31 (54)
	St. Dev.	73.67	41.02	0.00	0.00	73.67	41.02
	Minimum	20.00	12.50	0.00	0.00	20.00	12.50
	Maximum	400.00	250.00	0.00	0.00	400.00	250.00
Hybrid maize	**Mean**	197.90 (51)	35.08 (16)	105.32 (93)	34.47 (118)	138.11 (144)	34.54 (134)
	St. Dev.	98.18	20.02	82.00	30.97	98.34	29.82
	Minimum	57.38	13.73	36.89	7.32	36.89	7.32
	Maximum	400.00	80.00	350.00	200.00	400.00	200.00

Figures in parentheses represent number of respondents, St. Dev. for standard deviation.

1.1.12 Household equipments and implements

According to Adesina and Baidu-Forson (1995), ownership of household equipment and implements is an important determinant of adoption of new technology. The most frequently owned household equipment (owned by at least 50% of the households surveyed) were hand hoes, panga, bowls, buckets, cooking pots, chairs, tables, torches, water containers, hurricane lamps, watch/lock, spongy mattress, radio, bicycles, iron sheets houses.

Most households surveyed had at least one hand hoe. About 56.67% of all households had bicycles, 78.17% owned radios and 85.67% had spongy mattress. Household equipment owned by less than 50% of the surveyed households included spades and by less than 25% included ox plough, ox cart and bush knives. All of these equipments are important in managing staple maize fields. The low percentage of ownership of these equipments provides is evidence that farmers do not achieve the proper management of maize fields. Ownership of bicycles (71% of adopters and 51% of non-adopters), radios (68% of adopters and 82% of non-adopters) and spongy mattress (85.8% of adopters and 85.6% of non-adopters) was insignificantly different between the two groups indicating that these household equipments are not associated with the decision to adopt IRM package.

1.1.13 Livestock production

Keeping livestock is one of livelihood activities carried out by farmers in western Kenya and Table 29 shows the proportions of respondents involved in livestock production. Most households kept poultry followed by other types of livestock like cattle, goats, sheep and pigs. Furthermore there was no significance difference between IRM adopters and non-adopters according to the proportion of respondents owning livestock.

Table 29: Distribution of respondents by type of livestock owned

Livestock type	IRM adopters		Non-adopters	
	Freq.	%	Freq.	%
Poultry	125	29.1	284	24.1
Local cattle	112	26.0	264	22.4
Sheep	73	17.0	102	8.6
Improved cattle	65	15.1	395	33.5
Goat	53	12.3	130	11.0
Pigs	2	0.5	5	0.4

Note: The frequency of respondents having different types of livestock is less than the sample size because some of them did not own some or all types of livestock

However, with exceptions of goat and sheep, the average number of livestock owned by IRM adopters was higher than non-adopters as shown Table 30 below, these results suggest that while there was little initiative in livestock production among farmers, IRM adopters owned slightly more animals for each livestock type than non-adopters.

Table 30: Average number of each of the major livestock types kept per household

Items	Adopter category	Local cattle	Improved cattle	Goat	Sheep	Poultry	Pigs
Mean	**Adopter**	4.2	2.0	3.3	4.9	16.9	8
	Non-adopter	4.1	1.8	4.2	5.4	15.3	3.6
St. dev.	**Adopter**	2.5	1.2	2.2	5.1	15.1	7.1
	Non-adopter	3.5	1.1	3.5	4.6	14.3	2.9
Maximum	**Adopter**	15	5	12	20	100	13
	Non-adopter	20	67	26	31	100	8

1.1.14 Maize cropping calendar

Table 31 shows the maize cropping calendar in the study area during the long and short rains seasons. The long rains season begins in March with land preparation and ends in December for maize subdivided as follows: its planting period from mid-February to

April, the harvesting time from October to mid-December with a mid season from June to September. For the short rains season, its starts from October to February structured as follows: a planting period from October to November and a harvest period from March to mid-April with a mid season between December and February. The month of May is normally more labour demanding for both IRM adopters and non-adopters under the three undertaken activities including ploughing and weeding which according to farmers are more labour intensive than other farm activities.

Table 31: Maize cropping calendar

Activities undertaken each month for maize											
Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	1	1	2	2	4	6	6	7	8	9	9
			3	3	5	5	7	8	9		
				4					1*	2*	4*
6*	7*	8*	9*							3*	5*

Key: Note that numbers in the Table 17 represent farm operations as shown below
1 = Land preparation 4 = Weeding 7 = Guard crops
2 = Ploughing 5 = Fertilizers application 8 = Harvesting
3 = Planting 6 = Pesticide application 9 = Post harvest
*Second crop

1.1.15 Food security and IRM adoption

Food security is perceived as a function of having sufficient maize as a staple food and could be defined in relation to the adequacy of food availability, the adequacy of food access and the reliability of both and asking farmers to indicate exactly if the amount of crop they produced to be stored will meet the household food requirement throughout the year and about 72% of adopters versus 22% reported their food to be able to sustain till the next harvest. When asked to give reasons for failure of food to be sufficient, several reasons were given in Table 32. The results show that *Striga* infestation and soil fertility were in both groups that gave the stiffest challenges to food security with as leaders IRM adopters.

Table 32: Distribution of respondents by reasons for food shortage

Major causes of food shortage	IRM adopters		Non-adopters	
	Freq.	%	Freq.	%
***Striga* infestation**	147	31.7	337	26.5
Low soil fertility	127	27.4	291	22.9
Drought affect crop and livestock	57	12.3	179	14.1
Land shortage	51	11.0	187	14.7
Pest infestation to crop	27	5.8	94	7.4
Labour shortage	21	4.5	56	4.4
Conflict	14	3.1	60	4.7
Flooding	19	4.2	66	5.2
Total	463	100	1270	100

The study found also that food shortage reached its peak period from March to April and farmers did undertake various strategies to cope with food insecurity as illustrated in Table 33. Most of respondent in both groups considered the use of their own savings as best copping strategy for food shortage followed by selling livestock for IRM adopters and petty business for non-adopters.

Table 33: Coping strategies for food shortage

Coping strategies	IRM adopters		Non-adopters	
	Freq.	%	Freq.	%
Use own savings	102	22.6	273	23.3
Sell local brew	21	4.6	70	6.0
Grow horticultural crops	60	13.3	185	15.8
Sell livestock	86	19.0	133	11.3
Get one meal per day	50	11.1	118	10.1
Honey collection	6	1.3	34	2.9
Remittances from relatives	45	10.0	134	11.4
Petty business	74	16.4	190	16.2
Fishing	8	1.8	35	3.0
Total	452	100	1172	100

1.2 Farmers' acceptance of the novel IRM package

More than 200 varieties of maize developed through CGIAR-supported research are being accepted and grown by farmers in developing countries for their various advantages (Stern *et al*., 2005). Acceptance of IRM technology is influenced by potential adopters' perceptions. Farmer's perceptions on willingness to accept IRM package were reported to vary by district depending upon three types of factors. The continual extent of *Striga* infestation, the form and depth of IRM dissemination in the study area including the information and incentives provided to farmers and the external factors affecting price and demand.

In western Kenya, where maize production had been badly affected by *Striga*, the majority of farmers agreed to free their land from *Striga* by using IRM package without delay only if the seeds were available. IRM package still unknown in the area where some farmers hesitate to plant it, instead waited and observed its performance from volunteer neighbours. During some interviews it was pointed that farmers heard about the novel IRM from various information sources. The dissemination mechanisms included on-farm testing, seminars on *Striga* control using IRM, and through provision of extension materials such as leaflets, radio programmes and recently through mobile phones messages.

IRM has been developed at CIMMYT-Kenya in collaboration with the Kenya Agricultural Research Institute (KARI). KARI multiplied seeds for technology testing and plant breeding. The practicality of coating Imazapyr resistant maize seeds with the Imazapyr herbicide was first demonstrated through collaborative research at the KARI-Kibos station outside of Kisumu (Kanampiu *et al*., 2002). However, by 2004, it was necessary to test this technology on a larger scale and for such an undertaking; AATF stepped in and funded the multiplication of IRM by Western Seed Company. A campaign of pre-release testing of IRM was launched by AATF (Otieno *et al.*, 2005) and IRM has been commercialised in Kenya after successful on-farm demonstrations facilitated by AATF, WeRATE, a consortium of 12 NGOs and six farmer organisations, KARI, the Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT), Maseno and Moi universities. Over 13,000 farmers in western Kenya have participated in the on-farm demonstrations which began in 2004. Later, IRM hybrid variety was approved by KEPHIS and released to commercial seed companies. The Kenyan Pest Control Products Board (PCPB) approved Imazapyr as *Striga*way under application from BASF and top serve (Kenya) in June of 2006. Through on-farm trials or demonstrations, farmers gained first-hand experience in growing IRM and were able to learn directly from their own experiences about the best technology for *Striga* control. For farmers who had not participated in on-farm trials or demonstrations, they felt that the information they received was inadequate. As a result of inadequate information on planting and husbandry requirements on the novel IRM package, some farmers planted IRM without following its guidelines and thus did not meet performance expectations. Other farmers were reticent about expressing their perception towards IRM package because of being a new variety or because of insufficient information received about IRM.

Presumably, the farmers who participated in on-farm demonstrations became informants in their communities on testing results and assisted other farmers to build their preferences for informed judgments about different maize varieties.

Assessment of farmers' preferences among alternative maize crop enterprises could provide useful feedback for research and extension, especially when they are quantified. Using field trial and tests in follow-up studies provide a cost-effective and quick method to assess adoption potential over western Kenya with IRM.

To understand better farmers' criteria of adoption and determine their perceptions on IRM package among farmers who were exposed to it since on-farm variety trials and demonstrations to its adoption, the study used a qualitative analysis based on maize ranking.

Farmers in western Kenya grow several varieties of maize which could be grouped into three: IRM, other hybrid variety and local maize variety. Local maize variety is by far the most common one followed by hybrid maize varieties. In addition to these two types of varieties, the novel one, the IRM which is been adopted to control the effect of *Striga*. These varieties were evaluated for preference against some performances attributes which were important to farmers in their comparison between the technologies they had and the new they were up to before its adoption decision.

In the case studies, asking farmers whether a practice was adoptable did not prove to be very useful; nearly all farmers gave positive assessments probably because they felt that criticising a practice would be insulting to the researcher. Rather, adoption was best ascertained by examining whether farmers continued using or expanded use of a practice following a trial and whether neighbouring farmers took it up. Adoption was found to depend on a range of criteria in addition to financial profitability, such as risk, compatibility with farmers' values and difficult-to-quantify benefits that were often omitted from economic analyses. The adoption of a technology also depends on its feasibility from the farmers' point of view, and its value to them. Apparent constraints, such as labour bottlenecks that are cited when farmers attach a low value to an activity, may disappear when the farmers' perception of the value increases. Thus, the feasibility of a technology is dependent upon the technology's perceived value.

This analysis could not only provide a list of selection criteria used by farmers, but could also help clarify the relative weighting of the criteria employed by farmers when making selections. Farmers consistently got and used 16 different criteria when ranking the types of maize (Table 34). It was found that these could be grouped into eight categories: criteria relating to (1) yield, (2) consumption, (3) time/duration, (4) biotic stress, (5) abiotic stress, (6) management, (7) sale, and (8) storage.

Adoption of IRM depends on farmers' perceptions of its performance attributes and the results are presented in Table 34. IRM had more positive attributes than the four found by Manyong *et al.* (2008b), this study found six positive attributes of high yield, tasty *ugali* (corn meal), tasty green maize, early maturity, ability to disperse *Striga* and resistance to biotic stress. These were however weighed against three less positive attributes of high labour requirement, high input, and complexity in farm management. The results too showed that hybrid maize had four positive attributes of high biomass, resistance to abiotic stress, high market returns and ease to selling due to appearance attractiveness. For the local maize, it had no positive attributes and according to farmers, they still produced it for its less costs.

The overall trend was also reflected by the Nyanza and Western province farmers (Table 35). The farmers in Nyanza pointed out that local maize had higher biomass, higher tasty *ugali*, higher tasty green maize and earlier maturity compared to other while hybrid maize had higher resistance to abiotic stress and higher labour requirements and IRM had higher market return than the other two varieties. The Western province farmers, because of their important number of adopters, revealed that IRM had higher tasty *ugali,* higher tasty green maize, earlier maturity, higher resistance to abiotic stress and higher labour requirements compared to the other two varieties while hybrid had higher biomass and higher market return than local and IRM.

Table 34: Ranking of maize varieties against various attributes (% households)

Attributes/Criteria	IR	Hybrid	Local
Yield-related criteria			
High yield	79.3 (134)	49.7 (298)	22.5 (135)
High biomass (good animal feed)	26.0 (44)	34.3 (206)	28.3 (170)
Consumption			
Tasty *ugali*	45.0 (76)	34.3 (206)	37.5 (225)
Tasty green maize	46.2 (78)	25.0 (150)	37.0 (222)
Time/duration			
Early maturity	44.4 (75)	36.3 (218)	30.0 (180)
Biotic stress			
Disperse *Striga*	81.7 (138)	8.0 (48)	0.8 (05)
Resistance to biotic stress (weed, pests, diseases)	71.6 (121)	33.0 (198)	3.2 (19)
Abiotic stress			
Resistance to abiotic stress (wind, cold, drought)	30.2 (51)	38.2 (229)	20.0 (120)
Management-related criteria			
High labour requirement	40.8 (69)	30.8 (185)	1.7 (10)
High input	75.7 (128)	33.7 (202)	0.5 (03)
Careful/complex farm management	85.2 (144)	32.7 (196)	0.2 (01)
High management cost	61.5 (104)	32.7 (196)	1.2 (07)
Sale (Dry grain)			
Easy to sell (colour-attractiveness)	12.4 (21)	53.3 (320)	24.5 (147)
High market returns (weight)	36.7 (62)	47.8 (287)	23.2 (139)
Storage			
Less susceptible to storage pests (rats, weevils, etc)	43.2 (73)	17.0 (102)	42.8 (257)
Requires no/less post-harvest dusting	46.2 (78)	14.3 (86)	45.5 (273)

Figures in brackets indicate the number of respondents

Table 35: Ranking of maize varieties against various attributes: Nyanza vs Western farmers (%HH)

Attributes/Criteria	Nyanza			Western		
	IR	Hybrid	Local	IR	Hybrid	Local
Yield-related criteria						
High yield	71.6 (48)	53.7 (161)	28.0 (84)	84.3 (86)	45.7 (137)	17.0 (51)
High biomass (good animal feed)	9.0 (6)	31.0 (93)	35.7 (107)	37.3 (38)	37.7 (113)	21.0 (63)
Consumption						
Tasty *ugali*	19.4 (13)	33.7 (101)	47.0 (141)	61.8 (63)	35.0 (105)	28.0 (84)
Tasty green maize	16.4 (11)	16.7 (50)	46.0 (138)	65.7 (67)	33.3 (100)	28.0 (84)
Time/duration						
Early maturity	16.4 (11)	39.0 (117)	41.0 (123)	62.7 (64)	33.7 (101)	19.0 (57)
Biotic stress						
Disperse *Striga*	70.1 (47)	11.0 (33)	1.0 (3)	89.2 (91)	5.0 (15)	0.7 (2)
Resistance to biotic stress (weed, pests, diseases)	64.2 (43)	31.3 (94)	6.0 (18)	76.5 (78)	34.7 (104)	0.3 (1)
Abiotic stress						
Resistance to abiotic stress (wind, cold, drought)	10.4 (7)	41.0 (123)	28.0 (84)	43.1 (44)	35.3 (106)	12.0 (36)
Management-related criteria						
High labour requirement	29.9 (20)	41.0 (123)	1.0 (3)	48.0 (49)	20.7 (62)	2.3 (7)
High input	79.1 (53)	38.3 (115)	0.3 (1)	73.5 (75)	29.0 (87)	0.7 (2)
Careful/complex farm management	89.6 (60)	36.7 (110)	0.3 (1)	89.2 (91)	28.7 (86)	0.0 (0)
High management cost	65.7 (44)	36.7 (110)	0.7 (2)	65.7 (67)	28.7 (86)	1.7 (5)
Sale (Dry grain)						
Easy to sell (colour-attractiveness)	6.0 (4)	55.3 (166)	26.3 (79)	16.7 (17)	51.3 (154)	22.7 (68)
High market returns (weight)	52.2 (35)	46.7 (140)	24.7 (74)	26.5 (27)	49.0 (147)	21.7 (65)
Storage						
Less susceptible to storage pests (rats, weevils, etc)	41.8 (28)	17.0 (51)	46.3 (139)	44.1 (45)	17.0 (51)	39.3 (118)
Requires no/less post-harvest dusting	43.3 (29)	10.0 (30)	48.3 (145)	48.0 (49)	18.7 (56)	42.7 (128)

Figures in brackets indicate the number of respondents

IRM's Trials and demonstrations created good perceptions in farmers as illustrated these results, building a good basic preface for IRM adoption.

Appendix 2: Variability of gross margins across different maize enterprises, values in Ksh, 2007/08

Item	Average price per unit in ksh	Maize farming system typical for		
		Local maize (N=291)	IRM (N=169)	Hybrid maize (N=312)
Farm/plot size (ha)		0.36	0.23	0.41
Maize price (Ksh/kg)		20.00	20.00	20.00
Yield (kg/ha)		1,424.71	2,777.75	2,462.02
Gross revenue (Ksh/ha)		**28,494.16**	**55,555.03**	**49,240.38**
Operational costs:				
Land rent (Ksh/ha)	4,117/ha	-	646.37	582.26
Seeds (Ksh/ha)	L:50, IR:160, H:130	547.85	852.54	1,455.83
DAP (Ksh/ha)	50/kg	885.78	730.77	1056.55
CAN (Ksh/ha)	40/kg	234.58	287.81	295.22
Manure (Ksh/ha)	10/kg	1,417.78	728.13	1,350.98
Pesticide (Ksh/ha)	170/lt	188.21	78.93	92.50
Oxen hiring charge (ksh/ha)	7,000/ha	6,240.00	3,323.48	3,657.50
Tractor hiring charge (Ksh/ha)	10,000/ha	-	8,550.00	8,100.00
Hired labour (Ksh/ha)	70/man-day	1,776.52	3,101.88	2,418.01
Total operational costs (Ksh/ha)		**1,928.30**	**3,801.94**	**4,196.01**
Gross margin (Ksh/ha)		**26,565.86**	**51,753.09**	**45,032.21**
Family labour (man-days/ha)		**108.47**	**122.32**	**138.11**

L: local maize, IR: IRM, H: hybrid maize

Appendix 3: Questionnaire used for survey

QUESTIONNAIRE ON ADOPTION AND IMPACT OF IMPROVED AGRICULTURAL TECHNOLOGIES IN DEVELOPING COUNTRIES: THE CASE OF IMAZAPYR-RESISTANT MAIZE FOR *STRIGA* CONTROL IN WESTERN KENYA

Type of farmer is: 1=Adopter [ ] 2 = Non-adopter [ ]

Were you involved in a Baseline Study? .... Yes=1 No=2
Were you involved in a Perception Study? ......Yes=1 No=2

I. GENERAL IDENTIFICATION VARIABLES (fill)

1. Name of the interviewer……………………………………………………………………….
2. Name of the respondent……………………………………………………………………….
3. Province……………………………………………………………….
4. District……………………………………………………………….
5. Division……………………………………………………………..
6. Sub-location………………………………………………………
7. Village……………………………………………………………….

II. HOUSEHOLD DEMOGRAPHIC CHARACTERISTICS

Household member	**ID code**	**Relationship to the household head** Head=**1** Spouse=**2** Son/Daughter=**3** Relative=**4** Un-related=**5**	**Age** (Years)	**Sex** Male=**1** Female=**2**	**Marital Status** Single=**1** married=**2** Widowed/Separated=**3**	**Education level** Pre-primary =**1** Primary =**2** Secondary= Tertiary =**4**	**Occupation** No occupation=**1** Crop farming=**2** Livestock keeping=**3** Mixed-farming=**4** Fishing=**5** Bee keeping=**6** Employed by government=**7** Employed by NGO=**8** Employed by private sector=**9** Self employed in partisan/business=**10**	**Association/group (codes)** Student=**1** Community development=**2** Cooperative=**3** Religious=**4** Credit &savings=**5** Men=**6** Women=**7** AIDS=**8** **Since when?**	**Current annual income** (Kshs)
	01								
	02								
	03								
	04								
	05								
	06								
	07								
	08								
	09								
	10								
	11								

III. HOUSEHOLD GENERAL FARMING ACTIVITIES

8. For what purpose do you produce maize?......... FOR HOME CONSUMPTION=1 FOR MARKET=2 FOR BOTH=3 OTHERS (SPECIFY)=4 ……………………………………

9. What types of crops did you cultivate last cropping season (fill the table below)? Give a conversion of the unit used in metric systems (e.g. 1 bag of maize = 90 kgs).

Crop	Size of land cultivated (ha)	Output (Kg)	Amount of crop sold (Kg)	Price per Unit (Kg)	Amount of crop consumed (Kg)	Amount of crop stored (Kg)

10. Who makes decisions in your household on the following? (Use table below)

Item	**Who makes decision** Father=1 Mother=2 Father and Mother=3 Son/Daughter=4	**Reason for making decision**
Crops grown		
Amount of produce to be sold		
Amount of produce to be consumed		
Amount of produce to be stored		
Distribution of income obtained from produce		
Purchase of household assets		
Food security coping mechanisms to be used		
Farm operation		
Sale of household assets		
Participation in non-farm activities		
New agricultural technology to be adopted		

11. What is the accessibility of the area of cultivation from the household location:………..
EASILY ACCESSIBLE=1 ACCESSIBLE=2 INACCESSIBLE=3

IV.MAIZE PRACTICES AND *STRIGA* CONTROL TECHNOLOGIES

12. What are the characteristics of good yield in maize stand? (Circle those that apply)

1. Large plant population
2. Leaf/foliage greenish
3. Stem thickness
4. Large cob size
5. Shorter time to tasseling
6. Other (specify) ……………………………………………………………………………………

13. Has your household ever abandoned maize production in any of maize plots? …. YES=1 NO=2

14. If Yes from 13 above, in which year and what was the main reason? (Use table and code)

Year	Reason for abandoning (use codes)
1.	
2.	
3.	
4.	

Codes for the reasons

1. *Striga* infestation
2. Low maize price
3. Higher input cost …………………
4. Maize market problem (specify) ………………………
5. Land shortage
6. Sickness
7. Others (specify)

15. Indicate the planting method for your maize production?

Practice	**Tick**	**Reasons for row planting (use the codes)**
Planting method 1. Row 2. Random	 …………… ……………	 ………… …………
Spacing between rows 3. Use recommended spacing 4. Use other spacing	 …………… ……………	 …………. ………….

Codes for reasons for row planting

1- Ease of field management
2- Increase yield
3- Other (specify) ………

16. Which maize cropping system did you choose and what is the reason for your choice? (Answer to the question using key)

Cropping pattern	Tick	Reasons (use codes)
1. Monocropping		
2. Intercropping with legumes		
3. Intercropping with non legumes		

Codes: 1.Saveslabor
3.Lessen risk of *Striga*
2.Land scarcity
4.Increases income

17. Where did you obtain the maize seeds which you planted during last season?
(Circle those that apply)

1. Ministry of Agriculture
2. Local NGO (name: ……………………………………………………..)
3. Neighbor/friend/relative
4. Other sources (mention) ………………………………………………

18. Are they certified seeds?........ YES=1 NO=2

19. Did you face problem with *Striga* weed? …… YES=1 NO=2

20. If Yes from 19 above, which control method did you use? (Circle those that apply)

1. Hand pulling
2. Hoe weeding
3. Crop rotation (mention): ……………………………………………………………………….
4. Trap and catch crops (specify)………………………………………………………………
5. Fertilizers (specify)……………………………………………………………………………….
6. IRM (*Ua* Kayongo)
7. Others (specify)………………………………………………………………………

21. Are you aware with the following *Striga* control technologies?

***Striga* control technology**	***Aware with the technology?*** Yes=**1** No=**2**	***If aware, current use status*** Currently using=**1** Abandoned=**2**	***Number of years since adoption****
Imazapyr (herbicide) Resistant (IR)-Maize variety (Ua Kayongo)			
Traditional practice (manuring, uprooting, burning)			

**** Applicable only for farmers who have already used the technology.***

22. If you are aware with any conventional *Striga* control technology, what was the source of information? If you are currently using any conventional *Striga* control technology, who gave/demonstrate the improved seed/management practice to you?

Conventional *Striga* control technology	**Source of information?** Farmers in the village=**1** Farmers in other villages=**2** Mass media (Radio, Newspapers)=**3** Extension agents=**4** Local NGOs=**5** International research institutes (CIMMYT, AATF, CIAT)=**6** National research institute (KARI)=**7** Others (specify)=**8** …………………	**Who gave/demonstrated seed/management practice?** Farmers in the village=**1** Farmers in other villages=**2** Extension agents=**3** Local NGOs=**4** International research institutes (CIMMYT, AATF, CIAT)=**5** National research institute (KARI)=**6** Others (specify)=**7** ………………
IR-Maize (Ua Kayongo)		
Striga-resistant maize (KSTP 94) grown with legumes		
Striga-resistant maize (WS 909) grown with legumes		
Intercropping of legumes followed by cassava/ Desmodium (Maize in the 3rd year)		
Push-Pull (Maize-Desmodium strip cropping)		

23. Have you adopted IR-Maize technology?...... Yes=1 No=2

24. If Yes from 23 above, why did you adopt it? (Circle those that apply)

1. High yield
2. Easy managed in the farm
3. Stable to weather changes
4. Good marketability
5. Others (specify) ………………………………………………………………………………

25. Since when (year), have you adopted IR-Maize technology?..................................

26. If No from 23 above, give the reasons for non-adoption by ranking them (Use table)

Reasons for non-adoption	**Tick**	**Rank (1=most to least important)**
Gathering more information about the technology		
Too risky to adopt		
Lack of IR-Maize seeds		
Traditional control practice is better		
Cash constraints to buy seeds and other inputs		
Others (specify)…………………………………………………………		

27. In case of non-adoption of IR-Maize, what is the likelihood of future adoption (Tick only one of the following Likelihood codes)

Likelihood of future adoption	**Tick**	**Give reasons for thinking never adopt it**
I will never adopt it		
Less likely		
Very likely		
Certainly		

28. Which of these field test instructions/guidelines of IR-Maize (*Ua Kayongo*) technology did you apply and those not applied and rank them according to its difficultly application

No	**Guidelines**	**APPLIED?** Yes=**1** No=**2**	**Reason for not applying** 1. Time consuming and laborious 2. Compromise with indigenous farming system 3. Has cost implications 4. Makes me dependent on external agents
1	Wash hands after planting IR-Maize (Ua Kayongo)		
2	Plant legumes & IR-Maize in different hole		
3	Mark an area of 20m*20m that was severely affected by *Striga* last season		
4	Broadcast the DAP and UREA across the soil surface and dig into the soil about 15cm		
5	No plant IR-Maize in the same hole with legumes		
6	Apply the CAN fertilizer following the second weeding		

29. Did you read and understood the IR-Maize (*Ua Kayongo*) field test instructions sheet provided before applying the technology? (circle only one answer)

1. Yes (read and understood)
2. Yes (read but could not understood)
3. No (did not read)

30. Mention source/type of training if you had any and who conducted the training?

Guidelines	**Type of training** Workshop=**1** Field Days=**2** Visit by an extension agent=**3** Public *Baraza*=**4** Others (specify)=**5**	**Who gave/demonstrated seed/management practice?** Extension officers=**1** Local NGOs =**2** International research institutes (CIMMYT, AATF, CIAT)=**3** National research institute (KARI)=**4** Others (specify)=**5**
Wash hands after planting IR-Maize (Ua Kayongo)		
Plant legumes & IR-Maize in different hole		
Mark an area of 20m*20m that was severely affected by *Striga* last season		
Broadcast the DAP and UREA across the soil surface and dig into the soil about 15cm		
Do not plant IR-Maize in the same hole with legumes		
Intercrop IR-Maize (Ua Kayongo) with other legumes		
Other (specify) ………………………		

31. How did you determine the area 20m X 20m trial plot for the IR-Maize technology?
(Circle one that apply)

1. Use tape measure
2. Use footsteps
3. Just guessed
4. An extension agent assisted me
5. Other means (mention) ………………………………………………………………

V. FARM RESOURCE ALLOCATION

32. Give the total land owned by your household…………………………………………..(hectares)

33. How many Kgs of farm inputs did you use during long rains 2008?

IR-Maize (*Ua Kayongo*) ………………………………..Kgs

Fertilizer ……………………..Kgs

34. Please provide the following information on land allocation to IR-Maize and inputs use during this long rains (2008)

Cropping systems	**Area (ha)**	**If intercropped with, name such of crop**	**Fertilizer (Kg applied)**				**Pesticide (Kg/Lt applied)**				**Seeds (Kg planted)**			
			DAP /UREA	**CAN**	**Manure**	**Others ……….. Type & quantity**	**Maize**	**Crop1**	**Crop2**	**Crop3**	**Maize**	**Crop1**	**Crop2**	Crop3
IR-Maize														
Local Maize														
Other Hybrid Maize														

35. Indicate source of land, cultural practice and method you apply?

Varieties of crops	**Local maize**	**IR-Maize**	**Other maize hybrid**
Plot ownership: OWN=**1** HIRED=**2**			
If hired, mention the plot area			
Hiring labour: YES=1 NO=2			
Using fallowing system: YES=**1** NO=**2** (If No, give reasons)			
Using crop rotation: YES=**1** NO=**2** (If No, give reasons)			
Use of fertilizer: YES=**1** NO=**2** (If No, give reasons)			
Land preparation methods HAND HOE=**1** TRACTOR=**2** OX-PLOUGH=**3**			
Land area			

36. Did you have land shortage for farming?....... YES=1, NO=2

37. If yes from 36 above, explain

	Tick
1. No more free land available……………………………………………………	
2. Land available is far away from this village (km)and walking time(hrs___Min.__)	
3. It is available in the village but expensive to buy…………………………………	
4. Others (specify)……………………………………………………………………	

38. If you hire labor, what was the reason? (Circle those that apply)

1. To meet time constraints
2. To inject skilled labour
3. To increase productivity
4. To ease work in the farm
5. Others (specify) ………………………………………………………

39. Indicate how much of the hired or family labor used in various operations for the type of maize you have grown last season?

Operation	**Type of labour**	**Local maize**					**IR-Maize**					**Other hybrid**				
			No. of people			**Man - Days**		**No. of people**			**Man - Days**		**No. of people**			**Man - Days**
			M	F	C			M	F	C			M	F	C	
Land Preparation	Hire															
	family															
Cultivation	Hire															
	family															
Planting	Hire															
	family															
Weeding	Hire															
	family															
Harvesting	Hire															
	family															
Transporting	Hire															
	family															
Marketing	Hire															
	family															
Total	Hire															
	family															

Note: M-Male F-Female C-Children

40. If you sold family labor during last season, please indicate wage rate per man-day? (Use table)

Type of work	Member involved (Use Id in the roster)	Type of labor sold			No. of days	Type of Payment	
		Casual	Seasonal	Permanent		In Cash (Amount)	In kind (Amount)

41. Indicate the distribution of family labor into your agricultural, non-agricultural and other activities in your household for the last season.

Type of labor	Wage rate /acre	Agricultural activities					Non-agricultural activities					Sales of labor				
			No. of people			No. of Days		No. of people			No. of Days		No of people			No. of Days
			M	F	C			M	F	C			M	F	C	
Hire																
family																

42. Are the following resources available for use by your household in your area? (Use table)

Source	Availability (use key)	Distance to the source (km)	Time of travel (minutes)
1.Drinking water			
2.Water for irrigation			
3.Grazing land for livestock			
4.Firewood			
5.Grain mill			
6.Health centres			
7.Schools			
8.Worship places			

Key on availability of resources

1.Readily available
2.Is in short supply
3.Not available

VI. MIGRATION

43. Are you born in this village?....... YES=1, NO=2

44. If No from 43 above, which year did you migrate into this village?…………(year) **and from where?**………(name of place)

45. How did you get land?

	Tick
1. Cleared new land (bush/forest)……………………………………………….…………………	
2. Bought (ha)………..(at /ha)……………………………………………………	
3. Given by a friend/relative………………………………………………………….	
4. Obtained free of charge (abandoned land)…………………………………………	
5. Inherited……………………………………………………………………...............	
6. Allocation by village government (paid fee was ……………) ……………..........	
7. Renting in at…………………………………………………………………	
8. Villagisation programs……………………………………………………….	
9. Others (specify)………………………………………………………………	

46. What is the major reason for migrating in? (select from the list below)

	Tick
1. Depleted soil …………………………………………………………………………………	
2. Search for areas supposed to be without *Striga*………………………………………	
3. W………………………………………………………………………………………	
4. Coming closer to town services e.g. hospital……………………………………………..	
5. Search for employment…………………………………………………………………	
6. Villagisation program……………………………………………………………………..	
7. Followed other relatives…………………………………………………………………..	
8. Others (specify) ……………………………………………………………………….	

VII. IR-MAIZE PRODUCTIVITY & FARM MANAGEMENT PRACTICES

47. What was the yield you obtained in the last three (3) years?

Year	**Local maize**	**IR-Maize**	**Other maize hybrid**
2005/2006			
2006/2007			
2007/2008			

48. Out of the maize varieties you are using/you have used, indicate the advantage of each against others by giving your impression in Table below (tick one only across the row)

Concern	**Attributes**	**IR-Maize**	**Hybrid varieties**	**Local varieties**
Yield	High yield			
	High biomass (good animal feed)			
Consumption	Tasty-ugali			
	Tasty-green maize			
Time/duration	Early maturity			
Biotic stress	Disperse *Striga*			
	Resistance to biotic stress (weed, pests, diseases)			
Abiotic stress	Resistance to abiotic stress (wind, cold, drought, lodging)			
Management	High labour requirement			
	High input			
	Careful/complex farm management			
	High management cost			
Sale (Dry grain)	Easy to sell (colour-attractiveness)			
	High market returns (weight)			
Storage	Less susceptible to storage pests (rats, weevils, etc)			
	Requires no/less post-harvest dusting			

49. What are according to you the most important constraints in applying IR-Maize technology? Rank those applicable only

Constraints	**Rank (the first three starting with the most important reason)**
1. IR-Maize kit not available	
2. Very small amount of IR-Maize supplied	
3. Difficult to follow IR-Maize kit conditions/guidelines	
4. Prefer the traditional methods in controlling *Striga*	
5. IR-Maize seeds are expensive	
6. Weather (e.g. rainfall unreliability, cold, drought-abiotic stress)	
7. Farm size	
8. Land availability	
9. Lodging	
10. Weeds, Pests and diseases (biotic)	
11. Others (mention)………………………………………………	

50. How many times do you normally weed your maize field before maturity?......
ONCE=1 TWICE=2 THRICE=3

51. How many times do you weed after introduction of IR-Maize technology?.......
ONCE=1 TWICE=2 THRICE=3 MORE=4

52. Does IR-Maize production improve income level to your household?....... YES=1 NO=2

VIII. INCOME AND COSTS - ASSETS

53. If land was hired how much did you pay last cropping season?________________ha/plot

54. Please provide the amount of income obtained from the following crop and non-crop income sources during the last 3 years (Use tables below)

54a. *Crop income sources*

Category	**Acreage and Amount (Kshs)**					
	2005/2006		**2006/2007**		**2007/2008**	
	ha	Amount	ha	Amount	ha	Amount
Local maize						
IR-Maize						
Other hybrid maize (specify)						
i.						
ii.						
iii.						
Other crops (specify)						
i.						
ii.						
iii.						

54b. ***Non-crop income sources***

Non-crop income sources	Amount (Kshs)		
	2005/2006	**2006/2007**	**2007/2008**
Livestock			
Beekeeping			
Fishing			
Charcoal making			
Petty trade			
Weaving/pottery			
Blacksmith (e.g. bicycle repair etc)			
Labour selling (casual)			
Formal employment			
Remittances from relatives			
Credit (formal and informal)			
Others (specify)……………………………………			

55. Give production distribution for maize and other crops productions

Production	**Local maize**		**IR-Maize**		**Other maize hybrid**		**Other crop:…………………**	
	First season	Second season	First season	Second season	First season	Second season	First season	Second season
Amount consumed								
Amount sold								
Amount given to relatives								
Amount stored								

56. Give number for each of the following items by your farm and household you own

Items owned by household (Please tick in front of items you got after adopting IR-Maize if any)	**Since when?**	**Number of items**	**Initial price/unit**	**Useful life**	**Salvage value**
1.Axe					
2.Bicycles					
3.Bowl					
4.Bucket					
5.Bush knife					
6.Chair					
7.Charcoal stove					
8.Cooking pot					
9.Hand hoe					
10.House built with cement/burnt bricks					
11.Hurricane lamp					
12.Iron sheet houses					
13.Kerosene stove					
14.Motorbike					
15.Ox cart					
16.Ox plough					
17.Panga					
18.Radio					
19.Rooms under cement floors					
20.Sewing machine					
21.Spade					
22.Spongy mattress					
23.Table					
24.Torch					
25.Watch/ clock					
26.Water container (jerrican)					
27.Wheel barrow					

57. Did you borrow money in the last five years? ……… YES=1 NO=2

58. If yes from 58 above, please fill the Table below.

Source	**Year borrowed**	**Amount borrowed**	**Reasons for borrowing**	**Interest rate**

59. Have you completed repaying back your loan?....... YES=1 NO=2

60. If No from 60 above, why? ………………………………………………………………

61. Do you keep livestock?....... YES=1 No=2

62. If yes from 62 above, please fill the following table

Type of livestock	Number		Animals sold (only for those who sold)	Price/animal	Value (Kshs)
	local	improved			
Cattle					
Poultry					
Pig					
Goat					
Sheep					
Others (Specify)					

63. Indicate number, breed and management for the various livestock types in your farm over the year 2008

Type	No. kept		Management system	Key for management system
	Before IR-Maize	After IR-Maize		
Cattle - Local				
1. Improved				
2. Oxen				1= zero grazing
Goats				2= semi grazing
Sheep				3= open grazing
Pigs				
Donkeys				
Chicken				
Ducks				
Others (specify)				

64. Is there any other income obtained from livestock enterprises?........ Yes=1 No=2

65. If yes from 65 above, please fill the table below

Livestock/Product type	Unit	Home consumption	Amount sold	Price per unit
1.Oxen Acres tilled	Acres/year			
Load transport	Kg/year			
2.Livestock				
Cattle				
Sheep				
Goats				
3.Others (specify)				

IX. FOOD UTILIZATION AND SECURITY

66. Please indicate the nature/type of the following meals per day in your household

Type of meal	Nature/type of meal
Breakfast	
Lunch	
Dinner	

67. Did you know exactly what amount of crop produced to be stored that will meet the household food requirement throughout the year? ……… YES=1 NO=2

68. If Yes from 68 above, what factors/indicators determine the amount of your food staple to be stored? (Circle those that apply)

1. Level of production
2. Food requirement of the household
3. Family size
4. Preference and taste
5. Capacity of the storage facilities
6. Availability of the other alternative foods
7. Others (specify) …………………………………………………………

69. What factors determine the amount of produce to be sold? (Circle those that apply)

1. Household cash needs
2. Good prices
3. Level of production
4. Storage facilities available
5. Others (specify)……………… ……………………………………………

70. How much was planned for the following purposes:

Purpose	Crops (Use codes)	Amount Planned (kgs)
Selling		
Consumption		
Presents/remittances		
Loans/debt repayment		
Brewing		
Seeds		
Ceremonial parties		
Stored for the future		
Others (specify) …………………		

Codes for crops
1=Maize
2=Beans
3=Sorghum
4=Potatoes
5=Banana
6=Kales
7=Cowpeas
8=Others (specify) …

71. Last season when did you start consuming the stored food?... Immediately after harvest=1
Three months=2 More than 3 months=3 Nothing stored=4

72. In your opinion what was/were the major cause(s) of the food shortage? (Please rank only those that apply)

Cause	**Rank:** 1=Major cause, 2=2nd major cause,	**Suggest solutions**
Striga infestation		
Drought affect crop and livestock		
Pest infestation to crop		
Low soil fertility		
Land shortage		
Labour shortage		
Conflict		
Flooding		
Others (specify)……………		

73. Indicate months in a year in which your household food stores run out of food
(from)……………………………..(to)………………………

74. After running short of own food, indicate the strategies used by your household to ensure adequate food during seasonal hunger period by ranking?

Strategy for solving seasonal hunger problems	Rank the strategy 1 = most important
1.Use own savings	
2.Sell local brew	
3.Grow horticultural crops	
4.Sell livestock	
5.Get one meal per day	
6.Honey collection	
7.Remittances from relatives	
8.Petty business	
9.Fishing	
10.Others (specify) ………………………………	

75. Have you notice any change in daily frequency of maize meals intake since you adopt (or did not adopt) IRM? …… Yes=1 No=2

76. If Yes, which changes? ………

1.From 3 to2 6.From 1 to 2
2.From 3 to 1 7.From 1 to 3
3.From 2 to 1 8.From 2 to 3

X. COMMUNICATION MEDIA FACILITY AND COMMENTS ON TECHNOLOGY ADOPTION

77. In the past 3-5 years of experiences, do you have access to any kind of mass media? ...... YES=1 NO=2

78. If Yes from 77 above, which mass media was more accessible to you?....... Radio=1 Newspaper=2 Others (specify)……………………………………………………………..

79. In your opinion, did these media help you in learning about IR-Maize practices and adoption of the available technology?....... YES=1 NO=2

80. Are there any local beliefs that interfere with adoption of IR-Maize?....... YES=1 NO=2

81. If Yes from 80 above, mention them

1. ……………………………………………………………………………………………………
2. …………………………………………………………………………………………………….
3. ……………………………………………………………………………………………….

82. Did you receive a visit from an extension agent (FEW, NGO, Private Vets)……. (YES=1; NO=2) **Or participated in field days/tours/shows/seminars …….** (YES=1; NO=2) **on improved agricultural technologies during last 5years?**

XI. OVERALL PERFORMANCE (for adopters)

83. Is IR-Maize technology appropriate to you?...... YES=1 NO=2

84. At which level?...... HIGH=1 MODERATE=2 LOW=3

85. Is IR-Maize technology simple for using?........ YES=1 NO=2

86. If No from 85 above, why?

(1) ……………………………………………………………………………………………
(2) ……………………………………………………………………………………………

87. What is the level of your involvement in the implementation of IR-Maize technology (Use ranking guide)?........ HIGH=1 MODERATE=2 LOW=3

88. Are you comfortable with input price to achieve expected output?........ YES=1 NO=2

89. What was your level of satisfaction (Use ranking guide)?......HIGH=1 MODERATE=2 LOW=3

90. Are the mechanisms for IR-Maize dissemination adequate?....... YES=1 NO=2

91. Has IR-Maize technology impacted positively on you?........ YES=1 NO=2

92. If yes from 91 above, on which sector?
(1) Socio-economic….. (1) Environmental…. (3)Socioeconomic and environmental…….(4) Others: specify…………………………………………………………

93. Do you intend using IR-Maize technology continuously in the future?....... YES=1 NO=2

94. If yes from 93 above, will it be in wholly or in combination with other varieties?...... Yes=1 No=2

95. Do you have any comment to improve adoption of IR-Maize technology?

………

……

Appendix 4: Guide questions Used for Informants

Type of informant is: …………………………………..

Are you involved in IRM technology project? .... Yes=1, No=2
Are you using IRM technology? .... Yes=1, No=2

I. GENERAL IDENTIFICATION VARIABLES (fill)

1. Name of the respondent……………………………………………….
2. Gender of the respondent ……………………………………………..
3. Province……………………………………………………………….
4. District………………………………………………………………
5. Division……………………………………………………………..
6. Sub-location………………………………………………………...
7. Village………………………………………………………………

II. SERIES OF GUIDE QUESTIONS

1. Story of IRM technology
2. Perceived benefits of IRM variety at various levels
3. Perceived inconvenients of IRM variety
4. IRM diffusion mechanisms
5. Adoption of IRM variety
6. Reasons of non-adoption of IRM
7. Personal opinion for the success of IRM adoption
8. Recommendations and conclusions

Appendix 5: National Maize Variety List from KEPHIS, Kenya

AHP: African Highlands Produce Company
EABL: East African Breweries Limited
EAC: East African Community
GLS: Grey leaf spot
GWK: George Williamson Kenya
ICIPE: International Centre for Insect Physiology and Ecology
KARI: Kenya Agricultural Research Institute
KESREF: Kenya Sugar Research Foundation
KSC: Kenya Seed Company
Masl: Meters above sea level
MSV: Maize streak virus
ND: Data not available
OCD: Oil Crop Development Company
PBK: Pyrethrum Board of Kenya
SASA: South African Sugar Authority
SBI: Sugar Board of India
TRFK: Tea Research Foundation of Kenya

Species: *Zea mays* L.

Variety name/code	Year of release	Owner(s)	Maintainer and source	Optimal production altitude range (Masl)	Duration to maturity (months)	Grain yield (t. ha^{-1}	Special attributes
1.H632	1964	KARI/Kenya Seed Co.	KARI/Kenya Seed Co.	1200-1700	5-7	6-8	Large kernels Dent
2.H622	1965	Kenya Seed Co/KARI	Kenya Seed Co/KARI	1200-1700	5-7	6-8	Large kernels Dent
3.H511	1967	Kenya Seed Co/KARI	Kenya Seed Co/KARI	1000-1500	4-5	4-6	Medium maturity
4.KAT CB	1967	Kenya Seed Co/KARI	Kenya Seed Co/KARI	900-1350	3-4	3-5	Early maturing
5.H512	1970	Kenya Seed Co/KARI	Kenya Seed Co/KARI	1200-1600	4-5	5-7	Large kernels
6.CCM	1974	Kenya Seed Co/KARI	Kenya Seed Co. Ltd	1-1200	4-5	5-7	Heat tolerant
7.H625	1981	KARI/Kenya Seed Co.	Kenya Seed Co/KARI	1500-2100	6-8	8-10	Prolific Good husk cover
8.H614D	1986	Kenya Seed Co/KARI	Kenya Seed Co. Ltd/KARI	1500-2100	6-9	8-10	Stable over locations and seasons Semi flint
9.H611D	1986	KARI/Kenya Seed Co	KARI/Kenya Seed Co	1700-2400	6-9	7.8	Frost tolerant
10.H612D	1986	KARI/Kenya Seed Co	KARI/Kenya Seed Co	1500-2100	6-8	7.8	Semi flint
11.H613D	1986	KARI/Kenya Seed Co	KARI/Kenya Seed Co	1500-2100	6-8	8-10	Semi Flint
12.H626	1989	Kenya Seed Co/KARI	Kenya Seed Co/KARI	1500-2100	6-8	8-10	Flint
13.PH1 (Pwani Hybrid)	1989	Kenya Seed Co	Kenya Seed Co	1-12000	3-4	5-7	Tolerant to lodging/strong stalks Drought tolerant
14.DLC1	1989	Kenya Seed Co/KARI	Kenya Seed Co/KARI	800-1200	2-3	2-4	Flint Very early
15.PAN 5195	1995	Pannar	Pannar Seeds (K)	1000-1800	4-5	5-6.3	Prolific Tolerant to maize streak virus
16.H627	1995	KSC/KARI	KSC/KARI	1500-2100	6-8	9-12	Semi-flint
17.PH 4	1995	Kenya Seed Co	Kenya Seed Co	1-1200	3-5	6-8	Heat tolerant, Good standability, Partial MSV resistance
18.DH01	1995	Kenya Seed Co	Kenya Seed Co	900-1400	3-4	4-6	Early, stays green
19.H513	1995	Kenya Seed Co	Kenya Seed Co	1200-1600	4-5	6-8	Good standability
20.DH02	1995	Kenya Seed Co	Kenya Seed Co	900-1400	3-4	4-6	Early, stays green
21.PHB 3253	1996	Pioneer Hybrid	Pioneer Hybrid, Zimbabwe	800-1800	4-5	7-9	Wide adaptation Good standability
22.H623	1999	Kenya Seed Co	Kenya Seed	1200-1700	5-7	7-9	Prolific, large

			Co				dent kernels
23.H628	1999	Kenya Seed Co	Kenya Seed Co	1500-2100	6-8	9-12	Flint
24.KH600-11D	2000	KARI	KARI	1500-1800	6-9	7-8	Good standability Stable performance
25.KSTP 94	2000	KARI	KARI	1350-1800	4-4	4-6	Tolerant to *Striga*
26.CG4141	2000	Monsanto	Monsanto (K)	900-1700	4-5	4-7	Earliness Fast dry down
27.H629	2000	Kenya Seed Co	Kenya Seed Co	1500-2100	6-8	9-11	Semi dent
28.DH03	2000	Kenya Seed Co	Kenya Seed Co	900-1500	3-4	5-6	Stays green Good standability
29.C5051	2000	Monsanto	Monsanto	1000-1800	4-5	5-8	Moderately tolerant to maize streak virus Easy to shell
30.PAN 5355	2000	Pannar Seed	Pannar Seed (K) Ltd	1000-1800	4-5	5-5.9	Moderate MSV resistance
31.H515	2000	Kenya Seed Co	Kenya Seed Co	1200-1500	4-5	6-8	Lodge resistant
32.H6211	2001	Kenya Seed Co	Kenya Seed Co	1500-2100	6-8	9-14	Early, Short Semi flint
33.H6212	2001	Kenya Seed Co	Kenya Seed Co	1500-2100	6-8	10-15	Short, semi flint Resistance to ear rot
34.FS650	2001	OCD (Faida Seeds)	OCD (Faida Seeds)	1500-2200	5-7	8-9	Tolerant to maize streak virus Good yielder Flint kernels
35.KH634 A	2001	KARI	KARI-Kakamega	1400-1800	3-5	5-6	Resistance to blight, Grey leaf spot
36.KH600-15A	2001	KARI	KARI-Kitale	1800-2500	6-8	7-8	Good stand ability
37.KH600-16A	2001	KARI-Kitale	KARI-Kitale	1800-2500	6-8	7-8	Stable Good standability
38.PAN 99	2001	Pannar Seed Co.	Pannar Seed (K)	1000-2000	5-6	7-8	Grey leaf spot tolerant Drought tolerant
39.PAN 5243	2001	Pannar Seed Company (S.A)	Pannar Seed (K) Ltd	800-1800	4-5	7-8	Tolerant to grey leaf spot and northern leaf blight Prolific
40.PAN 67	2001	Pannar Seed Company (S.A)	Pannar Seed (K) Ltd	800-1600	4-5	5-6	Resistant to maize streak virus Tolerant to low soil nitrogen
41.H516	2001	Kenya Seed Co.	Kenya Seed Co.	1200-1500	4-5	7-9	Resistant to blight, rust and lodging
42.DH04	2001	Kenya Seed Co.	Kenya Seed Co.	900-1500	3-4	5-6	Short stature

43.DH05	2001	Kenya Seed Co.	Kenya Seed Co.	900-1500	3-4	5-7	High yielding and early maturing
44.PAN 691	2001	Pannar Seed Ltd	Pannar Seed (K) Ltd	1700-2400	6-9	7-8	Grey leaf spot tolerant Good standability Low ear placement
45.Maseno Double Cobber	2002	Lagrotech Seed Co.	Lagrotech Seed Co.	1000-1600	3-4	4-6.8	Prolific-frequency of 30-80%) Flint kernels
46.PHB30 H83	2002	Pioneer Hibred Zimbabwe	Pioneer Hibred Zimbabwe	1000-2000	5-6	8-11	Grey leaf spot tolerant Ear rot resistance
47.H6213	2002	Kenya Seed Co.	Kenya Seed Co.	1600-2200	6-8	10-15	High yield Drought tolerant
48.WH 699	2002	Western Seed Company	Western Seed Company	1700-2200	6-8	7-9	Tolerant to smut
49.WH 904	2002	Western Seed Company	Western Seed Company	1000-1700	5-6	6-9	Tolerant to streak virus
50.WS 909	2002	Western Seed Company	Western Seed Company	0-1500	4-5	6-9	Tolerant to *Striga*
51.PAN 683	2003	Pannar Seed Company	Pannar Seed Company	2000	6-7	6-9	Late maturity Excellent standability Excellent tip cover Resistance to grey leaf spot
52.PAN 33	2003	Pannar Seed Company	Pannar Seed Company	800-1800	5-6	5.3	High yielding
53.WH501	2003	Western Seed Company	Western Seed Company	1300-1700	5-6	7-9	Suitable for low input production Tolerant to grey leaf spot, maize streak virus and northern leaf blight
54.WH 502	2003	Western Seed Company	Western Seed Company	1000-1700	4-5	6-9	Very tolerant to maize streak virus Tolerant to grey leaf spot, northern leaf blight, *Striga*, drought and low soil nitrogen tolerant
55.WH 504	2003	Western Seed Company	Western Seed Company	1000-2000	4.5-5.5	6-9	Tolerant to maize streak virus, grey leaf spot and northern leaf blight Green stems at harvest suitable for animal fodder Tolerant to drought and low

							soil nitrogen
56.WH 505	2003	Western Seed Company	Western Seed Company	500-2100	4.5-5.5	6-9	Tolerant to maize streak virus, grey leaf spot and northern leaf blight Green stems at harvest suitable for animal fodder Tolerant to low soil nitrogen
57.WH 509	2003	Western Seed Company	Western Seed Company	1000-1700	5-6	6-9	Tolerant to maize streak virus, grey leaf spot and northern leaf blight Tolerant to drought
58.WH 403	2003	Western Seed Company	Western Seed Company	1000-1500	4.5	5-8	Tolerant to leaf diseases Green stems at harvest suitable for animal fodder
59.WS 102	2003	Western Seed Company	Western Seed Company	0-1200	3-3.8	2-3	Tolerant to maize streak virus, drought and low soil nitrogen
60.WS 103	2003	Western Seed Company	Western Seed Company	0-1500	3-4	3-4	Tolerant to maize streak virus, grey leaf spot, northern blight, drought and low soil nitrogen
61.H6213	2002	Western Seed Company	Western Seed Company	1600-2200	6-8	9-14.5	Semi flint
62.H518	2002	Western Seed Company	Western Seed Company	1400-1700	4-5	7-9	Resistant to GLS, Rust, Blight
63.KH 600-17A	2002	KARI	KARI	1600-2300	5-6	7-11	Good standability
64.KH 600-18A	2002	KARI	KARI	1600-2300	5-6	8-12	Good disease tolerance
65.H519	2003	Western Seed Company	Western Seed Company	1200-1700	4-5	6.5	Prolific Resistance to ear rots, rust, grey leaf spot, northern leaf blight, stem and root lodging compared to H513; semi dent
66.H520	2003	Western Seed Company	Western Seed Company	1400-1700	4-5	4.5	Better resistance to northern blight, rust, ear rot, stem and root lodging

							Semi flint. Good husk cover
67.H521	2003	Western Seed Company	Western Seed Company	1000-1600	4-5.3	4.5	More tolerant to grey leaf spot, leaf blight, root and stalk lodging than H513; semi dent
68.H522	2003	Western Seed Company	Western Seed Company	1200-1600	4-5	6.3	Tolerant to grey leaf spot. Resistant to ear rot, root and stalk lodging; semi dent
69.H523	2003	Western Seed Company	Western Seed Company	1200-1600	4-5	6.6	Better yielding than H623; Tolerant to grey leaf spot Resistant to root and stalk lodging; semi dent
70.DH 8	2003	Western Seed Company	Western Seed Company	900-1500	3-4	4.9	Good performance in low yielding environments Resistant to stalk lodging and ear rots, semi dent
71.KSH6214	2004	Western Seed Company	Western Seed Company	1600-2100	6-7	9-12	Tolerant to GLS, leaf blight Lodging resistant Early maturing
72.KSH624	2004	Western Seed Company	Western Seed Company	1500-1800	5-6	8-11	Tolerance to GLS, leaf blight, rust High yielding
73.DH 10	2004	Western Seed Company	Western Seed Company	800-1400	3-4	5-6	Resistant to rust, ear rot and lodging, good husk cover, short stature
74.DH 09	2004	Western Seed Company	Western Seed Company	1000-1500	3-4	3-5	Resistant to root and stalk lodging, good husk cover, high yielding
75.PAN 15	2004	Pannar Seed Company	Pannar Seed Company	800-1800	4-5	4-6	Resistant to blight, rust, MSV, GLS Good husk cover and standability
76.SC Duma 41	2004	AgriSeedCo Ltd	SEEDCO Zambia	800-1800	4-5	6-7	Resistant to ear rot, rust, MSV, mottle virus, drought Early

							maturity
77.SC Duma 43	2004	AgriSeedCo Ltd	SEEDCO Zambia	800-1800	4-5	6-7	Resistant to ear rot, rust, MSV, drought Early maturity
78.FICA 4	2004	FICA seeds	FICA seeds	800-1800	4-5	6-7	Resistant to rust, MSV, GLS, blight, good husk cover, drought, *Striga* tolerant
79.DKC 80-53	2004	Monsanto (K) Ltd	Monsanto (K) Ltd	900-1700	4-5	5-8	Tolerant to GLS, MSV, Good standability, wide adaptability, prolific
80.DKC 80-73	2004	Monsanto (K) Ltd	Monsanto (K) Ltd	1500-1700	5-6	7-10	Tolerant to GLS, MSVt, Diplodia Good husk cover
81.DKC 80-33	2004	Monsanto (K) Ltd	Monsanto (K) Ltd	900-1700	5-6	6-8	Resistant to GLS, good standability
82.WS 202	2004	Western Seed Company	Western Seed Company	0-1500	3-4	3-5	Resistant to MSV, drought, low soil nitrogen
83.KH500-21A	2004	KARI	KARI Muguga	1600-2000	5-6	7-8	Good standability, husk cover, Resistant to MSV, head smut, Early maturing
84.KH500-31A	2004	KARI	KARI Muguga	1800-2100	6-7	6-7	Resistant to rust, MSV, blight Stays green (for fodder)
85.KH500-32A	2004	KARI	KARI Muguga	1300-1800	5-6	6-8	Resistant to blight, rust, MSV
86.KH500-33A	2004	KARI	KARI Muguga	1400-1800	5-6	7	Resistant to blight
87.KH500-34A	2004	KARI	KARI Muguga	1300-1800	5-6	6-8	Early maturing Resistant to rust, MSV, blight
88.KK SYN-1	2004	KARI	KARI	1500-1800	3-4	4-5	Wide adaptability Responsive to low input environment, Resistant to MSV
89.KK SYN-2	2004	KARI	KARI	1500-1800	3-4	5-6	Wide adaptability Responsive to low input

							environment, Resistant to MSV
90.KH 631Q	2004	KARI	KARI	1000-1500	4-5	5-7	Quality protein maize good husk cover, resistant to GLS, ear rot, rust, blight
91.EMB 204	2004	KARI	KARI	1000-1500	5-6	7-8	Quality protein maize good husk cover, resistant to GLS, ear rot, rust, blight
92.PHB 30G97	2003	Pioneer Hibred Zimbabwe	Pioneer Hibred Zimbabwe	1200-2000	4-5	6-9	Resistant to grey leaf spot Resistant to ear rots Tolerant to maize streak virus Good grain quality Best for mid-altitudes
93.Lagrotech early	2003	Lagrotech Seed Company	Lagrotech Seed Company	Below 1500	2.7-3.5	2.3	Good ear cover Early maturing *Striga* tolerant Drought escaping
94.Simba 61	2003	AgriSeed Co Ltd	SEEDCO Zambia	1800	4.5	7-10	Tolerant to MSV and GLS
95.DK 8071	2003	Monsanto	Monsanto	1500-1700	5	6-9	Flint grain
96.DK 8031	2003	Monsanto	Monsanto	900-1700	4-4.7	6-8	GLS tolerant
97.PHB 30G19	2006	Pioneer Hi-Bred Seeds	Pioneer Hi-Bred Seeds	1000-1800	5-6	8-10	Resistant to grey leaf spot Low ear placement Good husk cover and standability Lodging resistant
98.PHB 30V53	2006	Pioneer Hi-Bred Seeds	Pioneer Hi-Bred Seeds	1200-2000	5-6	8-11	Resistant to grey leaf spot Tolerant to maize streak virus, low ear placement Good husk cover
99.KH600-20A	2005	KARI	KARI Kitale	1800-2300	5-6	8-9	Good standability Good resistance to blight
100.PAN 4M-21	2005	Pannar Seed (PTY) Ltd	Pannar Seed (PTY) Ltd	1000-1500	3-4	4-5	Drought tolerant Flint grain Good husk cover Double cobber
101.SC	2006	AgriSeed Co	SEEDCO	1800-1900	5-6	8-12	Good

Tembo 73		Ltd	Zambia				standability Tolerant to grey leaf spot Tolerant to maize streak virus
102.SC Punda Milia 53	2005	AgriSeed Co Ltd	SEEDCO Zambia	1800-1900	5-6	8-13	Good standability Tolerant to grey leaf spot Tolerant to maize streak virus
103.SC Simba 63	2005	AgriSeed Co Ltd	SEEDCO Zambia	1200-1800	4-5	5-10	Drought tolerant, tolerant to grey leaf spot, MSV, blight and ear rot
104.DH 06	2007	Kenya Seed Co.	Kenya Seed Co.	900-1500	3-4	4-6.5	Good standability, good husk cover
105.DH 12	2007	Kenya Seed Co.	Kenya Seed Co.	900-1400	3-4	4-6	Tolerant to blight and rust, resistant to stalk lodge
106.Ua Kayongo 1	2004	KARI	Western Seed	1200-1600	4-5	4	Resistant to *Striga*
107.Ua Kayongo 2	2007	KARI	KARI Embu	1000-1500	4-5	4.2	Tolerant to herbicide for *Striga* control, GLS and MSV, drought tolerant, good ear placement
108.Ua Kayongo 3	2007	KARI	KARI Embu	1000-1500	4-5	4.3	Tolerant to herbicide for *Striga* control, GLS and MSV, root and stalk lodging
109.EV042 71	2007	KARI	KARI	1500-2100	4-5	4.5	Resistant to rust, good standability
110.PH 5	2007	Kenya Seed Co.	Kenya Seed Co.	0-1250	4-5	6-8	Resistant to lodging, Ear rot and rust, Good husk cover, Good standability
111.PAN 4M-19	2008	Pannar Seed (PTY) Ltd	Pannar Seed Co	900-1500	3-4	4-6	Flint, Drought tolerant, prolific, early maturing, fast dry down, good standability
112.PAN 4M-17	2008	Pannar Seed (PTY) Ltd	Pannar Seed Co	900-1500	3-4	4-6	Flint, Drought tolerant, early maturing

113.PAN 69	2008	Pannar Seed (PTY) Ltd	Pannar Seed Co	1200-1700	4-5	7-10	High yielding, wide adaptability, good standability, tolerant to leaf diseases
114.PAN 57	2008	Pannar Seed (PTY) Ltd	Pannar Seed Co	1200-1700	4-5	6-8	Flint, tolerant to leaf diseases
115.PAN 7M-97	2008	Pannar Seed (PTY) Ltd	Pannar Seed Co	1400-1700	4-5	7-10	High yielding, good standability, prolific
116.PAN 8M-91	2008	Pannar Seed (PTY) Ltd	Pannar Seed Co	1400-2000	5-6	8-10	Excellent GLS and rust tolerance, good for silage, prolific
117.PAN 7M-89	2008	Pannar Seed (PTY) Ltd	Pannar Seed Co	1400-2000	5-6	8-10	High yielding, tolerant to leaf diseases
118.KH500 -35E	2008	KARI	KARI	1200-1600	4-5	7	Resistant GLS, MSV, rust & blight, Stay green, good stalk for animal feed
119.KH500 -36E	2008	KARI	KARI	1200-1800	4-5	7	Resistant MSV, rust & blight Flint
120.KH500 -37E	2008	KARI	KARI	1200-1800	4-5	8	Resistant MSV, rust & blight
121.KH500 -39E	2008	KARI	KARI	1200-1800	4-5	8-9	Resistant GLS & blight
122.KEMB U 214	2008	KARI	KARI	1200-1600	4-5	7	Tolerant to stem borers
123.KH500 -40E	2008	KARI	KARI	1200-1800	4-5	7	Resistant to insect, tolerant to drought and low N
124.KH500 -44A	2008	KARI	KARI	1500-2100	4-5	6.95	Tolerant to MSV, Early
125.KH500 -22A	2008	KARI	KARI	1200-2100	4-5	6.9	Tolerant to MSV, Early
126.KH500 -43A	2008	KARI	KARI	1200-2100	5-6	6.5	Tolerant to MSV, Double cobber, high foliage (dual purpose)
127.KK BS-04	2008	KARI	KARI	All *Striga* infested regions	4-5	5-5.5	Tolerant to *Striga*, drought & low N, Resistant to rust & GLS, Good standability
128.KDH4 SBR	2008	KARI	KARI			5.15	Resistant to stem borers. Tolerant to

							drought & low N
129.KDH5 SBR	2008	KARI	KARI			4.77	Resistant to stem borers. Tolerant to drought & low N
130.KDH6 SBR	2008	KARI	KARI			5.06	Resistant to stem borers. Tolerant to drought & low N
131.KDH4 14-01 SBR	2008	KARI	KARI			5.15	Resistant to stem borers. Tolerant to drought & low N
132.KDH4 14-02 SBR	2008	KARI	KARI			4.77	Resistant to stem borers. Tolerant to drought & low N
133.KDH4 14-03 SBR	2008	KARI	KARI			5.06	Resistant to stem borers. Tolerant to drought & low N
134.KH600 -23A	2008	KARI	KARI	1800-2500	5-6	8.6-14.8	Resistant to GLS, rust & blight, Less lodging
135.KH600 -24A	2008	KARI	KARI	1800-2500	5-6	8.6-14.8	Resistant to GLS, rust & blight, Less lodging
136.KS-DH14	2008	Kenya Seed Co.	Kenya Seed Co.	800-1300	3.5-4.5	5.0-6.5	Drought tolerant, lodging resistant, stays green
137.KS-H6216	2008	Kenya Seed Co.	Kenya Seed Co.	1500-2100	6-7	8.0-9.5	Lodging resistant, Flint kernels
138.KS-H524	2008	Kenya Seed Co.	Kenya Seed Co.	1200-1500	4-5	7.5-8.5	Resistant to rust, GLS & ear rot
139.KS-H6217	2008	Kenya Seed Co.	Kenya Seed Co.	1500-2100	6-7	8.5-10	Lodging resistant, Flint kernels
140.KS-DH13	2008	Kenya Seed Co.	Kenya Seed Co.	800-1800	3.5-4.5	4.5-7.6	Good husk cover, drought tolerant, resistant to ear rot, GLS, blight & rust
141.KS-H6502	2008	Kenya Seed Co.	Kenya Seed Co.	1300-1800	5-6	7.5-9.0	Resistant to rust, lodging resistant, tolerant to GLS & blight

142.KS-H6503	2008	Kenya Seed Co.	Kenya Seed Co.	1300-1800	5-6	7.5-9.0	Resistant to rust, lodging resistant, tolerant to GLS & blight
143.PHB 30D79	2008	Pioneer Hi-Bred Seeds	Pioneer Hi-Bred Seeds	1000-1800	5-6	7-11	Good tolerance to blight & MSV, resistant to GLS, Strong stalks
144.WH002	2008	Western Seed Co.	Western Seed Co.				
145.WS105	2008	Western Seed Co.	Western Seed Co.				
146.WS202	2008	Western Seed Co.	Western Seed Co.				
147.WH404	2008	Western Seed Co.	Western Seed Co.				
148.WH301	2008	Western Seed Co.	Western Seed Co.				
149.WH302	2008	Western Seed Co.	Western Seed Co.				
150.WH405	2008	Western Seed Co.	Western Seed Co.				
151.WH605	2008	Western Seed Co.	Western Seed Co.				
152.WS303	2007	Western Seed Co.	Western Seed Co.				
153.SC Tembo 71	2006	AgriSeed Co Ltd	SEEDCO Zambia	1800-1900	5-5.5	8-13	Tolerant to GLS & MSV, good standability
154.SC Punda Milia 51	2006	AgriSeed Co Ltd	SEEDCO Zambia	800-1600	4-4.5	6-8	Tolerant to GLS & MSV, good standability, wide adaptability
155.WH 602	2006	Western Seed Co.	Western Seed Co.				
156.WH 101	2006	Western Seed Co.	Western Seed Co.				
157.WH 401	2006	Western Seed Co.	Western Seed Co.				
158.WH 402	2006	Western Seed Co.	Western Seed Co.				
159.WH 507	2006	Western Seed Co.	Western Seed Co.				
160.WH 508	2006	Western Seed Co.	Western Seed Co.				

NOTES

Year of release – refers to the year when the national variety release committee released the variety

Owner is Institution or individual breeder

Maintainer is the owner or one who maintains the original material on arrangement with the owner.

Appendix 6: Cash Flow Analysis of Community IRM Project in western Kenya

ITEMS	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**
IRM PROJECT BENEFICIARIES										
Households served by the project *[1]*	169	169	169	169	169	169	169	169	169	169
Average household size (with 2.3 growth rate) *[2]*	5.75	5.88	6.02	6.16	6.29	6.44	6.59	6.74	6.89	7.05
TOTAL NUMBER OF BENEFICIARIES *[3=1x2]*	971.75	993.72	1017.38	1041.04	1063.01	1088.36	1113.71	1139.06	1164.41	1191.45
OUTPUT AND BENEFITS										
Area under IRM (ha)- short rain season *[4]*	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60
Area under IRM (ha)- long rain season *[5]*	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21
Yield (ton/ha)- IRM *[6]*	2.80	5.60	11.20	22.40	44.80	89.60	179.20	358.40	716.80	1433.60
Average price in US $*/ton *[7]*	278.00	278	278	278	278	278	278	278	278	278
Total acreage under IRM *[8=4+5]*	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81
Total annual output (ton) *[9=6x8]*	178.67	357.3399	714.6798	1429.36	2858.719	5717.439	11434.88	22869.75	45739.51	91479.02
Annual revenue (US $) *[10=7x9]*	49670.25	99340.5	198681	397362	794724	1589448	3178896	6357792	12715584	25431167
GROSS BENEFITS (US $) *[11=10]*	49670.25	99340.5	198681	397362	794724	1589448	3178896	6357792	12715584	25431167
OVERHEAD AND PRODUCTION COSTS										
Community labour for IRM cultivation (man-days) *[12]*	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00
Wage rate per man-day (US $) *[13]*	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
IRM cultivation costs (US $) *[14=12x13]*	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84
Seeds planted (US $) *[15]*	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11
DAP used (US $) *[16]*	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28
CAN used (US $) *[17]*	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56
Manure used (US $) *[18]*	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03
Pesticide used (US $) *[19]*	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67
Oxen hiring charge (US $) *[20]*	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67
Tractor hiring charge (US $) *[21]*	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50
Land rent (US $) *[22]*	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77
INVESTMENT COSTS (US $) [23=14+15+16+17+18+19+20+21+22]	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43
NET BENEFITS (us $) *[24=11-23]*	**41062.82**	**90733.07**	**190073.6**	**388754.6**	**786116.6**	**1580841**	**3170288**	**6349184**	**12706976**	**25422560**
DISCOUNTED REVENUE (US $) *[25]*	**21733290.71**									
DISCOUNTED COSTS (US $) *[26]*	**52888.93**									
BENEFITS/COSTS RATIO *[27=24/23]*	**4.77**									
NET BENEFITS PER CAPITA (US $) *[28=24/3]*	**42.26**	**91.30647**	**186.8265**	**373.429**	**739.5194**	**1452.498**	**2846.601**	**5574.056**	**10912.8**	**21337.5**
NPV (US $)	**21680401.78**									

Appendix 7: IRM sensitivity analysis with 25% increase in the scheme yield

ITEMS	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
IRM PROJECT BENEFICIARIES										
Households served by the project *[1]*	169	169	169	169	169	169	169	169	169	169
Average household size (with 2.3 growth rate) *[2]*	5.75	5.88	6.02	6.16	6.29	6.44	6.59	6.74	6.89	7.05
TOTAL NUMBER OF BENEFICIARIES *[3=1x2]*	971.75	993.72	1017.38	1041.04	1063.01	1088.36	1113.71	1139.06	1164.41	1191.45
OUTPUT AND BENEFITS										
Area under IRM (ha)- short rain season *[4]*	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60
Area under IRM (ha)- long rain season *[5]*	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21
Yield (ton/ha)- IRM *[6]*	3.50	7.00	14.00	28.00	56.00	112.00	224.00	448.00	896.00	1792.00
Average price in US $*/ton *[7]*	278.00	278	278	278	278	278	278	278	278	278
Total acreage under IRM *[8=4+5]*	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81
Total annual output (ton) *[9=6x8]*	223.34	446.6749	893.3498	1786.7	3573.399	7146.798	14293.6	28587.19	57174.39	114348.8
Annual revenue (US $) *[10=7x9]*	62087.81	124175.6	248351.2	496702.5	993405	1986810	3973620	7947240	15894480	31788959
GROSS BENEFITS (US $) *[11=10]*	62087.81	124175.6	248351.2	496702.5	993405	1986810	3973620	7947240	15894480	31788959
OVERHEAD AND PRODUCTION COSTS										
Community labour for IRM cultivation (man-days) *[12]*	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00
Wage rate per man-day (US $) *[13]*	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
IRM cultivation costs (US $) *[14=12x13]*	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84
Seeds planted (US $) *[15]*	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11
DAP used (US $) *[16]*	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28
CAN used (US $) *[17]*	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56
Manure used (US $) *[18]*	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03
Pesticide used (US $) *[19]*	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67
Oxen hiring charge (US $) *[20]*	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67
Tractor hiring charge (US $) *[21]*	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50
Land rent (US $) *[22]*	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77
INVESTMENT COSTS (US $) [23=14+15+16+17+18+19+20+21+22]	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43
NET BENEFITS (us $) *[24=11-23]*	**53480.38**	**115568.2**	**239743.8**	**488095.1**	**984797.5**	**1978203**	**3965012**	**7938632**	**15885872**	**31780352**
DISCOUNTED REVENUE (US $) *[25]*	**27166613.39**									
DISCOUNTED COSTS (US $) *[26]*	**52888.93**									
BENEFITS/COSTS RATIO *[27=24/23]*	**6.21**									
NET BENEFITS PER CAPITA (US $) *[28=24/3]*	**55.04**	**116.2985**	**235.6482**	**468.8533**	**926.4236**	**1817.599**	**3560.184**	**6969.459**	**13642.85**	**26673.68**
NPV (US $)	**27113724.46**									

Appendix 8: IRM sensitivity analysis with 50% increase in the scheme yield

ITEMS	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
IRM PROJECT BENEFICIARIES										
Households served by the project *[1]*	169	169	169	169	169	169	169	169	169	169
Average household size (with 2.3 growth rate) *[2]*	5.75	5.88	6.02	6.16	6.29	6.44	6.59	6.74	6.89	7.05
TOTAL NUMBER OF BENEFICIARIES *[3=1x2]*	971.75	993.72	1017.38	1041.04	1063.01	1088.36	1113.71	1139.06	1164.41	1191.45
OUTPUT AND BENEFITS										
Area under IRM (ha)- short rain season *[4]*	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60
Area under IRM (ha)- long rain season *[5]*	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21
Yield (ton/ha)- IRM *[6]*	4.20	8.40	16.80	33.60	67.20	134.40	268.80	537.60	1075.20	2150.40
Average price in US $*/ton *[7]*	278.00	278	278	278	278	278	278	278	278	278
Total acreage under IRM *[8=4+5]*	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81
Total annual output (ton) *[9=6x8]*	268.00	536.0099	1072.02	2144.04	4288.079	8576.158	17152.32	34304.63	68609.26	137218.5
Annual revenue (US $) *[10=7x9]*	74505.37	149010.7	298021.5	596043	1192086	2384172	4768344	9536688	19073376	38146751
GROSS BENEFITS (US $) *[11=10]*	74505.37	149010.7	298021.5	596043	1192086	2384172	4768344	9536688	19073376	38146751
OVERHEAD AND PRODUCTION COSTS										
Community labour for IRM cultivation (man-days) *[12]*	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00
Wage rate per man-day (US $) *[13]*	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
IRM cultivation costs (US $) *[14=12x13]*	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84
Seeds planted (US $) *[15]*	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11
DAP used (US $) *[16]*	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28
CAN used (US $) *[17]*	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56
Manure used (US $) *[18]*	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03
Pesticide used (US $) *[19]*	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67
Oxen hiring charge (US $) *[20]*	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67
Tractor hiring charge (US $) *[21]*	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50
Land rent (US $) *[22]*	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77
INVESTMENT COSTS (US $) [23=14+15+16+17+18+19+20+21+22]	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43
NET BENEFITS (us $) *[24=11-23]*	**65897.94**	**140403.3**	**289414.1**	**587435.6**	**1183479**	**2375565**	**4759736**	**9528080**	**19064768**	**38138144**
DISCOUNTED REVENUE (US $) *[25]*	**32599936.06**									
DISCOUNTED COSTS (US $) *[26]*	**52888.93**									
BENEFITS/COSTS RATIO *[27=24/23]*	**7.66**									
NET BENEFITS PER CAPITA (US $) *[28=24/3]*	**67.81**	**141.2906**	**284.47**	**564.2776**	**1113.328**	**2182.701**	**4273.766**	**8364.863**	**16372.9**	**32009.86**
NPV (US $)	**32547047.13**									

Appendix 9: IRM sensitivity analysis with 75% increase in the scheme yield

ITEMS	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
IRM PROJECT BENEFICIARIES										
Households served by the project *[1]*	169	169	169	169	169	169	169	169	169	169
Average household size (with 2.3 growth rate) *[2]*	5.75	5.88	6.02	6.16	6.29	6.44	6.59	6.74	6.89	7.05
TOTAL NUMBER OF BENEFICIARIES *[3=1x2]*	971.75	993.72	1017.38	1041.04	1063.01	1088.36	1113.71	1139.06	1164.41	1191.45
OUTPUT AND BENEFITS										
Area under IRM (ha)- short rain season *[4]*	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60	25.60
Area under IRM (ha)- long rain season *[5]*	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21	38.21
Yield (ton/ha)- IRM *[6]*	4.90	9.80	19.60	39.20	78.40	156.80	313.60	627.20	1254.40	2508.80
Average price in US $*/ton *[7]*	278.00	278	278	278	278	278	278	278	278	278
Total acreage under IRM *[8=4+5]*	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81	63.81
Total annual output (ton) *[9=6x8]*	312.67	625.3449	1250.69	2501.379	5002.759	10005.52	20011.04	40022.07	80044.14	160088.3
Annual revenue (US $) *[10=7x9]*	86922.94	173845.9	347691.7	695383.5	1390767	2781534	5563068	11126136	22252271	44504543
GROSS BENEFITS (US $) *[11=10]*	86922.94	173845.9	347691.7	695383.5	1390767	2781534	5563068	11126136	22252271	44504543
OVERHEAD AND PRODUCTION COSTS										
Community labour for IRM cultivation (man-days) *[12]*	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00	2072.00
Wage rate per man-day (US $) *[13]*	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
IRM cultivation costs (US $) *[14=12x13]*	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84	2009.84
Seeds planted (US $) *[15]*	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11	2001.11
DAP used (US $) *[16]*	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28	1715.28
CAN used (US $) *[17]*	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56	675.56
Manure used (US $) *[18]*	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03	809.03
Pesticide used (US $) *[19]*	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67	7.67
Oxen hiring charge (US $) *[20]*	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67	1061.67
Tractor hiring charge (US $) *[21]*	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50	237.50
Land rent (US $) *[22]*	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77	89.77
INVESTMENT COSTS (US $) [23=14+15+16+17+18+19+20+21+22]	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43	8607.43
NET BENEFITS (us $) *[24=11-23]*	**78315.51**	**165238.4**	**339084.3**	**686776.1**	**1382160**	**2772927**	**5554460**	**11117528**	**22243664**	**44495936**
DISCOUNTED REVENUE (US $) *[25]*	**38033258.74**									
DISCOUNTED COSTS (US $) *[26]*	**52888.93**									
BENEFITS/COSTS RATIO *[27=24/23]*	**9.10**									
NET BENEFITS PER CAPITA (US $) *[28=24/3]*	**80.59**	**166.2827**	**333.2917**	**659.7019**	**1300.232**	**2547.803**	**4987.349**	**9760.266**	**19102.95**	**37346.04**
NPV (US $)	**37980369.81**									

Appendix 10: Cash Flow Analysis of Community Local Maize Project in western Kenya (Average yield decrease: 60% / year)

ITEMS	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
LOCAL MAIZE PROJECT BENEFICIARIES										
Households served by the project *[1]*	291	291	291	291	291	291	291	291	291	291
Average household size (with 2.3 growth rate) *[2]*	5.75	5.88	6.02	6.16	6.29	6.44	6.59	6.74	6.89	7.05
TOTAL NUMBER OF BENEFICIARIES *[3=1x2]*	1673.25	1711.08	1751.82	1792.56	1830.39	1874.04	1917.69	1961.34	2004.99	2051.55
OUTPUT AND BENEFITS										
Area under local maize (ha)- short rain season *[4]*	70.90	70.90	70.90	70.90	70.90	70.90	70.90	70.90	70.90	70.90
Area under local maize (ha)- long rain season *[5]*	105.82	105.82	105.82	105.82	105.82	105.82	105.82	105.82	105.82	105.82
Yield (ton/ha)- local maize *[6]*	1.42	0.57	0.23	0.09	0.03	0.01	0.00	0.00	0.00	0.00
Average price in US $*/ton *[7]*	278.00	278	278	278	278	278	278	278	278	278
Total acreage under local maize *[8=4+5]*	176.72	176.72	176.72	176.72	176.72	176.72	176.72	176.72	176.72	176.72
Total annual output (ton) *[9=6x8]*	250.94	100.7304	40.6456	15.9048	5.3016	1.7672	0	0	0	0
Annual revenue (US $) *[10=7x9]*	69761.99	28003.05	11299.48	4421.534	1473.845	491.2816	0	0	0	0
GROSS BENEFITS (US $) *[11=10]*	69761.99	28003.05	11299.48	4421.534	1473.845	491.2816	0	0	0	0
OVERHEAD AND PRODUCTION COSTS										
Community labour for local maize cultivation (man-days) *[12]*	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64
Wage rate per man-day (US $) *[13]*	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Local maize cultivation costs (US $) *[14=12x13]*	5293.91	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911
Seeds planted (US $) *[15]*	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24
DAP used (US $) *[16]*	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97
CAN used (US $) *[17]*	192.22	192.22	192.22	192.22	192.22	192.22	192.22	192.22	192.22	192.22
Manure used (US $) *[18]*	886.11	886.11	886.11	886.11	886.11	886.11	886.11	886.11	886.11	886.11
Pesticide used (US $) *[19]*	36.60	36.60	36.60	36.60	36.60	36.60	36.60	36.60	36.60	36.60
Oxen hiring charge (US $) *[20]*	606.67	606.67	606.67	606.67	606.67	606.67	606.67	606.67	606.67	606.67
Tractor hiring charge (US $) *[21]*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Land rent (US $) *[22]*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INVESTMENT COSTS (US $) [23=14+15+16+17+18+19+20+21+22]	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72
NET BENEFITS (us $) *[24=11-23]*	**59191.27**	**17432.33**	**728.756**	**-6149.19**	**-9096.88**	**-10079.4**	**-10570.7**	**-10570.7**	**-10570.7**	**-10570.7**
DISCOUNTED REVENUE (US $) *[25]*	**99264.89**									
DISCOUNTED COSTS (US $) *[26]*	**64952.50**									
BENEFITS/COSTS RATIO *[27=24/23]*	**5.60**									
NET BENEFITS PER CAPITA (US $) *[28=24/3]*	**35.38**	**10.18791**	**0.415999**	**-3.43039**	**-4.96991**	**-5.37845**	**-5.51222**	**-5.38954**	**-5.27221**	**-5.15255**
NPV (US $)	**34312.39**									

Appendix 11: Cash Flow Analysis of Community Local Maize Project in western Kenya (Minimum yield decrease: 20% / year)

ITEMS	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**
LOCAL MAIZE PROJECT BENEFICIARIES										
Households served by the project *[1]*	291	291	291	291	291	291	291	291	291	291
Average household size (with 2.3 growth rate) *[2]*	5.75	5.88	6.02	6.16	6.29	6.44	6.59	6.74	6.89	7.05
TOTAL NUMBER OF BENEFICIARIES *[3=1x2]*	1673.25	1711.08	1751.82	1792.56	1830.39	1874.04	1917.69	1961.34	2004.99	2051.55
OUTPUT AND BENEFITS										
Area under local maize (ha)- short rain season *[4]*	70.90	70.90	70.90	70.90	70.90	70.90	70.90	70.90	70.90	70.90
Area under local maize (ha)- long rain season *[5]*	105.82	105.82	105.82	105.82	105.82	105.82	105.82	105.82	105.82	105.82
Yield (ton/ha)- local maize *[6]*	1.42	1.14	0.91	0.73	0.58	0.46	0.37	0.30	0.24	0.19
Average price in US $*/ton *[7]*	278.00	278	278	278	278	278	278	278	278	278
Total acreage under local maize *[8=4+5]*	176.72	176.72	176.72	176.72	176.72	176.72	176.72	176.72	176.72	176.72
Total annual output (ton) *[9=6x8]*	250.94	201.4608	160.8152	129.0056	102.4976	81.2912	65.3864	53.016	42.4128	33.5768
Annual revenue (US $) *[10=7x9]*	69761.99	56006.1	44706.63	35863.56	28494.33	22598.95	18177.42	14738.45	11790.76	9334.35
GROSS BENEFITS (US $) ***[11=10]***	69761.99	56006.1	44706.63	35863.56	28494.33	22598.95	18177.42	14738.45	11790.76	9334.35
OVERHEAD AND PRODUCTION COSTS										
Community labour for local maize cultivation (man-days) *[12]*	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64
Wage rate per man-day (US $) *[13]*	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Local maize cultivation costs (US $) *[14=12x13]*	5293.91	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911
Seeds planted (US $) *[15]*	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24
DAP used (US $) *[16]*	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97
CAN used (US $) *[17]*	192.22	192.22	192.22	192.22	192.22	192.22	192.22	192.22	192.22	192.22
Manure used (US $) *[18]*	886.11	886.11	886.11	886.11	886.11	886.11	886.11	886.11	886.11	886.11
Pesticide used (US $) *[19]*	36.60	36.60	36.60	36.60	36.60	36.60	36.60	36.60	36.60	36.60
Oxen hiring charge (US $) *[20]*	606.67	606.67	606.67	606.67	606.67	606.67	606.67	606.67	606.67	606.67
Tractor hiring charge (US $) *[21]*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Land rent (US $) *[22]*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INVESTMENT COSTS (US $) [23=14+15+16+17+18+19+20+21+22]	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72
NET BENEFITS (us $) ***[24=11-23]***	**59191.27**	**45435.38**	**34135.9**	**25292.84**	**17923.61**	**12028.23**	**7606.698**	**4167.727**	**1220.038**	**-1236.37**
DISCOUNTED REVENUE (US $) ***[25]***	**223042.04**									
DISCOUNTED COSTS (US $) ***[26]***	**64952.50**									
BENEFITS/COSTS RATIO ***[27=24/23]***	**5.60**									
NET BENEFITS PER CAPITA (US $) ***[28=24/3]***	**35.38**	**26.55363**	**19.48597**	**14.1099**	**9.792237**	**6.418344**	**3.966594**	**2.124939**	**0.608501**	**-0.60265**
NPV (US $)	**158089.53**									

Appendix 12: Cash Flow Analysis of Community Local Maize Project in western Kenya (Maximum yield decrease: 100% /year)

ITEMS	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**
LOCAL MAIZE PROJECT BENEFICIARIES										
Households served by the project *[1]*	291	291	291	291	291	291	291	291	291	291
Average household size (with 2.3 growth rate) *[2]*	5.75	5.88	6.02	6.16	6.29	6.44	6.59	6.74	6.89	7.05
TOTAL NUMBER OF BENEFICIARIES *[3=1x2]*	1673.25	1711.08	1751.82	1792.56	1830.39	1874.04	1917.69	1961.34	2004.99	2051.55
OUTPUT AND BENEFITS										
Area under local maize (ha)- short rain season *[4]*	70.90	70.90	70.90	70.90	70.90	70.90	70.90	70.90	70.90	70.90
Area under local maize (ha)- long rain season *[5]*	105.82	105.82	105.82	105.82	105.82	105.82	105.82	105.82	105.82	105.82
Yield (ton/ha)- local maize *[6]*	1.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Average price in US $*/ton *[7]*	278.00	278	278	278	278	278	278	278	278	278
Total acreage under local maize *[8=4+5]*	176.72	176.72	176.72	176.72	176.72	176.72	176.72	176.72	176.72	176.72
Total annual output (ton) *[9=6x8]*	250.94	0	0	0	0	0	0	0	0	0
Annual revenue (US $) *[10=7x9]*	69761.99	0	0	0	0	0	0	0	0	0
GROSS BENEFITS (US $) *[11=10]*	69761.99	0	0	0	0	0	0	0	0	0
OVERHEAD AND PRODUCTION COSTS										
Community labour for local maize cultivation (man-days) *[12]*	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64	5457.64
Wage rate per man-day (US $) *[13]*	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Local maize cultivation costs (US $) *[14=12x13]*	5293.91	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911	5293.911
Seeds planted (US $) *[15]*	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24	2214.24
DAP used (US $) *[16]*	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97	1340.97
CAN used (US $) *[17]*	192.22	192.22	192.22	192.22	192.22	192.22	192.22	192.22	192.22	192.22
Manure used (US $) *[18]*	886.11	886.11	886.11	886.11	886.11	886.11	886.11	886.11	886.11	886.11
Pesticide used (US $) *[19]*	36.60	36.60	36.60	36.60	36.60	36.60	36.60	36.60	36.60	36.60
Oxen hiring charge (US $) *[20]*	606.67	606.67	606.67	606.67	606.67	606.67	606.67	606.67	606.67	606.67
Tractor hiring charge (US $) *[21]*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Land rent (US $) *[22]*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
INVESTMENT COSTS (US $) [23=14+15+16+17+18+19+20+21+22]	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72	10570.72
NET BENEFITS (us $) *[24=11-23]*	**59191.27**	**-10570.7**	**-10570.7**	**-10570.7**	**-10570.7**	**-10570.7**	**-10570.7**	**-10570.7**	**-10570.7**	**-10570.7**
DISCOUNTED REVENUE (US $) *[25]*	**63419.99**									
DISCOUNTED COSTS (US $) *[26]*	**64952.50**									
BENEFITS/COSTS RATIO *[27=24/23]*	**5.60**									
NET BENEFITS PER CAPITA (US $) *[28=24/3]*	**35.38**	**-6.17781**	**-6.03414**	**-5.897**	**-5.77512**	**-5.64061**	**-5.51222**	**-5.38954**	**-5.27221**	**-5.15255**
NPV (US $)	**-1532.51**									