AN ANALYSIS OF PUSH-PULL AND *IMAZAPYR* RESISTANT MAIZE TECHNOLOGIES ADOPTION FOR *STRIGA* CONTROL IN SIAYA COUNTY, KENYA

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DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and has never been submitted in this or any oth
university for the award of a degree.

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Recommendation

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DEDICATION

I dedicate this thesis to my father Samuel Mwangi, my mother Pauline Mwangi and my sister Beth Wanjiru for their continued support and prayers.

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May God Bless You All.

ABSTRACT

The volume of maize produced in Kenya has continued to fluctuate over the past eight years, thereby putting the country's food security situation in jeopardy. *Striga* weeds (*Striga hermonthica* (Del.) Benth and *Striga asiatica* [Scrophulariaceae] (L.) Kuntze) have been identified as the major contributing factor among other constraints. In an effort to address this challenge, research organizations have made efforts to develop and disseminate various technologies to control the weed. Among them, the International Centre of Insect Physiology and Ecology (ICIPE) and International Maize and Wheat Improvement Centre (CIMMYT) in collaboration with other stakeholders, have developed and promoted Push-Pull technology (PPT) and *Imazapyr* resistance (IR) maize technology respectively. Using a random sample of 326 farmers from Wagai division, Siaya county, this study comparatively evaluated the actual and potential adoption rates of PPT and IR maize technology, in order to allow for optimal use of resources in a more effective technology. Data were analysed using weighted index approach, ordered probit model, double hurdle model and Average Treatment Effect (ATE) estimation framework. The results from double hurdle and ordered probit models show that, the adoption and intensity of use decisions of both technologies as well as farmers' perception are influenced by different factors, which differed in magnitude and significance levels. These factors include: age and years of formal schooling attained by a household head, workforce, farmer group membership, and distance to the nearest administration centre among others. The weighted index results indicated farmers' preference of PPT over IR maize technology, as it was more effective in *Striga* control. From the ATE results, PPT which was preferred by farmers indicated a higher potential adoption rate (56.3%), compared to IR maize technology (46%) once the whole population is exposed. Based on farmers' perception and potential adoption rates of both technologies, PPT should be given priority in dissemination as a *Striga* eradicating strategy.

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LIST OF ACRONYMS AND ABBREVIATIONS

ATE	Average Treatment Effect
ATE0	Average Treatment Effect on the Untreated
ATE1	Average Treatment Effect on the Treated
BASF	Baden Aniline and Soda Factory
CIMMYT	International Maize and Wheat Improvement Centre
GoK	Government of Kenya
ICIPE	International Centre of Insect Physiology and Ecology
IR	Imazapyr Resistant
KARI	Kenya Agricultural Research Institute
KES	Kenya Shilling
LATE	Local Average Treatment Effect
MLE	Maximum Likelihood Estimators
NERICA	New Rice for Africa
PPT	Push-Pull Technology
PVS	Participatory Variety Selection

CHAPTER ONE

INTRODUCTION

1.1 Background information

Maize is the most important cereal crop grown for consumption in Kenya and the main staple food for about 90% of the population. Its production relies on small-scale farmers who contribute about 75% of the overall production from about 80% of the total maize area, with the remaining 25% being contributed by the large-scale farmers (GoK, 2007).

While the volume of maize production (MT) has fluctuated over the past eight (8) years, consumption has continued to increase, mainly due an increase in population growth rate estimated at 2.7% (GoK, 2010) as shown in Table 1.1. The fluctuations in production have been attributed to several constraints such as: low soil fertility, inadequate farm tools, liquidity problems, poor extension services, low quality seeds, *Striga* weeds and stemborers, among others (Odendo *et al.,* 2001). However, parasitic *Striga* weeds (*Striga hermonthica* (Del.) Benth and *Striga asiatica* [Scrophulariaceae] (L.) Kuntze) are considered the most important challenge in cereal production (Hassan *et al.,* 1994; Khan *et al.,* 2008c), and are estimated to cause up to 100% yield loss (Khan *et al.,* 2001). This translates to a great cash income loss which leads to food insecurity and poverty to the affected families (Khan *et al.,* 2008b). Among the most heavily *Striga* infested areas is western Kenya, where 76% of 200,000 ha of cropland are estimated to be infested (Rutto *et al.,* 2005).

Table 1.1: Maize production and consumption in Kenya, 2005-2011

Year	2005	2006	2007	2008	2009	2010	2011
Maize production (Million MT)	2.918	3.248	2.929	2.370	2.443	3.465	3.096
Maize consumption (Million MT)	2.891	2.979	3.069	3.240	3.240	-	-
Difference (Million MT)	+ 0.027	+ 0.268	- 0.140	- 0.870	- 0.797	-	-

Source: Economic review of agriculture, 2010; 2012.

It is in response to these challenges that International Maize and Wheat Improvement Centre (CIMMYT), International Centre of Insect Physiology and Ecology (ICIPE) and Kenya Agricultural Research Institute (KARI) in collaboration with other stakeholders have developed and been promoting various technologies to aid in the control of *Striga* weed.

Among these technologies include Push-Pull technology (PPT) and *Imazapyr* Resistant (IR) maize technology.

The PPT was developed by ICIPE in Kenya and Rothamsted Research in the United Kingdom, in collaboration with other research organizations in Eastern Africa as an integrated pest management strategy (Khan and Pickett, 2004). It involves intercropping cereal crops with a legume of the genus *desmodium* (*Desmotium uncinatun),* and this intercrop is surrounded by a perimeter of trap crops such as Napier grass. Besides repelling stemborer moths through its leaf volatiles, *desmodium* produces root exudates that limit the growth of *Striga* causing abortive germination (Khan *et al.,* 2007). This leguminous crop also improves soil fertility through nitrogen fixation, natural mulching and control of erosion. Both companion plants provide high value animal fodder which leads to a rise in milk production thereby increasing farmers' income. The technology is suitable to smallholder mixed cropping systems in Africa, and effectively addresses major production constraints thereby increasing maize yields from below 1 t/ha to 3.5 t/ha using locally available plants (Khan *et al.,* 2011). The technology was recently termed as 'the single most effective and efficient low-cost technology', for controlling *Striga* and stemborers problem faced by the majority of smallholder farmers in Eastern Africa, resulting in an overall and significant improvement of their food security and livelihoods (Fischler, 2010).

On the other hand, IR maize technology - commonly known as herbicide-coated maize or StrigAway technology - provides another option for farmers to suppress *Striga* and grow maize at the same time (Kanampiu *et al.,* 2002; Odhiambo and Woomer, 2005). The technology involves coating of maize seeds with a systemic herbicide called *Imazapyr*. The IR maize technology was developed by CIMMYT in collaboration with Weizmann Institute of Science in Israel, KARI and Baden Aniline and Soda Factory (BASF). The technology has two important attributes namely: herbicide resistant maize and herbicide *(Imazapyr)* coating. As the maize seeds germinate, they absorb the herbicide. The germinated maize then produces a chemical which induces germination of the *Striga* weed, but as the *Striga* seedlings attach to the roots of the maize to withdraw nutrients, they are killed by the herbicide. The *Imazapyr* which is not absorbed by the maize seedling diffuses into the surrounding soil and kills un-germinated *Striga* seeds (Kanampiu *et al.,*ibid). The technology has been known to suppress *Striga* from emergence (Kabambe *et al.,* 2007). Lack of IR maize seed and inefficient supply chain has been identified as the major constraints to the adoption of this technology (Mignouna *et al.,* 2010).

The two technologies have been termed as suitable to control *Striga* under small holder conditions. Their uptake and diffusion rates in Kenya and the Eastern Africa region have shown promising trends. For example, Khan *et al.* (2011) showed that, approximately 30,000 farmers in the East African region covering an area of about 15,000 ha have adopted PPT. Majority of these adopters are from western Kenya, central Kenya, Uganda and Tanzania. The number of IR maize technology adopters is however not known, but a study by Mignouna *et al.* (2011a) showed that the uptake is still low.

The development and dissemination of the two technologies is supported through external funding, whose continued support depends on the effectiveness of these projects in achieving the objectives of the target beneficiaries. This is expressed by how much and how fast these technologies are taken up by the targeted farmers, and therefore the extent to which they contribute to increased production of cereal crops. For continued funding of research, it is critical that there is a positive return to investment. Thus PPT and IR maize technology must demonstrate benefits hinged on high adoption rates and increased maize production. Raising productivity often requires a much higher level of adoption of new agricultural technologies than presently observed in the smallholder farming population (De Janvry and Sadoulet, 2002).

Though the two technologies have been disseminated to the target beneficiaries, a comparative assessment of their adoption rates (both actual and potential) is critical in order to ensure that the best technology is up-scaled.

1.2 Statement of the research problem

Whereas PPT and IR maize technology have demonstrated the effectiveness in controlling *Striga,* there is a dearth of empirical literature on the comparative uptake and potential of the two technologies and farmers' perceptions on their effectiveness, conditional on socio-economic and institutional challenges, and in the presence of multiplicity of resource demand for technology generation, to inform policy on the best bet option. Initial studies have shown a promising trend for PPT adoption, while the uptake of IR maize is still low and since the final adoption and continued use decisions of the two technologies lies with the farmers, this comparison is important in order to allow donors, researchers and extension agents target the most promising technology that is preferred by the farmers and has the highest potential adoption rate. This study thus evaluated the actual and potential adoption rates of the two technologies, while assessing the farmers' preference for the two, so as to direct the meagre resources available for agricultural development appropriately.

1.3 Objectives of the study

The overall objective was to promote the best practices and technologies for *Striga* weed control in western Kenya. The specific objectives were:

1. To determine farmers' perception on the effectiveness of PPT and IR maize technology in *Striga* control and the underlying determinants.
2. To determine the factors influencing adoption and intensity of PPT and IR maize technology use.
3. To estimate the actual and potential adoption rates of PPT and IR maize technology and their determinants.

1.4 Research hypotheses

1. There is no significant difference between farmers' perception on the effectiveness of PPT and IR maize technology in *Striga* control and their underlying factors.
2. Socio-economic, institutional and technological factors do not influence the uptake and intensity of PPT and IR maize technology use.
3. There is no significant difference between estimates of actual and potential adoption rates of PPT and IR maize technology and their determinants.

1.5 Justification of the study

Maize production in Kenya is an extremely relevant activity since it is a dominant food crop. However, its potential production has been greatly affected by *Striga* weed infestation, which has been identified as a major constraint especially in western Kenya and other parts of East Africa. As a control measure, PPT and IR maize technology have been widely promoted in Siaya county. The adoption of PPT has shown promising trends while that of IR maize technology is not known. By estimating the adoption gap and identifying factors that influence the adoption and intensity of PPT and IR maize technology use, this study aimed to provide guidance to the promoters of the two technologies and researchers to enhance their effectiveness in increasing the adoption rate. The added knowledge could be used to help the promoters make more informed decisions on how to enhance increased PPT and IR maize technology adoption through agricultural research. By determining the technology with higher potential adoption rates, policy makers will benefit by formulating policies which would direct agricultural investment appropriately. The characteristics which are perceived important by farmers for the most preferred technology would be highlighted and targeted by the technology developer so as to up-scale its adoption. This study uses superior models in various estimations that are rarely used especially Average Treatment Effect (ATE) and Cragg's double hurdle model which would be of benefit to the academia world. The results of this study are useful since the information added, could contribute to the success of the two technologies and also guide any other related program, which attempts to introduce technologies for adoption in settings that are similar to those in the study area. The results have implications well beyond the confines of the study area.

1.6 Limitation and scope of the study

There are several *Striga* eradicating strategies which farmers use in Siaya county e.g. soil fertility management practises, hand weeding, uprooting and burning of affected fields, but this study focused on PPT and IR maize technology since they were the two mostly modern promoted strategies in the study area. Although there were many counties where PPT and IR maize technology had been promoted, the study was limited to smallholder farmers producing maize in Siaya county. This is due to the fact that, it is one of the heavily *Striga* infested county in Nyanza region.

1.7 Operational definition of terms

1. **Technology adoption:** This is the mental process an individual passes from first hearing about an innovation to final uptake (Rogers, 1962).
2. **Push-Pull technology** is a method that controls *Striga* through the use of *desmodium* intercrops which suppress *witch weed* through an allelopathic mechanism. Their root exudates contain novel flavonoid compounds, which stimulate suicidal germination of *Striga* seeds and dramatically inhibit its attachment to host roots (Khan *et al.,* 2011).
3. **IR maize technology** is an approach for controlling *Striga* which combines a low dose of a systematic acetolactate synthesis inhibiting herbicide seed coating applied to *Imazapyr* resistant (IR) maize seed. *Imazapyr* is a non-selective herbicide used for the control of a broad range of weeds including terrestrial annual and perennial grasses and broadleaved herbs, woody species, riparian and emergent aquatic species (Kanampiu *et al.,* 2002).

1.8 Outline of the thesis

The remainder of this thesis is presented as follows. The next chapter describes the literature reviewed, discusses the conceptual and theoretical frameworks. Chapter three describes the study area, sampling procedure and data collection strategies used. It also gives a detailed description of variables used in various models in this study. In chapter four, survey descriptive statistics results are presented and discussed. The determinants of farmers' perception on the effectiveness of PPT and IR maize technology in controlling *Striga* as contained in index approach and ordered probit model are identified and discussed in chapter five. In chapter six, the determinants of adoption and intensity of use of PPT and IR maize technology are presented and discussed. The "unconditional" average partial effects are also discussed in this chapter. The estimates of actual and potential adoption rates and their determinants of PPT and IR maize technology are presented and discussed in detail in chapter seven. Summary, conclusions and implications are presented in chapter eight.

CHAPTER TWO

LITERATURE REVIEW

2.1 Determinants of technology adoption and intensity of use

Technology adoption is the mental process an individual passes from first learning about the existence of an innovation to final uptake (Rogers, 1962). The final adoption of a new technology at the individual farmer level could be defined as the degree of use in long run equilibrium, when the farmer has full information about the new innovation and its potential (Feder *et al.,* 1985). Adoption of new technologies usually depends on many factors among them their embodied characteristics such as: compatibility with the existing values and norms, complexity, observability, trialability, and relative advantage (Rogers, 1995). The factors influencing decision of a farmer to adopt embodies both the adopters and non-adopters' sub-population, but on the other hand, factors influencing intensity of adoption reflects on the adopters' sub-population only. This is due to the fact that, an individual must decide to adopt a technology before deciding on how much of the innovation to put into practice. However, despite farmers being aware of the benefits of new technology promoted, the uptake levels are lower than expected. Many studies have been carried out to identify the determinants of technology adoption and intensity of use. Several farm and farmers characteristics, institutional and technological factors have been identified to influence the farmer's decision to adopt and intensify the use of new technologies.

Since farmers are the end users of agricultural technologies being promoted, how they perceive them is very critical in shaping their adoption decisions. A farmer can be insensitive to a technology's characteristics or either have positive or negative perceptions. A study by Adesina and Baidu-Forson (1995) on the factors influencing the adoption of modern sorghum varieties in Burkina Faso, used Tobit model and indicated the importance of including farmers' perceptions in the adoption model besides socio-economic, demographical and institutional factors. This is due to the fact that, farmers might perceive new technologies being promoted differently from researchers and technology developers, though many adoption studies often overlook at the role of farmers' preferences (Adesina and Baidu-Forson, ibid).

Zegeye *et al.* (2001) while using logit regression assessed the determinants of adoption of improved maize technologies in major maize growing regions of Ethiopia. The findings showed a significant influence of attending formal training, distance to the nearest market centre, access to credit, tropical livestock units, access to extension services and family size to the decision of adopting improved maize technologies. The results therefore showed the importance of socio-economic and institutional factors inclusion in the adoption model but the study failed to assess the effect of farmers' perception on adoption of improved maize technologies. Moreover, the factors which influenced the intensity of using improved maize technologies by the farmers were not evaluated.

Mwabu *et al.* (2006) while assessing whether adoption of improved maize varieties reduces poverty in Kenya, used a bivariate probit model and indicated a significant influence of price of maize, education level of a farmer and distance to roads to the decision of adopting hybrid maize by farmers. The study however failed to include farmers' perception to the adoption model and did not evaluate the factors which influenced the decision of the farmers to expand the use of hybrid maize.

A study by Feleke and Zegeye (2006) on adoption of improved maize varieties in southern Ethiopia used logistic regression, and showed significant influence of several socio-economic and institutional factors such as access to credit, extension services and age of a farmer on the decision of farmers to adopt the technology. The study however, did not assess the influence of farmers' perception despite its importance in the decision to adopt new technologies. The determinants of continued use of the maize varieties were not evaluated.

In a study by Salasya *et al.* (2007) on factors influencing adoption of stress-tolerant maize hybrid (WH 502) in western Kenya, probit model results showed a positive relationship between adoption of the tolerant maize hybrid and education of the farmer, distance to the market and number of cattle owned by a household among others. The positive sign of distance to the market was unexpected and was explained by the fact that, seed quality probably increased with distance to the nearest market centre. The study however failed to determine the factors which influenced the intensity of use of WH 502 maize variety. Furthermore, the aspect of farmers' perception was overlooked in the adoption model.

While using logistic regression, Amudavi *et al.* (2008) studied the determinants of PPT expansion in western Kenya, and noted several socio-economic and institutional factors which significantly influenced the decision of farmers to expand the use of PPT. They included: large households, farmer group membership and residence in medium potential areas. The study however found no significant influence of education level, land size and tropical livestock unit (TLUs) on PPT expansion which was unexpected. The unexpected influence of education level attained by a farmer could be explained by the fact that, PPT is a knowledge intensive technology (Khan *et al.,* 2008a) and thus a positive relationship could have been ensued. Provision of livestock fodder is one of the benefits accrued by PPT adopters (Khan *et al.,* 2011) and thus a positive relationship between TLU and PPT expansion was expected. The study however did not incorporate farmers' perception in the model as well as determining the factors which influenced the decision of farmers to adopt PPT.

Khan *et al.* (2008c) used a logistic regression to evaluate the determinants of PPT adoption in western Kenya. The findings indicated a positive influence of a farmer's age, access to extension services and radio ownership to the decision of adopting PPT. However, gender influence was negative indicating a higher probability of female households in adoption of PPT. Besides not including farmers' perception in its adoption model, the study failed to determine the factors which influenced the farmers' decision to expand the use of PPT, since uptake of a technology is not only the decision to adopt but also how much of the technology is put into use.

Access to credit is crucial to farmers who are willing to adopt a new innovation, since it boosts the ability of farmers to relax their liquidity constraints (Simtowe *et al.*, 2009). This study used ordinary least squares (OLS) and Tobit regressions to evaluate the determinants of adoption of hybrid maize under credit constraints in Malawi, and the results show that, credit constrained households had a higher probability of reducing the amount of land cultivated under hybrid maize. Furthermore, age of the household head and total land owned had negative and positive effects respectively on the adoption of hybrid maize. Farmers' perception was however omitted from the adoption model.

In a study by Mignouna *et al.* (2010) on adoption of a new maize and production efficiency in western Kenya, Tobit model results indicated significant influence of several socio-economic, institutional and technological factors on the decision to adopt *Imazapyr* resistant maize (IRM). They included age and education level of a farmer, contact with extension agents, lack of seeds, membership in social group, effective pathway for IRM dissemination and compatibility of the technology among others. While using stochastic production frontier analysis, the study showed a significant increase in maize production after adopting IRM. This could be due to the fact that, IRM depletes *Striga* seed bank in the soil which negatively affect maize production and reduces its emergence (Kabambe *et al.*, 2007). The study however, did not evaluate the determinants of IRM expansion.

A study by Tura *et al.* (2010) used bivariate probit to assess the adoption and continued use of improved maize seeds in central Ethiopia. The findings indicated a significant influence of land size owned, access to credit and membership in cooperatives on farmers' decisions to adopt improved maize varieties while intensity of use of the seed was influenced by the proportion of farmland allocated to maize, literacy level of the household head, visits by extension agents, farmers' experience and household land size among others. The results indicated that, the determinants of the adoption and intensity of use decisions are not necessarily the same. However, the study never included the aspect of farmers' perception in modelling the two decisions.

Effective and efficient dissemination pathways are fundamental if high adoption rates of new technologies being promoted to farmers are to be realized. This would ensure that the speed of uptake is accelerated after farmers acquire reliable and relevant information in time. While carrying out a duration analysis of PPT adoption effects of dissemination pathways in western Kenya, Murage *et al.*(2011a) used a parametric (Weibull) functional form and indicated a positive influence of education level, household size and income level of a household to the speed of adopting PPT. However, just like Amudavi *et al.* (2008), tropical livestock units (TLU) had unexpected sign to the speed of PPT uptake which was surprising. Although the study determined the influence of several factors in the speed of adopting PPT, farmers' perception was overlooked. Moreover, the factors which influenced the speed of expanding the use of PPT were not evaluated.

While evaluating the determinants of adopting *Imazapyr* resistant maize for *Striga* control in western Kenya, Mignouna *et al.* (2011a) used a double hurdle approach and noted a significance difference, between the factors which influenced the decision to adopt and intensify the use of IRM. Although the study included farmers' perception towards IRM as a *Striga* control measure, unexpected negative sign was reported. This was explained by the fact that either, farmers' positive perception about the technology could have been altered by other perceptions, or due to negative correlation between perception and other technological characteristics not included in the model.

In an effort to assess the *Imazapyr*-resistant maize technology adoption for witch weed control in western Kenya, Mignouna *et al.* (2011b) used performance and penetration indices to estimate the adoption rates of the technology. Although the adoption rate of IRM in Siaya district was relatively higher than for other districts in western Kenya (48%), the overall adoption rate of the technology in the area was indicated as low (28%). Availability of inputs is very essential if a new technology is to be adopted by farmers a fact stressed by the study since lack of IRM seeds was highlighted by 50% of the respondents as a major reason for non-adoption of the technology. The study further noted that, for increased adoption of IRM technology, exposure to the technology should be increased. The study however, did not determine the factors which influenced the decision to adopt and intensify the use of IRM technology.

A study by Murage *et al.* (2012) used a two limit Tobit regression, to evaluate the effectiveness of dissemination pathways on adoption of PPT in western Kenya. The findings indicated that land size, distance to the tarmac, field days, farmer field schools and farmer teachers among others had a significant influence on adoption and intensity of use of PPT. The study however, did not include farmers' perception as a variable which could influence the adoption and intensity of use of PPT.

While using a logit model, Ebojei *et al.* (2012) assessed the socio-economic factors influencing the adoption of hybrid maize in Giwa local government area of Kaduna state, Nigeria. The study indicated a significant influence of age, income level, education level attained by a farmer and extension visits to the probability of adopting hybrid maize. Besides the study concentrating on socio-economic factors, and failing to assess farmers' perception on their decision to adopt the hybrid maize, it did not evaluate the factors which influenced the decision to intensify the technology's use.

2.2 Farmers' perception and their underlying determinants

Perception refers to a mental set, thought or a conceptual direction of an individual or group of individuals about an issue in perspective (Van den Ban and Hawkins, 1996). Since farmers could perceive differently new innovations being promoted from technology developers and researchers, evaluating their perception is very fundamental in trying to understand their preference. Furthermore, there is need to understand what factors influence farmers' perception in an effort to shape the manner in which they view the respective technologies.

How farmers' perceive a new technology's characteristics is very important in shaping their acceptance behaviour.

In an effort to understand farmers' perception towards technology characteristics, Reed *et al.* (1991) proposed an index approach and demonstrated the matching of characteristics of a service to the preferences of customers. The approach involves calculating how important a particular characteristic is to the target population (demand index) and how well the technology package supplies them (supply index). This is very critical since technology developers are able to understand which characteristics are important (not important) to farmers.

In a study by Sall *et al.* (2000) on quantitative assessment of improved rice variety adoption in Senegal, an index approach was used to quantify the farmers' perceptions. The study indicated farmers' satisfaction and dissatisfaction on several technology characteristics from the calculated demand, supply and attainment indices. The results indicated areas of improvement by the technology developers and also stressed the need to involve farmers during the whole development process of a new technology thus ensuring the characteristics they perceive important are considered.

While using a likert scale, Khan *et al.* (2008c) evaluated farmers' perceptions of PPT for control of cereal stemborers and *Striga* weed in western Kenya and noted that, most farmers regarded *Striga* and stemborer infestations as their major problems in maize production together with other constraints. Most of PPT adopters (over 80%) were satisfied with the technology's effectiveness in control of *Striga*. Majority of the respondents indicated satisfaction with the technology's benefits such as; improvement in soil fertility, increase in maize yields and improved livestock fodder. The study however did not determine the factors which influenced farmers' perception.

While assessing the economic analyses of maize storage innovations in Southern Benin, Adegbola (2010) used index approach to analyze farmers' perceptions concerning the characteristics of storage innovations. The results indicated a satisfaction of farmers with the manner the storage innovation supplies them. For example, effectiveness against pests and the length of the storage were the most important preferred characteristics and were satisfactorily provided by the storage innovation. However, farmers were not satisfied with the supply of availability of the sofa grain product and purchase price. This study therefore stresses the need, to evaluate farmers' perception of technology characteristics.

In western Kenya, Murage *et al.* (2011b) carried out a study on determining the smallholder farmers' preferences for technology dissemination pathways using ordered probit regression. The study indicated high preference of field days and farmer teachers by farmers while radio and barazas had the least. The findings were important in ensuring that, the most effective dissemination pathway is used in transferring information regarding PPT to farmers.

Negatu and Parikh (1999) used ordered probit to determine the impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru Woreda district of Ethiopia and found out a significant positive influence off-farm income, distance of villages to town and number of visits to the nearby zone city on marketability perception. On the other hand, proportion of vertisol-area owned positively influenced grain yield perception. These findings stressed the need to include socio-economic and institutional factors as determinants of farmers' perception.

While using a rank ordered logit model, Velandia *et al.* (2011) investigated the factors which influenced cotton farmers' perceptions about the importance of information sources in precision farming decisions in USA. The results showed a significant influence of age, land tenure, income, percentage of income from farming and location of the household to the farmers' perception on information sources. Therefore, information providers could be in a better position to tailor their services, to the farmers expectations based on the determinants highlighted in the findings.

2.3 Actual and potential adoption rates studies

For an individual to adopt a new technology, one has first to be aware of its existence. Therefore, adoption is conditional on exposure subjected to farmers. For farmers to be exposed, they must be able to access necessary technological information and this call for an effective and efficient dissemination pathway. In western Kenya, several dissemination pathways have been identified to be effective in the diffusion of information to farmers. The most preferred were: field days and farmer teachers while radio and barazas were least preferred (Murage, 2011). The rate of adoption of a new technology being promoted is often determined by the availability of information to the farmers. Information availability is usually determined by cost incurred by farmers in its access and thus affordability of that information is fundamental. The farmer must know that a technology exists and that it's beneficial so as to upscale its adoption.

Sources of information available to the farmers are also very critical in shaping the individual's decision to adopt a new technology being promoted. They should be cheap and credible in order to encourage farmers to trust them. The manner in which information is presented to the farmers is equally important as the content of the information.

Farmers can be discouraged from searching for information due to high transaction costs involved and this could lead to information asymmetry. Institutions which assist in easing the effect of transaction costs on information search are fundamental for farmers adopt a new technology (Shiferaw *et al.,* 2009). The most notable institution is farmer group membership where several adoption studies have indicated a positive relationship between the variable and the decision to adopt (Amudavi *et al.,* 2008; Shiferaw *et al.,*ibid; Simtowe *et al.,* 2010).

Transaction costs incurred by farmers while searching for information are bound to increase as the distance from the household's location to the nearest agricultural office increase. Thus, farmers who are closer to the agricultural offices are expected to have a higher probability of being aware of existence of a new technology (Simtowe *et al.,* 2010).

Observed low adoption rates experienced in agricultural technologies being developed and promoted by different stakeholders in developing and developed nations can be explained by lack of awareness of the existence of the technology by a large proportion of the smallholder farming population (Diagne and Demont, 2007). Since adoption of a new innovation is conditioned on awareness of its existence, an individual could be able to estimate the adoption rates of that particular technology using exposure as the treatment variable as used in several adoption studies (Diagne and Demont, ibid; Diagne, 2009; Nguezet *et al.,* 2010).

The actual adoption rate is the uptake level which a technology has achieved at a particular point in time. On the other hand, potential adoption rate is the level at which that technology could have achieved, if the whole target population was made aware/exposed to the technology from the first time it was introduced in a particular region (Diagne and Demont, 2007). The difference between potential adoption rate and actual adoption rate is referred to as the adoption gap, or the unmet demand that is to be exploited once the whole population is made aware of existence of the new technology being promoted.

Several studies have been carried out to estimate the actual and potential adoption of Nerica rice varieties in some parts of Africa but very little has been done on any other agricultural technology in Kenya and Africa as a whole. Therefore, the impact of awareness/exposure on the adoption of any other technology apart from Nerica rice varieties is scanty in literature.

While using average treatment effect, Diagne (2006) evaluated the diffusion and adoption of Nerica rice varieties in Côte d'ivoire and indicated a huge adoption gap (23%) which could be exploited by making sure all the population were made aware of the existence of the varieties. Probability of exposure was positively influenced by several socio-economic and institutional factors among them: years of formal schooling of a farmer, number of Nerica varieties known in the village and village PVS. However, it was negatively influenced by the number of national agricultural research systems upland varieties known in the village. On adoption, household size, knowledge of Nerica varieties by the farmer and the farmers having practiced upland rice cultivation had a positive influence while age of a farmer and the fact that a farmer had a secondary occupation were some of the factors which had a negative influence on adoption decisions of farmers. The study however, did not assess the determinants of adoption intensity as well as farmers' perception inclusion in the adoption model.

In a study by Diagne and Demont (2007), average treatment effect estimation framework was used to show that observed sample adoption rate does not consistently estimate the population adoption rate even if the sample is randomly acquired. The main reason for using ATE in this study was due to the fact that it caters for selectivity bias and brings out the aspect of counterfactual thus providing consistent estimates of adoption rates unlike classical adoption models. The results indicated a 14% adoption gap which could be attained once the whole population was exposed to the Nerica rice varieties in Côte d'ivoire. Several factors which influenced adoption of Nerica rice varieties included: number of varieties known in a village, participation in participatory varietal selection (PVS) and being a resident of a village PVS among others. However, the study omitted perception in the adoption model, which is very important in shaping the adoption decisions of farmers.

Diagne (2009) used ATE estimation framework to assess the technological change in smallholder agriculture with an aim of bridging the adoption gap by understanding its source. The study indicated low actual adoption rates and high adoption gaps of Nerica rice varieties in Côte d'ivoire, Guinea, Benin and Gambia suggesting that the technology has potential which is yet to be realized due to limited awareness to the farmers in those countries. The determinants of awareness and adoption were different and differed in magnitude indicating that the two processes are not influenced by the same factors.

Low adoption rates of improved groundnut varieties in Malawi have been experienced over the past years, and have been attributed to lack of awareness to the whole population. This led to Simtowe *et al.* (2010) conduct a study on estimation of actual and potential adoption rates of improved groundnut varieties and found out that, only 26% of the sampled farmers grew at least one of the improved groundnut varieties. The potential adoption rate of improved groundnut for the population was estimated at 37%. Awareness of improved varieties was mainly found to be influenced by information access variables, with adoption being largely influenced by economic constraints. These results add weight to the findings of Diagne (2009), where adoption decision and probability of exposure were influenced by different factors.

A study by Nguezet *et al.* (2010) used ATE to estimate the actual and potential adoption rates of Nerica rice varieties in Nigeria. The findings indicated a huge adoption gap of the varieties due to limited awareness of its existence. Several socio-economic/demographic characteristics such as: years of experience positively influenced the probability of exposure to Nerica rice varieties while gender and main occupation of the farmer had a negative influence. On the other hand, age of a farmer, years of experience spent in growing upland rice and vocational training positively influenced the decision of farmers to adopt Nerica rice varieties while main occupation and gender of a farmer had negative influence. Although several factors had similar directional effect on the adoption decision and probability of exposure to Nerica rice varieties (years of experience, main occupation and gender of a farmer), some factors had an influence on either of the decisions (age of a farmer and vocation training). Thus, probability of exposure and adoption of Nerica rice varieties was influenced by different factors.

2.4 Summary and conclusion

From the reviewed literature, several knowledge gaps can be identified that guided this study in formulating its objectives and choice of the econometric models used in various estimations in order to fill them.

Technology adoption is not only a question of the decision to adopt, but also how much of the technology an individual puts into use. Various studies determine the factors which either influence the decision to adopt or intensity of use of a technology separately (Zegeye *et al.*, 2001; Mwabu *et al.*, 2006; Feleke and Zegeye, 2006; Salasya *et al.*, 2007; Amudavi *et al.*, 2008; Mignouna *et al.*, 2010; Ebojei *et al.*, 2012). However, only a few studies determine the factors influencing both adoption and intensity of use decisions together (Tura *et al.*, 2010; Mignouna *et al.*, 2011a; Murage *et al.*, 2012). Therefore, this study aimed to fill this gap by evaluating the factors which influenced the adoption and intensity of use of PPT and IR maize technology together, since both decisions are equally important in uptake of technologies.

Some studies have used Tobit model to evaluate the determinants of adoption and intensity of use of a new technology (Simtowe *et al.*, 2009; Murage *et al.*, 2012) which assumes that the two decisions are influenced by the same set of factors and are simultaneously made. However, very few studies have used Cragg's double hurdle model (Mignouna *et al.*, 2011a) which assumes that the two processes are independent and influenced by different set of factors. It also assumes that the two decisions are sequentially made. This study therefore aimed to fill this gap by evaluating the determinants of adopting and expanding the use of PPT and IR maize technology using the Cragg's double hurdle model.

Adoption studies always overlook the effect of farmers' perception (Adesina and Baidu-Forson, 1995). This is quite evident in the reviewed adoption literature,as many studies failed to include the variable in their respective regressions (Zegeye *et al.*, 2001; Mwabu *et al.*, 2006; Feleke and Zegeye, 2006; Salasya *et al.*, 2007; Diagne and Demont, 2007; Amudavi *et al.*, 2008; Khan *et al.*, 2008c; Diagne, 2009; Tura *et al.*, 2010; Nguezet *et al.*, 2010; Murage *et al.*, 2012; Ebojei *et al.*, 2012). However, Mignouna *et al.* (2011a) is an exception. This study aimed therefore to fill this gap by assessing the effect of perception on the decision to adopt and intensify the use of PPT and IR maize technology.

How farmers perceive technology's characteristics is fundamental in identifying which attributes satisfy (not satisfy) their expectations. Very few studies have been conducted on this aspect (Reed *et al.*, 1991; Sall *et al.*, 2000; Adegbola, 2010). This study used index approach to elicit which characteristics of PPT and IR maize technology are more important to the farmers and how well the technologies addresses them.

Several studies have been carried out on adoption of PPT and IR maize technology (Salasya *et al.,* 2007; Amudavi *et al.,* 2008; Khan *et al.,* 2008c; Mignouna *et al.,* 2010; Mignouna *et al.,* 2011a; Mignouna *et al.,* 2011b; Murage *et al.*, 2012) but very few studies have quantified the adoption rates. At best, they regard the adoption of the two technologies as either low or promising. In fact, no reviewed study has used ATE estimation framework to estimate the adoption rates of the two technologies despite its superiority in deriving consistent nonparametric and parametric estimators of population adoption rates and their determinants, unlike classical adoption models as demonstrated by several researchers (e.g. Diagne and Demont, 2007; Diagne, 2009; Simtowe *et al.,* 2010; Nguezet *et al.,* 2010). This knowledge gap was aimed to be filled by using, ATE to estimate the actual and potential adoption rates of PPT and IR maize technology and their determinants.

Several studies have been carried out on the adoption of PPT and IR maize technology (e.g. Salasya *et al.,* 2007; Amudavi *et al.,* 2008; Khan *et al.*, 2008c; Mignouna *et al.,* 2010; Mignouna *et al.,* 2011a; Mignouna *et al.,* 2011b; Murage *et al.*, 2012) but none that this study is aware of has compared the two. The information on an analysis of PPT and IR maize technology is scanty in literature, and this study aimed to fill this gap by comparing the uptake of the two *Striga* control innovations in Siaya county.

2.5 Theoretical framework

2.5.1 Theory on perception and adoption

Farmers are assumed to make adoption decisions based upon the objective of utility maximization, and will adopt an innovation when the utility of a new technology (U_k) exceeds the utility of a traditional technology (U_w). The utility derivable from a new technology is postulated to be a function of the vector of observed farm characteristics, farmer characteristics, institutional factors, perceived technology characteristics (X_i) and a random disturbance term having a zero mean. This arises from unobserved variation in preferences, attributes of the alternatives, and errors in optimisation. Perceived technology characteristics themselves are usually a function of objective/or subjective characteristics of a technology, farm and farmer-specific characteristics.

Following Adesina and Zinnah (1993), a farmer weighs the utility derived from adopting different technologies, and chooses the technology that promises higher utility than the traditional technology. If an individual's utility of adopting a new technology is denoted by $U_k(X)$ and the preference of adopting the traditional technology as $U_w(X)$ then, the preference for adopting the new and old technologies can be defined as a linear relationship as follows:

$$U_k(X) = XB_k + e_k \qquad (2.1)$$

$$U_w(X) = XB_w + e_w \qquad (2.2)$$

where B_k, B_w and e_k, e_w are the response coefficients and random disturbances associated with the adoption of new and traditional technologies respectively.

The probability of adopting a technology could be denoted by a dichotomous variable *Y*, which takes a value of 1 if the farmer is willing to adopt the new innovation and zero otherwise. The probability that a given farmer will adopt the new technology can be expressed as a function of *X* as follows:

$$\begin{aligned} P(Y=1) &= P(U_k > U_w) \\ &= P(XB_k + e_k > XB_w + e_w) \\ &= P[(X(B_k - B_w) > e_k - e_w] \qquad (2.3) \\ &= P(XB > e) \\ &= F(XB) \end{aligned}$$

where *P* is the probability function, $B = (B_k - B_w)$ which is a vector of unknown parameters and can be interpreted as the net influence of the vector of independent variables on adoption of the new technology, $e = (e_k - e_w)$ is a random disturbance term and *F*(*XB*) is cumulative distribution function *F* evaluated at *XB* (Rahm and Huffman,1984).

2.5.2 Theory on propensity score matching

Propensity Score Matching (PSM) is an impact assessment technique which constructs a statistical comparison group, which is based on a model of the probability of participating in the treatment, using observed characteristics. The approach captures the effects of different observed covariates (*X*), on participation in a single propensity score or index. Then the outcomes of adopting and non-adopting households with similar propensity scores are compared, with an aim of assessing the effect of a technology (Rosenbaum and Rubin, 1983).

Maize farmers are expected to increase their yields, after adopting PPT/IR maize technology, probably because the *Striga* weed would be mitigated or abated (Kanampiu *et al.,* 2002; Khan *et al.,* 2011). This would shift the production curve upwards from 1 to 2 (Figure 2.1).

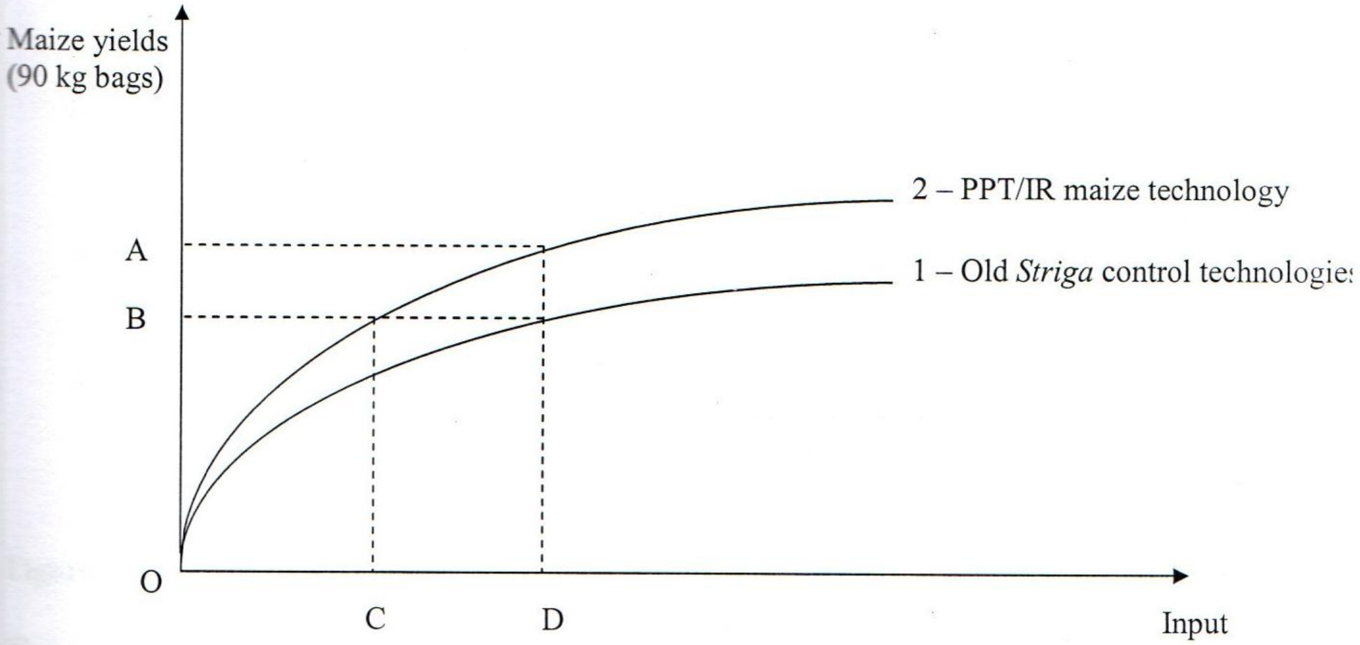

Figure 2.1: The nature of technology change

Using the same input level (OD), maize yields are expected to increase from OA to OB, due to the shift from production function 1 to 2. That would arise by adopting PPT/IR maize technology, and stopping the use of old *Striga* eradicating strategies. Alternatively, a farmer can produce the same output (maize yields) OB with a lower level of input (OC).

The impact of adopting PPT/IR maize technology on maize production can be evaluated as maize yield is expected to increase (A-B), due to the fact that, *Striga* weed would be mitigated or abated. As demonstrated in Figure 2.2, this increase in maize production would cause a parallel shift in the supply curve, through lowering the production costs per bag. This could be explained by the fact that, several costs especially labour costs incurred when using old *Striga* eradication strategies such as: uprooting of the weed or hand weeding, would be reduced.

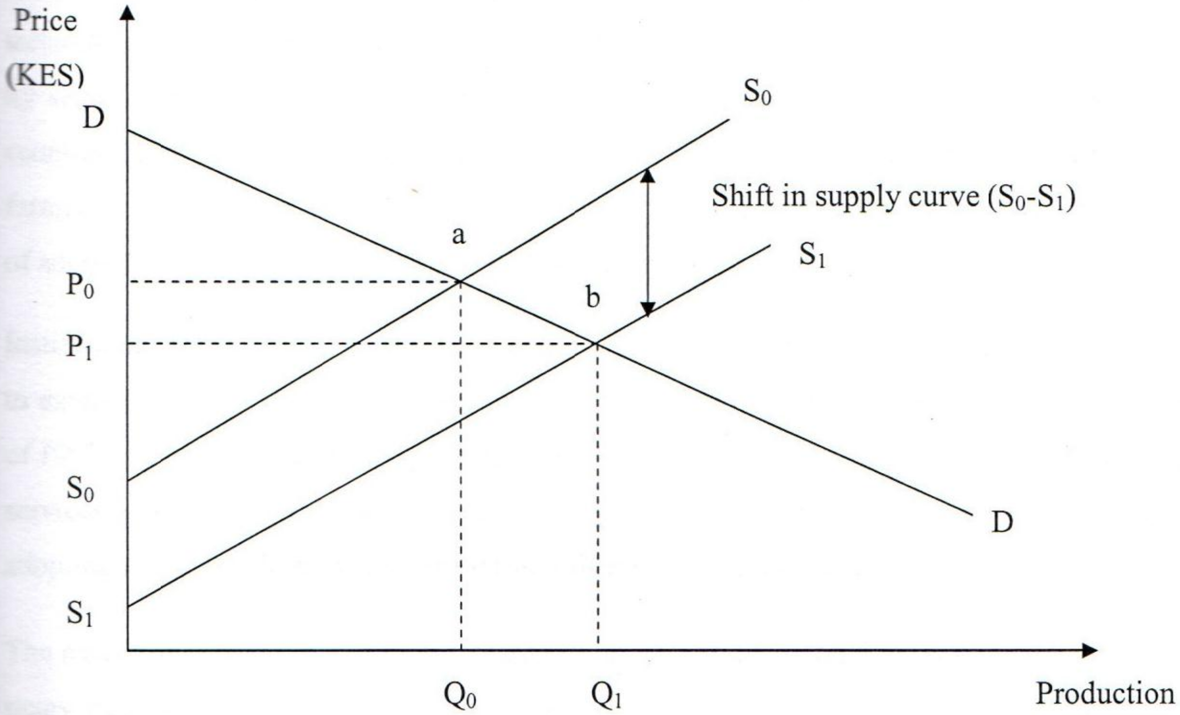

Figure 2.2: Shift in supply curve

The production of maize is expected to increase from Q_0 to Q_1 due to reduced effect of *Striga* weeds. This therefore, causes a shift in supply curve from S_0 to S_1, since farmers would produce more maize from their fields. As a result, total welfare effect would be represented by the area beneath the demand curve (DD), and between the two supply curves (S_0abS_1). This area shows the sum of consumer benefits (consumer surplus) represented by area P_0abP_1, and producer benefits (producer surplus) equal to area P_1bS_1 - P_0aS_0. The welfare effects indicate that, consumers would be gaining while producers lose.

2.6 Conceptual framework

The conceptual framework (Figure 2.3) outlines the conceptualized interrelationships for the study, the key variables involved and how they are interrelated. In theory, Feder *et al.* (1985) presented factors that can affect adoption of new technologies and they include: availability of credit, limited access to information (extension services), risk attitude, land tenure, membership to groups, labour availability and unreliable supply of farm inputs. Thus in this study, those factors were categorized into market and institution factors, and hypothesized to have a direct positive influence on the adoption of PPT and IR maize technology.

Adesina and Baidu-Forson (1995) indicated that, a farmer's decision to adopt a new technology and how much of the technology to adopt (adoption intensity) can be influenced by socio-economic factors. This study therefore, postulates a positive influence of socio-economic factors such as: age, income levels, land size owned by a household, gender of a farmer, household assets, education level attained by a farmer and family size to the decision of adopting and expanding the use of PPT and IR maize technology.

Institutional factors such as: access to credit facilities, farmer group membership and access to extension services are postulated to positively influence the adoption and intensity of use of PPT and IR maize technology. Therefore, those farmers who access credit and extension services and being members of producer groups, were postulated to have high probability of adopting and expanding the use of PPT and IR maize technology and vice versa.

The aspect of farmers' perception towards technology's attributes is always overlooked, with many studies focussing more on the socio-economic and institutional factors while analysing the factors influencing farmers' decision to adopt a technology (Adesina and Baidu-Forson, 1995). This study therefore, included perception as a factor which was hypothesized to positively influence the decision to adopt and intensify the use of PPT and IR maize technology.

Transport and communication infrastructures variables such as: distance to the nearest shopping centre which was used as a proxy of input and output market, was hypothesized to negatively influence adoption and expansion of PPT and IR maize technology. On the other hand, a negative influence was postulated between distance to the nearest administration centre from a household's location to the decision of adopting and expanding the use of PPT and IR maize technology. This variable was used as a proxy of information access, since most agricultural offices are located in administration centres especially at the county level.

Some technological factors e.g. cost and availability of the *desmodium* and IR maize seed were postulated to negatively influence adoption and expansion of PPT and IR maize technology directly. However, other technological characteristics such as: how effective both technologies are in *Striga* control and seed germination rate among others, were postulated to positively influence perception, which in turn positively influence the decision of a farmer to adopt both technologies.

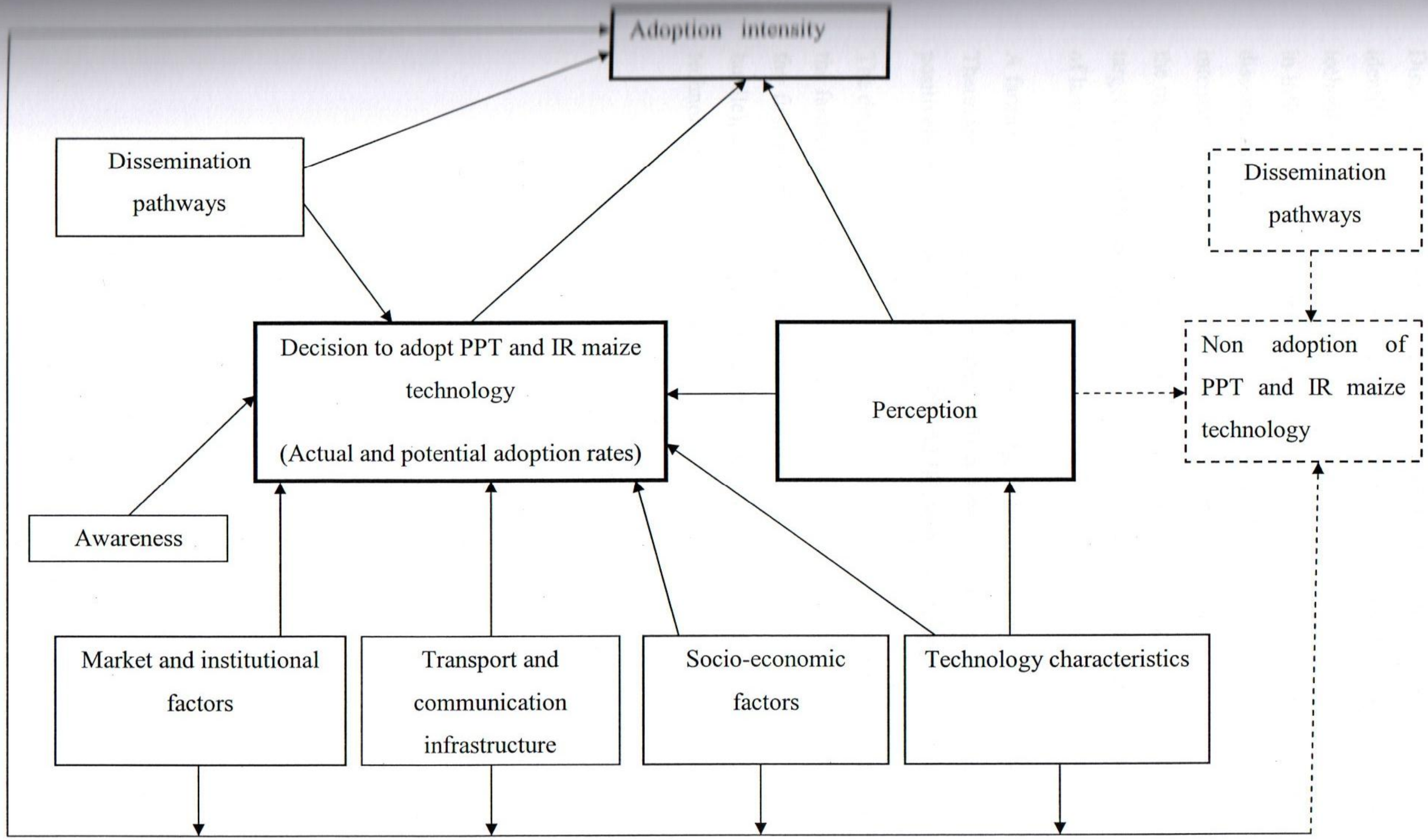

Figure 2.3: Conceptual framework

(Author's compilation)

Dissemination pathways chosen by technology promoters to relay information have been identified to be very important, in influencing the decision to adopt and expand the use of a technology. Several pathways especially field days, field teachers among others are important in influencing the decision to adopt PPT (Murage, 2011). This study therefore, hypothesized dissemination pathways to have a direct positive influence on the decision to adopt and intensify the use of IR maize technology and PPT in Siaya county. This is due to the fact that, the more effective and efficient a dissemination pathway is in transmitting information to the target households, the higher the probability of the farmers adopting and expanding the area of land put under PPT and IR maize technology.

A farmer can only adopt a new technology being promoted if he/she is aware of its existence. Therefore, in this study, exposure to a new technology (awareness) was postulated to positively influence adoption of PPT and IR maize technology.

The decision to expand the use of PPT and IR maize technology was expected, to follow after the farmers had decided to adopt the two technologies respectively. Therefore, after making the first decision of adopting PPT and IR maize technology (hence going over the first hurdle), the second decision making, which is that of how much of PPT and IR maize technology to put into use sets in.

CHAPTER THREE

METHODOLOGY

3.1 Study area

Siaya is one of the 6 counties that comprise Nyanza Province. It is bordered by Busia district to the North, Vihiga and Butere-Mumias districts to the North-East, Bondo district to the South, and Kisumu district to the South-East. The county covers an area of 1773 square kilometres (Km^2), of this 1263 Km^2 is agricultural land and 253 Km^2 is covered by water with population estimated at 550,224 persons (GoK, 2010). It lies between latitude 0° 26' to 0° 18' North and longitude 33° 58' East and 34° 33' West. Siaya county is divided into seven administrative divisions: Yala, Wagai, Karemo, Ugunja, Boro, Uranga, and Ukwala. The largest division is Ukwala with an area of 319 Km^2, followed by Karemo with an area of 235 Km^2, while Boro being the smallest division with a total area of 180 Km^2. Siaya county has two rainy seasons (bimodal) with the long rains falling between March and June and short rains between September and December. The geography of the land influences distribution and amount of rainfall. The area is drier in the western part towards Bondo district and is wetter towards the higher altitudes in the eastern part. On the highlands, the rainfall ranges between 800-2000 mm per annum (p.a.) and the lower areas receive between 800-1600 mm p.a. The altitude of the county rises from 1,140 m in the eastern parts to 1,400 m above sea level in the west. The mean minimum temperature is 15°C while the mean maximum temperature is 30°C. Humidity is relatively high with mean evaporation being between 1800 mm to 2000 mm p.a. The main food crops include maize, beans, sorghum, sweet potatoes, cassava, groundnuts, bananas and cash crops are sugarcane and coffee. Livestock enterprises include indigenous cattle, dairy, goats, sheep and poultry (GoK, 2002).

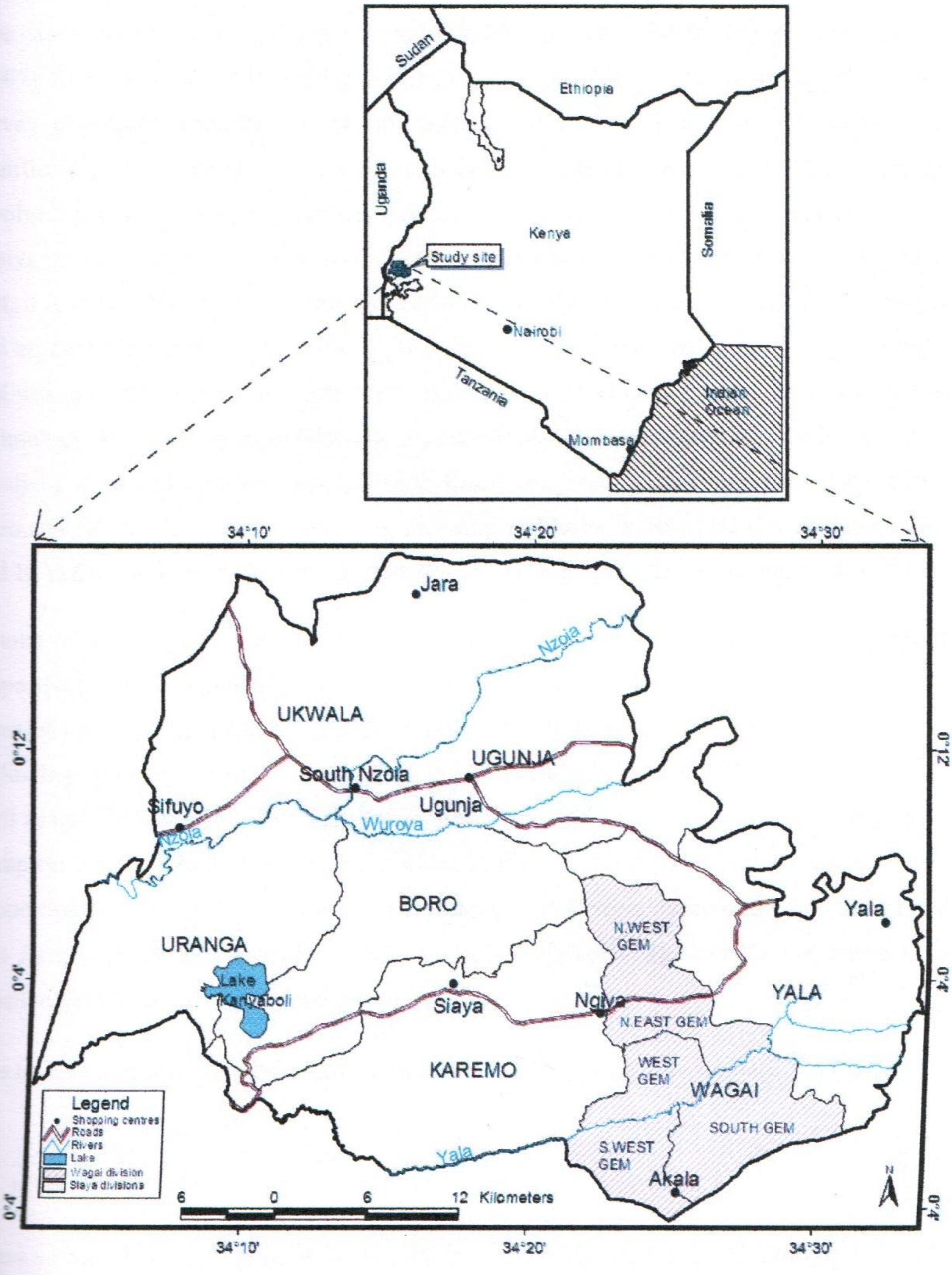

Figure 3.1: Map of the study area

3.2 Sampling procedure and data collection

This study employed a sampling procedure similar to that used by Diagne and Demont (2007), Simtowe *et al.* (2010), Diagne (2009) and Nguezet *et al.* (2010) among others. The survey population consisted of all smallholder farmers in Siaya county.A multi stage stratified sampling procedure was used in selecting households for this study. The first stage involved purposive sampling of Siaya county where *Striga* is most prevalent in western Kenya. In the second stage, Wagai division was purposively sampled. This was on the basis that, it is in this division where the two technology promoters had conducted demonstrations and on-farm trials within Siaya county. The third stage involved selection of sample villages and was not entirely random, since it purposively included villages where PPT and IR maize technology staff had been conducting on-farm trials and demonstrations within the five locations of Wagai division namely: North East Gem, South East Gem, West Gem, South Gem and North West Gem. In selecting the sample villages, a list of all villages where PPT and IR maize had been introduced (called PPT and IR villages) was constituted first.

A total of 32 villages (17 and 15 villages in the PPT and IR maize technology subsamples respectively) were sampled. These included non-PPT and non-IR villages, which were sampled randomly after compiling a list of neighbouring villages within 5 to 15 km where the technology promoters had not undertaken any research activity. The PPT and IR villages as well as non-PPT and non-IR villages were used as strata. Fourth stage involved compiling a complete list of all households in the sampled villages where farmers were drawn randomly proportionately to size. The total sample drawn was 326 farmers which comprised of 175 and 151 farmers in the PPT and IR maize technology subsamples. The sample was drawn from smallholder farmers that grew maize in the division.

The total sample size was computed based on the following formula (Kothari, 2005).

$$n = \frac{Z^2 p.q.N}{e^2(N-1) + Z^2 p.q} \tag{3.1}$$

where n= sample size, p= population proportion with the characteristic of interest, $q = (1 - p)$ N= size of the population, e = margin of error, Z= critical value at the desired confidence interval.

Given a population of approximately 4000 maize farmers in the study area who had the characteristics of interest, and assuming acceptable error of 5%, the sample size was calculated as follows:

$$n = \frac{(1.96)^2 * (0.5) * (0.5) * 4000}{(0.05)^2 (4000 - 1) + (1.96)^2 * (0.5) * (0.5)} = 350 \tag{3.2}$$

However, due to non-responses, a few farmers were not interviewed. Pre-testing of questionnaires was carried out before actual data collection and amendments done which made sure the required data was collected for the analysis. Data on socio-economic, institutional, technological, transport and communication factors were collected.

3.3 Description of variable used in the analysis

Table 3.1 gives a description of the variables used in various regression models. The explanatory variables chosen were mainly based on literature review findings. A description of these variables is given thereafter discussing their expected effects on the farmers' perception and adoption and intensity of use of PPT and IR maize technology.

The variable *AGEHHH* (age of the household head), measured in years, was hypothesized to have either a positive or negative sign. Older farmers usually have more experience in farming activities, and are better able to assess the attributes of a technology than younger farmers. However, it could also be that older farmers are less risk takers (risk averse) than younger farmers, and therefore are less likely to adopt new technologies (Adesina and Baidu-Forson, 1995; Rahelizatovo and Gillespie, 2004). This therefore clearly shows that, there is no agreement in the adoption literature, on the direction of the age of a famer as a factor which influences adoption of a given technology. There is also no consensus in literature on the expected sign of age as it influences farmers' perception. It could be that, older farmers due to their vast experience in farming tend to have positive perception towards the effectiveness of a *Striga* controlling technology or vice versa. Schtinkey *et al.* (1992) established a positive relationship between age and farmers' preference for various information sources. On the other hand, several studies have indicated a negative relationship (Bagheri *et al.*, 2008; Velandia *et al.*, 2011).

It was postulated that, *GENDERHHH* (gender of a household head) which is a qualitative variable, taking the value of 1 if the respondent was a male and zero if a female, would positively influence the adoption and intensity of use of PPT and IR maize technology. Thus, male headed households had a higher probability of adopting and intensifying the use of PPT and IR maize technology. This is due to the fact that, females are more risk averse to new technology and their concern being essentially sustenance of food security, any technology that appear to affect the known equilibrium will not be readily adopted. Therefore, male headed households are hypothesized to be less risk averse than the female headed households due to the fact that, they have greater access to resources and information (Kaliba *et al.,* 2000; Yesuf and Bluffstone, 2009). Thus the *a priori* sign was expected to be positive.

It was hypothesized that, *YRSCHHH* (education level attained by a household head) measured by the number of years spent in formal schooling, would positively influence the adoption and intensity decisions of a farmer. This is due to the fact that, it is a good proxy of managerial ability. An educated farmer is expected to understand and interpret information better than a non-educated one. Some studies have indicated a positive relationship between years spent in formal school and the decision of a household head to adopt a new technology (Genius *et al.,* 2006; Ajewole, 2010). Education can be used as a proxy of a farmer's ability to acquire and effectively use information (Genius *et al.,* ibid). A more educated farmer is hypothesized to have positive perception towards PPT or IR maize technology effectiveness in controlling *Striga*. Several studies have indicated a positive relationship between the education level attained by a farmer and perception (Velandia *et al.,* 2011).

The variable *WORKFORCE* (total labour force of a household), measured by the number of members in a household between 18-65 years, was postulated to positively influence intensity of use of PPT and IR maize technology. This was in line with the definition of labour force in Kenya (GoK, 2010), which also conforms to most international definitions. The households with larger workforce are expected to have a higher probability of intensifying the use of PPT and IR maize technology and vice versa. Household size has been used by some studies as a proxy to labour availability, and a positive relationship between size of the household and the extent of adopting IR maize indicated (Mignouna *et al.,* 2011b). However, some studies have included two variables i.e. labour availability and household size, and noted a positive relationship between labour availability and the decision to adopt irrigated rice production (Jamala *et al.,* 2011).

It was postulated that, *FGMEM* (group membership) which is a qualitative variable taking the value of 1, if a household head is a member of a farmer group and zero if not, would positively or negatively influence a farmer's decision to adopt, and intensify the use of PPT and IR maize technology. This could be attributed to the fact that, when farmers are in a group, they tend to share costs incurred, and the transaction as well as transformation costs are lowered. This therefore explains a positive relationship (Amudavi *et al.,* 2008; Shiferaw *et al.,* 2009; Simtowe *et al.,* 2010). On the other hand, some studies have indicated a negative relationship between group membership and decision to adopt new innovations (Bayard *et al.,* 2006; Murage *et al.,* 2011a). Social capital which are the networks, values and norms that govern interactions among people (Grootaert, 2001) are crucial in reducing the transaction costs incurred by farmers. In fact, Wambugu *et al.* (2009) indicated a positive relationship between social capital and the performance of producer organizations.

A negative relationship between *DSADMN* (distance to the nearest administration centre) measured in kilometres, and the decision to adopt and expand the use of PPT and IR maize technology was hypothesized. This is because, agricultural offices are usually located in an administration centre especially in a county level and are used as proxy of information availability. The further away a household's location is from the administration centre, the less likely it is to adopt or intensify the use of a new technology and vice versa, due to the availability and accessibility of information. Simtowe *et al.* (2010) incorporated the variable in the groundnut adoption model, and reported a negative sign showing an inverse relationship between the variables.

The relationship between *DSPCNTR* (distance to the nearest shopping centre) measured in kilometres, and the extent of PPT and IR maize technology use was hypothesized to be negative. This is because, after uptake the households were expected to sell their surpluses to the nearest market. It was thus used as a proxy of nearness to the input and output market. The further away a household is located from the market, the more difficult it becomes to sell outputs and buy inputs due to transaction and transformation costs involved.

The variable *EXTENACS* (access to extension) which qualitative taking the value of 1, if a household head accessed extension services and zero if not, was postulated to positively influence the decision to adopt and expand the use of PPT and IR maize technology. This is in line with Adesina and Baidu-Forson (1995), who found a significant positive relationship between access to extension services and the adoption decision. Extension agents usually furnish farmers with information on how to use a new technology and help them understand its attributes and characteristics. They expose farmers to new technologies by relaying information to them, which could shape their decisions towards adoption.

Table 3.1: General description of variables used in the various regression models

Variable	Description of the variable	Measurement	Type	Model in which the variable is used
DEPENDENT				
ADPTN	Whether a household head had adopted PPT/IR maize technology	1 = Yes, 0 = No	Dummy	DH,ATE
INTEN	Ratio of the area under PPT/IR maize technology to the total household's cultivated land	Unit less	Continuous	DH
EXPOSURE	Whether a household head was aware of the existence of PPT/IR maize technology	1 = Yes, 0 = No	Dummy	ATE
INDEPENDENT				
AGEHHH	Age of the household head	Years	Continuous	OP,DH,ATE
GENDERHHH	Gender of the household head	1 = Male, 0 = Female	Dummy	OP,DH,ATE
YRSCHHH	Years of schooling of the household head	Years	Continuous	OP,DH,ATE
WORKFORCE	Members of a household who could offer labour (between 18-65 years)	Persons	Dummy	OP,DH
CULTLAND	Total household's cultivated land	Acres	Continuous	DH
EXTENACS	Whether a farmer had sought extension services	1 = Yes, 0 = No	Dummy	OP,DH,ATE
FGMEM	Whether a farmer was a group member	1 = Yes, 0 = No	Dummy	OP,DH,ATE
DSADMN	Distance of the household from the nearest administration centre	Kilometres	Continuous	OP,DH,ATE
LOGINCOME	Household's income level	KES	Continuous	OP,DH,ATE
TLU	Tropical livestock unit of a household	Units	Continuous	OP,DH,ATE
RADOWNSP	Whether a household head owned a radio	1 = Yes, 0 = No	Dummy	OP,DH,ATE
LANDSZ	Total land size owned by a household	Acres	Continuous	OP,DH,ATE
HHSIZE	Number of members in a household	Persons	Continuous	OP,DH,ATE
INTEXTDSADMN	Interactive variable between extension access and distance to the nearest administration centre	Unit less	Continuous	DH
PERCPRANK	Perception of a household head towards the effectiveness of IR maize technology and PPT in controlling *Striga*.	3 = Very good, 2 = Good, 1 = Poor, 0 = No perception	Categorical	OP,DH
MOBOWNSP	Whether a household head owned a mobile phone	1 = Yes, 0 = No	Dummy	OP,DH
DSPCNTR	Distance to the nearest shopping centre	Kilometres	Continuous	DH
INTPERCYRSC	Interactive variable between perception and years of schooling	Unit less	Continuous	DH
FRMLBPAT	Household's head farm labour participation	1 = Full time, 0 = Otherwise	Dummy	DH

Note: OP = Ordered Probit, DH = Double hurdle model ATE = Average treatment effect estimation framework
Source: Survey data, 2012.

The variable *TLU*[1] (tropical livestock unit) measured in the number of units owned by a household, was used as a proxy of wealth. This is due to the fact that, it's often used as a source of income for farmers to reinvest in adoption and intensification of agricultural technologies. Therefore this study hypothesized that, the larger the TLU a household had the higher the probability of adopting and intensifying the use of PPT and IR maize technology. The variable has been used by several authors (Amudavi *et al.,* 2008; Salasya *et al.,* 2007; Murage, 2011).

It was hypothesized that, *LOGINCOME* (income level of a household), measured in KES, would have a positive influence in making adoption and intensity decisions. This is due to the fact that, households with higher incomes are more likely to adopt or intensify the use of PPT and IR maize technology since they are less cash constrained, and are more risk loving than households with low incomes who are more risk averse (Rosenzweig and Binswanger, 1993). Since the cost of buying IR seed, *desmodium* seed and Napier grass as well as setting and maintaining the PPT plots is high, this shows that only households with a higher income level were more likely to adopt PPT and IR maize technology. The income levels of households were calculated from crop/livestock sales, off-farm and non-farm income. Several adoption studies have included this variable (Ebojei *et al.,* 2012). A positive relationship between income level of a household and perception was hypothesized.

The relationship between *RADOWNSP* (ownership of a radio) which is a qualitative variable, taking the value of 1 if a household owns a radio and zero if otherwise, and the decision to adopt and intensify the use of PPT and IR maize technology, was hypothesized to be positive. This was in line with Simtowe *et al.* (2010), who indicated a positive influence of owning a radio to the decision of adopting groundnuts in Malawi. This is because, radio as a dissemination pathway is mostly used by technology promoters, to reach large masses by airing agricultural programmes and also advertisements.

In this study, the variable *MOBOWNSP* (mobile phone ownership) was considered as qualitative, taking the value of 1 if a household head owns a mobile phone and zero if otherwise. It was hypothesized to positively influence, the adoption intensity of PPT and IR maize technology. This is due to the fact that, farmers who own a mobile phone, could use it to gather information which could be vital in wooing them to decide on the extent of

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[1] Total livestock unit was computed as (0.7 for cow + 0.5 for Heifer + 0.3 for calf +0.1 for goat + 0.1 for sheep +0.01 for chicken + 0.2 for Pigs) FAO (1986)

adoption(intensity). It was therefore used as a proxy of information access. The farmers could even call each other or extension agents and consult. Kirui *et al.* (2010) indicated a moderate use of mobile-phone based banking among smallholders in Kenya, which is mainly used in agricultural related purposes such as: purchase of seed, fertilizer for planting and topdressing, farm equipment/implements among others. Ownership of caller-ID and second phone lines has an indirect impact on attitude and intention of users, thereby influencing beliefs about the innovation's compatibility and observability (Vishwanath and Goldhaber, 2003).

It was postulated that, *HHSIZE* (total number of members in a household), measured by the number of persons in a household, would positively influence the decision of farmers to adopt PPT and IR maize technology. This variable can be viewed from two angles. The total number of members in a household could be used as a proxy of family labour (Southavilay *et al.*, 2012; Udensi, 2012). On the other hand, members in a household could also be involved in off-farm activities thereby earning income which could be vital in the adoption of new innovations (Yirga, 2007).

The variable *PERCPRANK* (perception on the effectiveness of PPT and IR maize technology towards *Striga* control),which was considered as a categorical taking the values of 3, 2 ,1 and 0 if a household's head perception was "very good", "good", "poor" or "no perception" (insensitive) respectively, was postulated to positively influence adoption intensity. The higher the perception rate i.e. "very good", the higher would be the probability of intensifying the use of PPT or IR maize technology. Some studies have included perception in the adoption model and found a significant positive influence (Adesina and Baidu-Forson, 1995). However, Mignouna *et al.* (2011b) hypothesized a positive relationship, but the results showed a negative sign which was not expected. This unexpected sign was attributed to the possibility that, farmers' positive perception about IR maize could have been distorted by other perceptions, or due to negative correlation between the variable and other varietal characteristics not included in the model. It could also due to the fact that, farmers' perception is subjective and prone to bias.

Interactive variables have been used in several studies (Yun, 2003). There are two types of interactive variables: either between dummy variables or between dummy and continuous variables (Yun, ibid). The study argued that, interaction terms of sets of dummy variables could be treated as another set of categorical variables. The interaction variables between dummy variables can be treated the same as the "usual" set of dummy variables or there could be an interaction between categorical variables and continuous variables. The variables should be centred at the mean since the coefficients becomes easier to interpret. This involves subtracting the mean from each observation of the independent variable of interest so that the new mean is equal to zero. The most important thing to put in mind is that, all the variables that are part of the interaction should stay in the equation even if these main effects are not significant (Young, 2006).

In this study therefore, two interactive variables were incorporated with the aim of assessing the product effect that such a variable might have on adoption and intensity decisions of PPT and IR maize technology. The study hypothesized a negative relationship between access to extension and distance to the nearest administration centre which hosts extension agents. Therefore, as the distance increases, the probability of accessing extension services decreases due to the costs involved. The two were interacted (INTEXTDSADMN) with a postulated negative sign.

Perception and years spent in formal school (education level) can be interacted, thus creating a new variable (INTPERCYRSC) as used in this study. This is because, the more educated a farmer is, the more the likelihood that he/she will be able to access and effectively use information. This therefore changes how a farmer perceives the effectiveness of PPT or IR maize technology in controlling *Striga*.

In this study, *ADPTN* (adoption status of a household head) was considered as a qualitative variable, taking the values of 1 if a household head had adopted PPT/IR maize technology or 0 if otherwise. It was used as a dependent variable in the determination of factors which influenced the decision to adopt PPT/IR maize technology. It was postulated to be positively or negatively influenced by several socio-economic and institutional factors.

The variable *INTEN* (ratio of the area under PPT/IR maize technology to the total household's cultivated land), was used to denote the intensity of PPT and IR maize technology adoption. It was used as a dependent variable, in analysing the determinants of expanding the use of PPT and IR maize technology.

The variable *EXPOSURE* (whether a household head was aware of the existence of PPT/IR maize technology) is qualitative, taking the value of 1 if a household head was exposed or 0 if not. It was used as a dependent variable in evaluating the actual and potential adoption rates of PPT and IR maize technology.

CHAPTER FOUR

FARM AND FARMER'S CHARACTERISTICS: A DESCRIPTIVE ANALYSIS

4.1 Descriptive statistics for selected farm and farmers' characteristics

Table 4.1 presents the summary statistics of variables used in this study. Several variables showed significant mean differences between adopters and non-adopters. The mean difference for *AGEHHH* (age of a household head), *YRSCHHH* (years of schooling of a household head), *LANDSZ* (land size owned by a household), *HHSIZE* (household size), *DSADMN* (distance to the nearest administration centre) and *TLU* (tropical livestock unit) were significant at 1% while *LOGINCOME* (income level of a household) was significant at 10% level for PPT. On the other hand, the mean differences for *YRSCHHH* (years of schooling of a household head), *HHSIZE* (household size) and *LOGINCOME* (income levels of a household head) of the adopters and non-adopters of IR maize technology, were significant at 1% while *LANDSZ* (land size owned by a household) and *DSADMN* (distance to the nearest administration centre) were significant at 10% level.

The average age of PPT adopters and non-adopters was 50 and 40 years respectively. On the other hand, the adopters of IR maize technology were on average aged 51 years compared to 48 years of non-adopters. The mean difference between the average ages of adopter and non-adopters of PPT was significant at 1% level, while it was insignificant for adopter and non-adopters of IR maize technology. On average, household heads from PPT sub-population were younger (44 years), as compared to their IR maize technology counterparts (49 years). It is apparent that, the adopters of both technologies were older compared to their respective non-adopters.

On average, adopters of PPT and IR maize technology had spent approximately 9 years in formal schools while the non-adopters for both technologies had about 4 years. The mean difference for the number of years in schooling for both technologies was highly significant at 1% level. This indicated that, adopters of both technologies were more educated than non-adopters. This compares fairly well with the population statistics in Kenya where 79.5% of the population nationally and in particular 91.9% in Nyanza province can read and write (GoK, 2007). This compares fairly closely with the average years spent in formal school by a household randomly selected from the sample (6 years). This shows that literacy levels in the study area are high.

Table 4.1:Descriptive statistics for selected farmers' and farm characteristics

Variable	Pooled data N = 326	PPT N = 175	IR maize technology N = 151	t -value	χ^2	PPT				IR maize technology			
						Adopters N = 61	Non-Adopters N=114	t-value	χ^2	Adopters N = 53	Non-Adopters N = 98	t-value	χ^2
	Mean/ percent	Mean/ percent	Mean/ percent			Mean/ percent	Mean/ percent			Mean/ percent	Mean/ percent		
AGEHHH	47	44	49	-4.2***		50	40	5.7***		51	48	1.1	
	(13.1)	(12.4)	(13.3)			(9.3)	(12.4)			(14.9)	(12.1)		
YRSCHHH	6.0	5.9	6.1	-0.5		8.8	4.3	7.8***		9.2	4.5	6.9***	
	(4.3)	(4.2)	(4.5)			(3.7)	(3.6)			(4.6)	(3.6)		
LANDSZ	3.8	4.7	2.8	7.9***		5.6	4.2	3.9***		3.0	2.7	2.3**	
	(2.3)	(2.4)	(1.8)			(2.2)	(2.3)			(2.0)	(1.6)		
HHSIZE	6.0	7.0	6.0	3.4***		9.0	5.0	11.0***		6 .0	5.0	2.7***	
	(2.7)	(3.3)	(1.8)			(2.3)	(2.6)			(2.1)	(1.5)		
LOGINCOME	4.6	4.5	4.6	-4.1***		4.7	4.6	2.2*		4.6	4.5	5.0***	
	(1.1)	(0.9)	(0.9)			(0.4)	(0.4)			(1.2)	(0.4)		
DSADMN	3.7	3.8	3.6	0.7		2.3	4.6	-6.0***		2.4	4.2	-4.1***	
	(2.7)	(2.6)	(2.8)			(1.7)	(2.6)			(2.2)	(2.9)		
TLU	3.2	3.0	3.4	-1.2		4.6	2.2	6.7***		3.8	3.2	1.4	
	(2.6)	(2.5)	(2.6)			(2.5)	(2.1)			(2.9)	(2.4)		
WORKFORCE	4.0	5.0	4.0	3.3***		8.0	3.0	15.1***		6.0	3.0	6.8***	
	(3.0)	(3.1)	(2.8)			(2.4)	(1.8)			(3.6)	(1.5)		
DSPCNTR	3.0	3.0	3.1	-0.5		2.4	3.3	-2.0***		2.7	3.9	2.6**	
	(2.7)	(2.6)	(2.8)			(2.3)	(2.7)			(2.6)	(3.1)		
INTEXTDSADMN	1.6	1.9	1.2	2.8***		1.7	2.0	-0.7		1.4	1.1	0.7	
	(2.4)	(2.5)	(2.2)			(1.8)	(2.8)			(1.9)	(2.3)		
INTPERCYRSC	7.3	7.1	7.5	-0.3		20.4	0.0	19.2***		21.3	0.0	14.7***	
	(12.5)	(11.8)	(13.3)			(11.4)	(0.0)			(14.4)	(0.0)		
INTEN	0.1	0.03	0.14	-6.0***		0.07	0.0	17.8***		0.4	0.0	14.5***	
	(0.1)	(0.1)	(0.3)			(0.04)	(0.0)			(0.3)	(0.0)		
GENDERHHH (%)					1.1				11.7***				2.5
1 = Male	45.4	45.3	54.7			63.9	36.8			54.7	51.2		
FGMEM (%)					2.0				19.7***				39.2***
1 = Yes	47.2	50.9	43.0			73.8	38.6			77.4	24.5		
PERCPRANK (%)					1.8				95.9***				45.1***

Variable	Pooled data N = 326	PPT N = 175	IR maize technology N = 151	t-value	χ^2	PPT				IR maize technology			
						Adopters N = 61	Non-Adopters N=114	t-value	χ^2	Adopters N = 53	Non-Adopters N = 98	t-value	χ^2
	Mean/ percent	Mean/ percent	Mean/ percent			Mean/ percent	Mean/ percent			Mean/ percent	Mean/ percent		
0 = No perception	65.0	65.1	64.9			0.0	76.3			0.0	41.8		
3 = Very good	20.6	21.7	19.2			62.3	11.4			54.7	12.2		
EXTENACS (%)					5.4^{**}				19.6^{***}				0.6
1 = Yes	50.0	56.0	43.0			78.7	43.9			66.0	69.4		
MOBOWNSP (%)					6.0^{**}				2.6				2.0
1 = Yes	70.2	76.0	63.6			68.9	79.8			86.8	79.0		
RADOWNSP (%)					0.364				1.8				5.2^{**}
1 = Yes	71.2	72.6	69.5			78.7	69.3			81.1	63.3		
FRMLBPAT (%)					2.3				0.1				0.0
1 = Full time	59.8	56.0	64.2			54.1	57.0			64.2	64.3		
ADPTN (%)					0.0								
1 = Yes	35.0	34.9	35.1			34.9				35.1			
EXPOSURE (%)					16.5^{***}				90.5^{***}				30.4^{***}
1 = Yes	61	50.9	72.8			100	24.6			100	58.2		

Note: Figures in the parentheses are the standard deviations associated with the means for the variables indicated.
$^{***}P < 0.01$, $^{**}P < 0.05$ and $^{*}P < 0.10$ mean significant at 1%, 5% and 10% probability levels, respectively.
Source: Survey data, 2012.

The average land size owned by a PPT and IR maize technology adopter was 5.6 and 3.0 acres respectively. On the other hand, non-adopters of PPT and IR maize technology owned 4.2 and 2.7 acres respectively. The mean difference in average land sizes owned by PPT and IR maize adopters was significant at 1% and 5% level respectively. This shows that, adopters of both technologies own relatively large tracks of land as compared to the non-adopters. On average, households in PPT sub-population owned relatively larger tracks of land (4.7 acres) as compared to their IR maize technology counterparts (2.8 acres). However, a household randomly selected from the whole sample would own 3.8 acres of land on average.

On average, *HHSIZE* (household size) of PPT and IR maize technology adopters was 9 and 7 members respectively, while that of non-adopters was 5 for both technologies. The adopting households for both technologies were bigger in size, as compared to their non-adopting counterparts. The average number of members in a household from PPT sub-population, was higher (7 persons) than the IR maize sub-population (6 persons). The national and Nyanza province average household sizes is 5 persons, which is on average 1 person more (4 persons), than that of Siaya county (GoK, 2007).

The average income levels of PPT and IR maize technology adopting households was KES 53,951 and KES 44,566, while the non-adopters had KES 40,926 and KES 31,768 respectively. The mean difference between the income levels was significant at 10% for PPT adopter and non-adopters and significantly different at 1% for IR maize technology. Thus, the adopters for both technologies had a higher income levels compared to the non-adopters. Most of PPT adopting households were male-headed (63.9%), compared to 54.7% for the IR maize technology.

Most of PPT adopting households were male headed (63.9%), compared to 54.7% of IR maize technology. However, approximately 45.3% households from the PPT sub-population were male headed compared to 54.7% from the IR maize technology sub-population. About 45.4% of the sampled households were male headed and this compares fairly closely to 49.3% of households headed by men nationally and 47.6% in Siaya county (GoK, 2007).

On average, *DSADMN* (distance from PPT adopting households to the nearest administration centre), was 2.3 km as compared to 4.6 km of non-adopters. On the other hand, the adopting households of IR maize technology covered approximately 2.4 km to the nearest administration centre, compared to 4.2 km covered by non-adopters. This showed that, adopters of both technologies were closely located to the agricultural offices where they could access information. On average, households in the PPT sub-population were generally further away from the nearest administration centre (3.8 km), as compared to their counterparts in IR maize technology sub-population (3.6 km). A household randomly drawn from all sampled farmers, was likely to be 3.7 km away from the nearest administration centre.

The adopters of PPT and IR maize technology owned on average, a total of 4.6 and 3.8 *TLUs* (tropical livestock units) respectively. Their respective non-adopters owned approximately 2.2 and 3.1 units, and reflected the importance of livestock ownership in adopting these technologies. In the PPT sub-population, households on average owned fewer *TLUs* (3.0), as compared to their IR maize technology counterparts (3.4 units).

About 73.8% of PPT adopters were members of farmer groups, as compared to 77.4% of IR maize technology. This shows the importance of social capital in adoption of the two technologies. However, more household heads in the PPT sub-population (50.9%) were members of farmer groups, as opposed to 43.0% in IR maize technology sub-population. From the whole sample, 47.2% of household heads were members of farmer groups (Table 4.1).

Approximately 57% of PPT adopters had accessed extension services, compared to 66% of IR maize technology. This shows the importance of information availability and accessibility, in the adoption of the two technologies. More households from the PPT sub-population (56%), had accessed extension services, compared to 43% in the IR maize technology sub-population. On average, 50% of the whole sample had accessed extension services.

The majority of PPT adopters (78.7%) and IR maize technology adopters (81.1%) owned a radio, which was very vital in information dissemination. This compares fairly closely to the population who own a radio in Nyanza province (75%) and 74% in Kenya (GoK, 2010). More households in the PPT sub-population (72.6%) own a radio, as compared to those in IR maize technology sub-population (69.9%).

Most of PPT adopters (62.3%) and IR maize technology adopters (54.7%), rated the effectiveness of the respective technologies as "very good" in controlling *Striga*. There were more farmers who had a high perception on PPT as effective in *Striga* control (21.7%), as compared to IR maize technology (19.2%).

On average, *DSPCNTR* (distance from PPT adopting households to the nearest shopping centre) was approximately 2.4 km, as compared to 3.3 km covered by non-adopters. On the other hand, IR maize technology adopters were close to the nearest shopping centre (2.7 km), compared to the non-adopters (3.9 km). This showed that, adopters were closer to the market compared to the non-adopters. On average, PPT and IR maize technology households were approximately 3.0 km away from the nearest shopping centre, which was used as a proxy of input and output market.

Majority of PPT adopters (68.9%) and IR maize technology adopters (86.8%) owned a mobile phone. On the other hand, non-adopters showed similar results where, majority of PPT non-adopters (79.3%) and IR maize technology non-adopters (79%) owned a mobile phone. On average, 63.2% of Kenyan population owns a mobile phone which is fairly close to 57.7% of Nyanza province (GoK, 2010). On average, 76% of the households in the PPT sub-population own a mobile phone as compared to their counterparts in IR maize technology sub-population (63.6%). On the other hand, ownership of a mobile phone was high in the study area (70.3%).

On average, PPT adopting households had a higher workforce (8 persons), as compared to non-adopting households (3 persons). On the other hand, adopting households of IR maize technology had approximately 6 persons, compared to 3 persons of the non-adopting households on average. Therefore, adopting households had a higher workforce compared to the non-adopting ones. Nationally, 54.2% of the population are aged between 15-64 years compared to Nyanza province (53.1%) and Siaya county (52%), which is the age bracket considered as labour force (GoK, 2010). The labour force within the PPT sub-population (5 persons), was higher than in IR maize technology sub-population (4 persons). This compares fairly closely to the national average, where a larger part of the population is between 15-64 years.

Approximately 54.1% of the PPT adopting household's head were fulltime farmers, compared to 57% of non-adopters. On the other hand, approximately 64% of adopters and non-adopters of IR maize technology were full time farmers. More of households in the IR maize technology sub-population (64.2%) were full time farmers, compared to those in PPT sub-population (56.0%). Therefore, more households in PPT sub-population (44%) were involved in off-farm activities, compared to those in IR maize technology sub-population (35.8%). The product of the interactive variable between distance to the nearest centre and access to extension services had a mean of 1.7 for PPT adopters, compared to 1.4 for the IR maize technology adopters.

Approximately 34.9% of households from the PPT sub-population were adopters, as compared to 35.1% from the IR maize technology sub-population. There were more exposed households from IR maize technology sub-population (72.8%), as opposed to 50.9% from the PPT sub-population. Approximately 61% of the whole sample was aware of the existence of either PPT or IR maize technology (Table 4.1).

CHAPTER FIVE

DETERMINANTS OF FARMERS' PERCEPTION ON THE EFFECTIVENESS OF PPT AND IR MAIZE TECHNOLOGY IN CONTROLLING *STRIGA*

5.1 Introduction

Many adoption studies often assume that a technology which is promoted to farmers is usually more suitable, and very little considerations have been made as to whether its characteristics are satisfactory as perceived by farmers. Several studies have shown that in addition to farmers' socio-economic characteristics and institutional factors, farmers' perceptions of the specific characteristics of a new innovation are also important in shaping their preferences (Adegbola, 2010). While few studies assess the significance of analysing characteristics which are perceived important by farmers as embodied in a new technology, a study by Sall *et al.* (2000) is an exception. It analysed farmers' perception on characteristics of improved rice variety and how much they match with rice growers needs using an index approach developed by Reed *et al.* (1991).

The formations of these perceptions are usually influenced by some factors among them: socio-economic and institutional factors. Understanding these determinants is important to researchers and extension agents of PPT and IR maize technology, since they are able to formulate appropriate strategies to positively shape the farmers perception. Many studies do not analyse the effect of these factors on farmers' perception though some are exceptions (Bagheri *et al.,* 2008).

Information available to a farmer could either influence positively or negatively the shaping of farmers perceptions. For an individual to form positive perceptions towards the effectiveness of PPT or IR maize technology, then relevant information should be made readily available. If the information is received from trusted sources, then positive attitudes towards characteristics of new innovations are more likely to be developed. The information should not only be available but also affordable. The farmers should be able to cheaply acquire the information since most of them are cash constrained. This calls for an effective dissemination pathway which would ensure speed of information dissemination to the target population (Murage *et al.,* 2011b). This chapter therefore, shows how important it is to analyse the perception of farmers towards technology characteristics and further determine the factors which influence farmers' perception on the effectiveness of PPT and IR maize technology in controlling *Striga*.

5.2 Data

Data used in this study were from a survey conducted between February and March 2012. The descriptions of variables used are presented in Table 3.1 in chapter 3. The major data collected was on farmers' perception towards several characteristics of PPT and IR maize technology. Data on several socio-economic and institutional factors including age, gender and education level attained by a household head, total land size owned by a household, distance to the nearest administration centre, income level of a household were collected. In addition, data on tropical livestock units owned by a household, the total labour force in a household, farmer group membership, radio ownership and whether a household head accessed extension services were also collected.

5.3The analytical strategy

5.3.1 Index approach

To assess farmers' perceptions of PPT and IR maize technology's characteristics, an index approach was used. This method has been used by several authors among them Reed *et al.* (1991), Sall *et al.* (2000) and Adegbola (2010). It was appropriate since there were several technology characteristics which farmers were expected to rank. The characteristics ranked were in comparison to the conventional methods such as: soybean-maize rotation, hand weeding, uprooting among others, which the farmers have been using to eradicate *Striga* weeds in Siaya county before the introduction of PPT and IR maize technologies. The characteristics included: capital requirement, labour requirement, effectiveness in *Striga* control, availability of *desmodium* seed, affordability of *desmodium* seed, land requirement, intercropping with other leguminous crops especially beans, soil fertility improvement, and livestock fodder production (for PPT) and capital requirement, labour requirement, effectiveness in *Striga* control, availability of IR maize seed, affordability of IR maize seed, chemicals used being safe for human health and other seeds, intercropping maize with other leguminous crops especially beans, seed germination rate and seed being a hybrid (for IR maize). Farmers were asked to rate the importance of each characteristic of PPT and IR maize technology using a 3-point likert scale, where 1 = not important, 2 = important and 3 = very important. Furthermore, they rated how well the respective technology supplied them using a 3-point likert scale where, 1 = poor, 2 = good and 3 = very good.

This approach was used to calculate the indices with an aim of ascertaining how important a characteristic in question was to farmers (demand index), how well the respective technologies satisfied farmers expectations (supply index) and how the importance and supply of these characteristics matched (attainment index). The three (3) indices calculated for each characteristic of PPT and IR maize technologies are represented in an equation as follows:

The first index is demand index (*D/h*) that measures the level of importance, of each characteristic of either the PPT or IR maize technology compared to the conventional methods farmers have been using before the introduction of the two technologies.

$$D/h = \frac{1}{d_1 N}\sum_{j=1}^{r} d_j t_j \text{ such that } d_1 > d_2 > \ldots\ldots\ldots\ldots > d_r > 0 \tag{5.1}$$

where *h* is a characteristic of PPT and IR maize technology, d_j is the ordinal demand weight (4 = very important, 2 = important, 1 = not important) and reflects the expectation of the producers for each characteristic of a *Striga* control technology, t_j represents the number of farmers who rate the characteristic *h* at the j^{th} degree of importance and *N* is the total number of respondents.

The second index is the supply index (*S/h*), which measures the perception of the farmers on the degree to which each desired characteristic is achieved in PPT and IR maize technology.

$$S/h = \frac{1}{s_1 N}\sum_{i=1}^{n} s_i g_i \text{ such that } s_1 \ldots\ldots\ldots\ldots > s_{n-1} > 0 > s_n \tag{5.2}$$

where *h* is a characteristic of PPT and IR maize technology, s_i is the ordinal supply weight (3 = very good, 1 = good, -2 = poor) with g_i being the number of farmers who rate the characteristic *h* at the i^{th} level of the quality as being embodied in the PPT or IR maize technology.

The third index is the attainment index (*W/h*) which measures how farmers' perceptions of the importance of a characteristic match with the extent, to which this characteristic is perceived to be supplied in the PPT and IR maize technology.

$$W/h = \frac{1}{s_1 d_1 N}\sum_{j=1}^{r}\sum_{i=1}^{n} s_i d_j k_{ij} \tag{5.3}$$

where h is a characteristic of PPT and IR maize technology, k_{ij} is the number of farmers who will rate the characteristic h at the j^{th} degree of importance and consider also that this characteristic h is provided at i^{th} degree of quality by PPT or IR maize technology.

This study used two weights in calculating demand and supply indices. The condition is that demand and supply weights chosen should all be positive, except the supply weight for the least rating "poor" which should be negative and is obtained when all the farmers rate the quality of characteristic h of PPT and IR maize technology as poor (see equations 6 and 7) as described by Reed *et al.* (1991) and Sall *et al.* (2000). Four sets of weights were used to calculate the indices namely: s_A (2, 1, -1) d_A (5, 3, 1), s_B (1, 0, -1) d_B (5, 2, 1), s_C (3, 1, -2) d_C (4, 2, 1) and s_D (3, 1, -1) d_D (3, 2, 1).

These supply weights (s_A, s_B, s_C, s_D) and demand weights (d_A, d_B, d_C, d_D) were selected following equations 6 and 7. To test the robustness of the results for the attainment index using different combinations of weights, Spearman and Pearson correlation coefficients were calculated for each set as indicated by Reed *et al.* (1991) and Sall *et al.* (2000). The former measures consistency in rating characteristics, while the latter evaluating the linear relation among various attributes. The results presented in this chapter reflect the use of the third combination of weights indicated above.

5.3.2 Ordered probit model

This model was used to determine the factors which influenced farmers' perception on the effectiveness of PPT and IR maize technology in controlling *Striga*. The model was preferred since the dependent variable was categorical and ordered and has been widely used to measure perceptions (Ngathou *et al.*, 2005). Multinomial logit/probit models can also be used in scenarios where dependent variable is multiple, but requires the choices to be unordered and have the disadvantage of what is well known as, the independence of irrelevant alternatives (IIR) property (Greene, 2007). This therefore, causes an overestimation of the probabilities and hence the preference of ordered probit model in this study. In the formulation of the model, the observed responses were represented by a variable Y_i which denotes the preference rank given by farmer i on the effectiveness of PPT or IR maize technology in *Striga* control. This was in comparison to the conventional methods that the farmers have been using, before the dissemination of PPT and IR maize technology. The variable takes on j different values which are naturally ordered, in this case 4 values namely:

j = 1, 2, 3 and 4 representing no perception, poor, good and very good rankings respectively).

However, these observed values are assumed to be derived from some unobservable latent variable.

$$Y_i^* = X_i\beta + \varepsilon_i \tag{5.4}$$

where X_i represents the observable individual specific factors on which data was collected, β is a vector of parameters to be estimated and ε_i is the stochastic disturbance term whose distribution is estimated to be normal [$\varepsilon_i \sim N(0,\sigma^2)$].

The values for observed choice outcome Y_i are assumed to be related to the latent variable y_i^* as follows:

$$\begin{aligned} Y_i &= 1 \text{ iff } && y_i^* \le \theta_1 \\ Y_i &= 2 \text{ iff } && \theta_1 < y_i^* \\ Y_i &= 3 \text{ iff } && \theta_1 < y_i^* \le \theta_3 \\ Y_i &= 4 \text{ iff } && y_i^* > \theta_3 \end{aligned} \tag{5.5}$$

where θ_i, $i = 1, 2, 3$ are unobservable thresholds. The probability of each observed outcome falling in a given category is given as:

$$\begin{aligned} \Pr(Y_i = 1) &= \varphi(\mu_0 - X_i'\beta) \\ \Pr(Y_i = 2) &= \varphi(\mu_1 - X_i'\beta) - \varphi(\mu_0 - X_i'\beta) \\ \Pr(Y_i = 3) &= \varphi(\mu_2 - X_i'\beta) - \varphi(\mu_1 - X_i'\beta) \\ \Pr(Y_i = 4) &= \varphi(X_i'\beta - \mu_2) \end{aligned} \tag{5.6}$$

where ϕ is the cumulative density function of $\mu_i, \beta = \alpha/\sigma$ and $\mu_{j-1} = \theta_j / \sigma$. The coefficients of ordered probit are usually difficult to interpret (Woodridge, 2002). A positive parameter estimate indicates that an increase in the respective variable would shift weight of an individual from category 1 to 4. The effect on probability of being in category 2 and 3 is ambiguous since the sign of the parameter does not provide a qualitative indication as shown in equation 11. Marginal effects which measures the expected change in predicted probability associated with changes in the explanatory variables, are often used rather than the coefficients.

From equation (11), the marginal effects are estimated by taking the first derivative of the log likelihood function (for $\beta > 0$):

$$\begin{aligned}
&\frac{\partial \Pr(Y_i = 1)}{\partial x} = -\phi(-X_i{}'\beta)\beta_x < 0, \\
&\frac{\partial \Pr(Y_i = 4)}{\partial x} = \phi(\overline{\mu}_2 - X_i{}'\beta)\beta_x > 0, \\
&\frac{\partial \Pr(Y_i = k)}{\partial x} = [\phi(\overline{\mu}_{k-1} - X_i{}'\beta) - \phi(\overline{\mu}_{k-2} - X_i{}'\beta)]\beta_x ; k = 2,3; \overline{\mu}_0 = 0
\end{aligned} \tag{5.7}$$

where β_x is the parameter of variable x. The signs of the coefficients and those of the marginal effects of the least outcome (no perception) should be opposite. However, they should be the same as the highest outcome designated as “very good” (Greene, 2007).

Empirically, the ordered probit regression which was used to estimate the relation between perception ranks and other attributes was fitted as follows:

$$\begin{aligned}
PERCPRANK = \beta_0 + \beta_1 AGEHHH + \beta_2 GENDERHHH + \beta_3 YRSCHHH + \beta_4 LANDSZ + \\
\beta_5 WORKFORCE + \beta_6 EXTENACS + \beta_7 FGMEM + \beta_8 DSADMN + \\
\beta_9 LOGINCOME + \beta_{10} TLU + \beta_{11} RADOWNSP + \varepsilon_i
\end{aligned} \tag{5.8}$$

PERCPRANK is the dependent variable and was measured as the observed ordered response for each technology’s effectiveness in control of *Striga* which takes on any of the four possible outcomes (0, 1, 2 and 3). Variance inflation factor (VIF) was used to test for multicollinearity problem in all the explanatory variables used in the model as indicated in appendices 1 and 2. All the variables had a VIF of less than 10 as required (Maddala, 1993).

5.4 Results and discussion

5.4.1 Farmers’ perception on PPT and IR maize technology characteristics compared to conventional control methods – The index approach

Table 5.1 shows the demand, supply and attainment indices calculated from perception ratings of PPT and IR maize technology characteristics. Demand index of an effective *Striga* eradicating technology was higher for PPT (0.868) as compared to IR maize technology (0.778). This indicates how *Striga* weed in the area is a big challenge to maize farmers. This are in line with findings by Rutto *et al.* (2005) in a study on farmers’ perceptions and evaluation of integrated approaches to combat *Striga*, stemborer and soil fertility problems in western Kenya. The supply index for PPT effectiveness was 0.678 compared to that of IR maize technology (0.394). This means a satisfactory perception by farmers on how PPT has addressed the *Striga* problem, unlike IR maize technology. In fact, the attainment index for PPT (0.588) was higher than that of IR maize technology (0.307). This demonstrates that, farmers perceive PPT to have at least attained 58.8% in its effectiveness as a *Striga* control measure, as compared to 30.7% of IR maize technology.

Intercropping of maize with other leguminous crops especially beans, had positive demand indices for PPT (0.768) and IR maize technology (0.703). This showed that, approximately 76.8% and 70.3% of the farmers rated the characteristic as relatively important (Table 5.1). The supply indices of this characteristic for PPT (-0.475) and IR maize technology (-0.365) were however negative, showing that both technologies do not give farmers a chance to intercrop maize with beans. The characteristic's low attainment indices for PPT (-0.364) and IR maize technology (-0.257) indicates that, even though both technologies provide a low level of satisfaction to farmers, IR maize technology was better off compared to PPT since intercropping could be practised only when the plants are not planted in the same hole (Kanampiu *et al.,* 2002). Therefore, the negative supply index of IR maize technology (-0.365) could be attributed to lack of information to farmers on the how to intercrop. These findings concur with several other studies (Amudavi *et al.,* 2008).

The demand indices for capital requirement characteristic of PPT (0.750) and that for IR maize technology (0.816) were high implying that, farmers rated the characteristic as very crucial in determining the adoption of PPT and IR maize technology. Their respective supply indices (-0.077) for PPT and (-0.204) for IR maize technology was negative, indicating that they are relatively capital intensive.

Labour requirement characteristic is fundamental if farmers are to adopt PPT and IR maize technology. This is indicated by their respective demand indices (0.720) and (0.736). However, PPT is labour intensive as evidence by the negative supply index (-0.202), and the attainment index (-0.146) as indicated in Table 5.1.

The characteristic of PPT as a source of livestock fodder had a demand index of 0.713 implying that, farmers highly regarded this characteristic since the technology is able to supply fodder for livestock. These results are consistent with the findings by (Khan *et al.,* 2008a) who found that, having livestock was the major entry point for the adoption of PPT by smallholder farmers. The supply index was also high (0.765) implying that, farmers were satisfied with the technology in provision of livestock feeds, and this was confirmed by the attainment index (0.546).

Table 5.1: Estimation results of farmers' perceptions on PPT and IR maize technology characteristics compared to conventional methods

Characteristic	PPT			IR maize technology		
	Demand index	Supply index	Attainment index	Demand index	Supply index	Attainment index
Effectiveness in *Striga* control	0.868	0.678	0.588	0.778	0.394	0.307
Intercropping with other leguminous crops especially beans	0.768	-0.475	-0.364	0.703	-0.365	-0.257
Capital requirement	0.750	-0.077	-0.054	0.816	-0.204	-0.166
Labour requirement	0.720	-0.202	-0.146	0.736	0.068	0.050
Soil fertility improvement	0.750	0.530	0.398	-	-	-
Livestock fodder production	0.713	0.765	0.546	-	-	-
Availability of *desmodium* seed	0.713	0.226	0.171	-	-	-
Affordability of *desmodium* seed	0.569	0.132	0.075	-	-	-
Land requirement	0.553	0.071	0.039	-	-	-
Availability of IR maize seed	-	-	-	0.774	-0.352	-0.273
Affordability of IR maize seed	-	-	-	0.665	-0.233	-0.155
Chemicals used being safe for human health and other seeds	-	-	-	0.642	-0.321	-0.206
Seed being a hybrid	-	-	-	0.632	-0.126	-0.080
Seed germination rate	-	-	-	0.627	0.088	0.055

Source: Survey data, 2012.

The ability of PPT to improve soil fertility was relatively important to the farmers, and this is shown by its demand index of 0.750. Farmers' perception on its supply was satisfactory (supply index = 0.530) while the attainment index was relatively low (0.398). *Desmodium* is a nitrogen-fixing legume which improves soil fertility (Khan and Pickett, 2004), but this characteristic of PPT is not perceived to be as important as the *Striga* control.

Availability of *desmodium* seed is a key characteristic if farmers have to adopt PPT. It no wonder that the demand index for this characteristic was high (demand index = 0.713) and this showed that for a technology to be adopted, inputs must be available to the farmers. This has been one of the challenging factors constraining adoption of PPT. The supply of the seed is relatively low and is evident by the supply index (0.226). However, most of the farmers received *desmodium* seed from technology promoters and some had been trained on how to multiply it through community based seed multiplication, which eased the problem of availability (Khan *et al.*,2011). This characteristic was highlighted by Amudavi *et al.* (2008), where 46% of the farmers cited it as a major constraint hindering the adoption of PPT.

Availability of IR maize seed was rated by approximately 77.4% of farmers as very fundamental to them in shaping their adoption decision (demand index = 0.774), yet the supply and attainment index were negative (-0.352 and -0.273) as indicated in Table 5.1. This would imply inability to access the IR seed by the farmers either due to high costs or the seeds not available in the market. Mignouna *et al.* (2010) reported a significant influence of lack of IR seed on the decision to adopt.

For smallholder farmers to adopt a technology, affordability of inputs is essential. This therefore explains why characteristic of affordability of IR maize seed had a high demand index of 0.665. However, given the perceived high cost of seeds, the supply and attainment indices were negative (-0.233 and -0.155). Woomer and Savala (2007) indicated that the IR seed cost $2.20[2] per kg which is relatively more expensive than the normal hybrid seeds.

The characteristics of seed being a hybrid and germination rate were regarded as very essential in adopting IR maize technology, with demand indices of 0.632 and 0.627 respectively (Table 5.1). However, the supply and attainment indices were negative (-0.126 and 0.080 respectively) implying that, farmers were not satisfied with the two characteristics

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[2] 187 KES - 1 US dollar was equivalent to 85 KES at the time of this study (i.e. February, 2012).

of IR maize technology. The seed germination rate characteristic had positive but low supply and attainment indices (0.088 and 0.055).

5.4.2 Determinants of farmers' perception on the effectiveness of PPT and IR maize technology

Table 5.2 and Table 5.3 present results of the ordered probit model, on the factors which influence farmer's perception of the effectiveness of PPT and IR maize technology in the control of *Striga.* Older farmers rated the effectiveness of PPT and IR maize technology as "very good" compared to younger farmers as shown by the (ME = 0.002). The effect of age on perception is mixed in past studies. For example, Schtinkey *et al.* (1992) established a positive relationship between age and farmers' preference for various information sources. However, Velandia *et al.* (2011) indicated that, a farmer's interest/decision to acquire information about precision farming decreases as age increases. Age could have a positive or negative influence on perception due to the fact that, older farmers have vast experience in farming. This in turn helps them to practise the technology as required thus getting favourable results, which shape their perception positively while their younger counterparts are more risk takers.

The marginal effect for *WORKFORCE* (household labour force) was negative (ME = -0.055) for farmers who were insensitive ("no perception") on PPT effectiveness, and positive (ME = 0.008) for those farmers who perceived the technology as "very good" in *Striga* control (Table 5.2). On the other hand, although the least outcome ("no perception") towards IR maize technology indicated a significant negative marginal effect (ME = -0.024), the "very good" perception category had a consistent positive sign (ME = 0.007) as described by (Greene, 2007), but was insignificant (Table 5.3). This could be attributed to the fact that, as workforce increase, the household has an increased probability of sharing ideas and decisions amongst the members. Furthermore, it could also mean an increment in availability of labour for PPT which is labour intensive, due to an increase in the number of members who could offer farm labour.

Table 5.2: Ordered probit results on the determinants of farmers' perception on effectiveness of PPT in controlling *Striga*

Variable	Coefficient	Marginal effects for the different levels of perception (ME)			
		No perception	Poor	Good	Very good
		dy/dx	dy/dx	dy/dx	dy/dx
AGEHHH (age of a household head)	0.056 (0.014)***	-0.012 (0.003)***	0.009 (0.003)***	0.002 (0.001)**	0.002 (0.001)*
GENDERHHH (gender of a household head)	0.338 (0.277)	-0.076 (0.064)	0.052 (0.045)	0.012 (0.011)	0.012 (0.012)
YRSCHHH (years of formal schooling attained by a household head)	0.055 (0.035)	-0.012 (0.008)	0.008 (0.006)	0.002 (0.001)	0.002 (0.002)
WORKFORCE (labour force in a household)	0.251 (0.052)***	-0.055 (0.015)***	0.039 (0.012)***	0.009 (0.004)**	0.008 (0.005)*
LANDSZ (total land owned by a household)	0.067 (0.062)	-0.015 (0.013)	0.010 (0.009)	0.002 (0.002)	0.002 (0.001)
EXTENACS (access to extension services)	0.246 (0.302)	-0.054 (0.064)	0.039 (0.046)	0.008 (0.010)	0.008 (0.010)
FGMEM (farmer group membership)	1.324 (0.292)***	-0.292 (0.078)***	0.189 (0.057)***	0.048 (0.023)**	0.0548 (0.029)*
DSADMN (distance to the nearest administration centre)	-0.319 (0.079)***	0.070 (0.019)***	-0.049 (0.016)***	-0.011 (0.005)**	-0.010 (0.006)*
LOGINCOME (income level of a household)	0.114 (0.091)	-0.025 (0.021)	0.017 (0.015)	0.004 (0.003)	0.004 (0.004)
TLU (tropical livestock units owned)	0.050 (0.058)	-0.011 (0.013)	0.008 (0.009)	0.002 (0.002)	0.002 (0.002)
RADOWNSP (radio ownership)	-0.343 (0.324)	0.082 (0.085)	-0.055 (0.056)	-0.013 (0.015)	-0.014 (0.017)
/cut 1	5.662 (0.995)				
/ cut 2	6.463 (1.044)				
/ cut 3	6.808 (1.051)				
N	175				
LR chi2 (11)	173.34				
Prob > chi2	0.0000				
Pseudo R^2	0.5146				

Note: Figures in the parentheses are the standard errors associated with the coefficients and marginal effects.
$^{***}P < 0.01$, $^{**}P < 0.05$ and $^{*}P < 0.10$ mean significant at 1%, 5% and 10% probability levels, respectively.
Source: Survey data, 2012.

Farmers who participated in group activities and were members proved to be more sensitive to perception on PPT and IR maize technology effectiveness in *Striga* control (ME = 0.0548) and (ME = 0.191) respectively, as opposed to those who did not participate. Group membership is very crucial in shaping farmers' perception on the effectiveness of a technology, because they give farmers opportunities to be trained and acquire vital information easily and cheaply, unlike those who are not in groups due to reduced transaction costs. Some studies are in tandem with these findings (Tura *et al.,* 2010).

The *DSADMN* (distance to the nearest administration centre) had positive marginal effects (ME = 0.070) and (ME = 0.040), for those farmers who were insensitive to perception ("no perception") of PPT and IR maize technology respectively. On the other hand, "very good" rating category had negative marginal effects (ME = -0.010) and (ME = -0.012). This means that, the further away farmers are from nearest agricultural offices, the less likely they are expected to rate the effectiveness of PPT and IR maize technology in controlling *Striga* as "very good". The results demonstrate that, transaction and transformation costs are likely to increase with an increase in distance from the agricultural offices, and therefore transactions costs matter in the perception of a technology's effectiveness in addressing constraints in agriculture. This is consistent to findings by Ngathou *et al.* (2005) who established that, access to information is important in shaping farmers' preference for a new technology being promoted.

The marginal effects for *LOGINCOME* (income levels of a household) was negative (ME = -0.067) for the farmers who had limited perception ("no perception") on IR maize technology, and statistically significant at 10% level. Although the marginal effect of "good" category (ME = 0.023) was significant, the highest outcome category ("very good") was consistent in sign (positive) but insignificant (Table 5.3). On the other hand, the variable was insignificant for PPT. The wealthier farmers therefore, are more likely to have a high perception rating as opposed to a limited one of IR maize technology effectiveness. This could be due to the fact that, they are capable of accessing and effectively utilizing the required information since they are more risk loving, unlike their counterparts with lower levels of income. This is in line with findings by Negatu and Parikh (1999) who established that, farmers with a higher income level were more likely to positively influence the perception for marketability of the new wheat variety than low income farmers.

Table 5.3: Ordered probit results on the determinants of farmers' perception on effectiveness of IR maize technology in controlling *Striga*

Variable	Coefficient	Marginal effects for the different levels of perception (ME)			
		No perception	Poor	Good	Very good
		dy/dx	dy/dx	dy/dx	dy/dx
AGEHHH (age of a household head)	0.023 (0.010)	-0.007 (0.003)**	0.003 (0.001)*	0.003 (0.001)*	0.002 (0.001)*
GENDERHHH (gender of a household head)	-0.063 (0.266)	0.020 (0.085)	-0.007 (0.031)	-0.007 (0.029)	-0.006 (0.026)
YRSCHHH (years of formal schooling attained by a household head)	0.105 (0.031)***	-0.034 (0.010)***	0.012 (0.005)**	0.012 (0.004)***	0.010 (0.004)**
WORKFORCE (labour force in a household)	0.075 (0.044)*	-0.024 (0.015)*	0.009 (0.006)	0.008 (0.005)	0.007 (0.005)
LANDSZ (total land owned by a household)	0.096 (0.066)	-0.031 (0.021)	0.011 (0.008)	0.011 (0.008)	0.009 (0.007)
EXTENACS (access to extension services)	0.493 (0.282)*	-0.162 (0.095)*	0.055 (0.034)	0.055 (0.035)	0.052 (0.035)
FGMEM (farmer group membership)	1.480 (0.283)***	-0.478 (0.082)***	0.133 (0.043)***	0.153 (0.047)***	0.191 (0.054)***
DSADMN (distance to the nearest administration centre)	-0.125 (0.054)**	0.040 (0.017)**	-0.015 (0.008)*	-0.014 (0.007)**	-0.012 (0.006)**
LOGINCOME (income level of a household)	0.207 (0.116)*	-0.067 (0.038)*	0.024 (0.015)	0.023 (0.014)*	0.020 (0.013)
TLU (tropical livestock units owned)	0.010 (0.052)	-0.003 (0.017)	0.001 (0.006)	0.001 (0.006)	0.001 (0.005)
RADOWNSP (radio ownership)	0.023 (0.010)**	-0.183 (0.082)**	0.071 (0.040)*	0.062 (0.031)**	0.051 (0.025)**
/cut 1	4.800 (0.938)				
/ cut 2	5.295 (0.963)				
/ cut 3	5.831 (0.982)				
N	151				
LR chi2 (11)	114.96				
Prob > chi2	0.0000				
Pseudo R^2	0.3807				

Note: Figures in the parentheses are the standard errors associated with the coefficients and marginal effects.
$^{***}P < 0.01$, $^{**}P < 0.05$ and $^{*}P < 0.10$ mean significant at 1%, 5% and 10% probability levels, respectively.
Source: Survey data, 2012.

The marginal effects for *YRSCHHH* (number of years spent in formal schooling by a household head) had negative marginal effects (ME = -0.034) for those farmers who were insensitive to perception ("no perception"), as opposed to (ME = 0.010) for those farmers who were more sensitive ("very good") to perception of IR maize technology's effectiveness in controlling *Striga*. Thus, the more educated farmers were more likely to have a "very good" perception rating, as compared to their counterparts who have spent few years in school. Education level of a respondent positively influences the probability of ranking the alternative available information sources to the farmers (Velandia *et al.,* 2011). Farmers with high levels of education are likely to rely more on outside sources of information, compared to their own experience acquired through farming (Ngathou *et al.,* 2005).

Marginal effect for *RADOWNSP* (radio ownership) was negative (ME = -0.183) for the farmers who had "no perception" on the effectiveness of IR maize technology as a *Striga* control measure as opposed to positive (ME = 0.051), for those who had a higher perception rating. This could be due to the fact that, vernacular stations especially West FM run IR maize technology's programmes and advertisements. Therefore, vital information about the technology is made available to the listeners, thus shaping their perception to "very good". The variable was insignificant for PPT sub-population. This is consistent to the findings by Simtowe *et al.* (2010) who established that, radio ownership improved information access regarding new varieties released and seed sources that would in turn, shape farmers' perception towards the effectiveness of a promoted technology.

5.5 Conclusion

This chapter determined farmers' perception on the effectiveness of PPT and IR maize technology in *Striga* control and their determining factors. The results showed that, PPT technology has done relatively well in supplying farmers with characteristics that they perceive important to them especially effectiveness in *Striga* control, livestock fodder production and soil fertility improvement. However, it is still struggling to supply some key characteristics such as: intercropping maize with other leguminous crops especially beans, labour requirement and capital requirement. On the other hand, IR maize technology seemed to have relatively satisfied farmers with the manner in which it supplied three (3) characteristics namely: effectiveness in *Striga* control, labour requirement and seed germination rate. All the other characteristics six (6) were poorly embodied in the technology package despite the farmers indicating a high level of importance to them.

Effectiveness in *Striga* control and capital requirement characteristics were better provided by PPT than IR maize technology. On the other hand, IR maize technology supplied to farmers intercropping maize with other leguminous crops especially beans and labour requirement characteristics better than PPT. This implies that, IR maize technology is less labour intensive than PPT.

Given farmers' perception, technology promoters should try and promote PPT, since it seemed to have satisfied the farmers with most of its characteristics especially, on the aspect of effectiveness in *Striga* control. However, they need to address several characteristics which farmers were not satisfied with namely: intercropping maize with other leguminous crops especially beans, labour requirement and capital requirement. Furthermore, they should target older farmers who are members of groups, and those households with a higher labour force. In addition, the farmers closer to the nearest administration centre should be targeted, as opposed to those located further away. The determinants of farmers' perception on the effectiveness of both technologies in controlling *Striga* are different and differed in magnitude. Therefore, the second hypothesis which stated that there is no significant difference between farmers' perception on the effectiveness of PPT and IR maize technology in *Striga* control and their underlying factors was rejected.

CHAPTER SIX

DETERMINANTS OF ADOPTION AND INTENSITY OF USE OF PPT AND IR MAIZE TECHNOLOGY

6.1 Introduction

Developing countries usually face the task of increasing agricultural productivity and at the same time ensuring sustainability of the resource base available (Ersado *et al.,* 2004). Technology is usually the most important factor in increasing agricultural productivity. The rate of adoption of a new technology is subject to its profitability or effectiveness, degree of risk associated with it, capital requirements, agricultural policies, and socioeconomic characteristics of farmers (Rogers, 1995). *Striga* weed menace has been a challenge in western Kenya and often rated as the major constraint in increasing maize production (Rutto *et al.,* 2005; Manyong *et al.,* 2008; Khan *et al.,* 2008b). The PPT and IR maize technology have been introduced as effective technologies to eradicate the witch weed with a positive trend towards their adoption. Since the two technologies use different approaches, their adoption and the intensity of use is likely to differ now and in future. The objective addressed in this chapter, is on determinants of adoption and intensity of use of the two technologies.

6.2. Data

The analysis in this chapter used cross sectional data collected randomly from maize producing farmers in Wagai division, Siaya county between February and March 2012. Several socio-economic, institutional, transport and communication infrastructures data was collected and used to evaluate their influence on the decision of adopting and expanding the use of PPT and IR maize technology. They included: age, gender, years of schooling and farm labour participation of a household head, total land size owned by a household, size of the household, extension access, farmer group membership, distance to the nearest administration centre, income level of a household, tropical livestock unit owned by a household, perception, mobile phone ownership and distance to the nearest shopping centre

6.3 Model specification and analysis

To achieve the second objective, a double hurdle model (DH model) was used. The model was preferred since it assumes that farmers make two sequential decisions with regard to willingness to adopt either PPT or IR maize technology, and the extent to which they are willing to intensify the use of these two technologies. It also assumes that, the factors influencing adoption are not necessarily the same factors influencing intensity of use. The DH model was originally proposed by Cragg (1971) and has been used by several authors (e.g. Olwande *et al.*, 2009; Burke, 2009 and Mignouna *et al.,* 2010).

The model consists of two tiers. The first decision that farmers have to make is that of whether a household will adopt PPT/plant IR maize or not. The second decision is about the amount of land that they will be allocated. It is only when an individual farmer had made a decision to adopt (hence going over the first hurdle), that the second decision making process sets in. The two decisions are whether to practise PPT/plant IR maize, and by how much. The second decision (intensity of use) was considered as the ratio of land allocated on PPT or IR maize to the total cultivated land of each household. The households must cross two hurdles in order to be considered as adopters. The model allows for the possibility that these two decisions are affected by a different set of variables. This makes it superior compared to other models especially Tobit, which assumes that, the two decisions are affected by the same factors.

The first equation in the double hurdle model relates to the decision to adopt either PPT or IR maize technology (*y*) and is expressed as follows:

$$\begin{aligned} &y_i = 1 \quad if\ y_i^* > 0\ and\ \ 0\ if\ y_i^* \leq 0 \\ &y_i^* = X_i^* \alpha + \varepsilon_i \end{aligned} \tag{6.1}$$

where y^* is latent adoption variable that takes the value of 1 if a household practised PPT /planted IR maize and 0 otherwise, X is a vector of household characteristics and α is a vector of parameters.

The second hurdle closely resembles the Tobit model and is expressed as follows:

$$\begin{aligned} &t_i = t_i^* \quad if\ t_i^* > 0\ and\ \ 0\ if\ y_i^* \leq 0 \\ &t_i = 0\ otherwise \\ &t_i^* = Z_i'\beta + v_i \end{aligned} \tag{6.2}$$

where t_i is the observed response on the proportion of land allocated to PPT or IR maize expressed as a ratio of the households total cultivated land, Z is a vector of the household characteristics and β is a vector of parameters. The respective errors (v_i and ε_i) are assumed to be independent (not correlated) and normally distributed. If this assumption of normality on the error terms breaks down then, the maximum likelihood estimates will be inconsistent. A number of approaches have been designed to transform the dependent variable, and latent variable to take care of the risk of breakdown of the normality assumption. The Box-Cox transformation is one of these approaches that take care of this risk. The log likelihood function of the Box-Cox Double Hurdle model can be written as:

$$LogL = \sum_{0} \ln\left[1 - \phi\left(\frac{x_i{}'\beta}{\sigma}\right)\right] + \sum_{+} \ln\left[\frac{1}{\sigma}\phi\left(\frac{y_i - x_i{}'\beta}{\sigma}\right)\right] \tag{6.3}$$

Most of the authors who have used DH model have just limited themselves to estimation of coefficients only. This study moved a step further and estimated the unconditional average partial effects (APE), and run bootstrapping replications on each observation. This helps in estimating the observed coefficient, standard errors and the P-values showing the significance levels described by Burke (2009).

One can calculate different partial effects which can be either "conditional" or "unconditional". The conditional partial effects of a variable (x_j) means it's only regarded in one of the two stages (tiers). The variable (x_j) will have a different conditional partial effect in stage one and in stage two, if it is included in both estimation stages. The unconditional partial effects of a variable (x_j) take into account both stages of the model. Following an example in Burke (2009), the conditional partial effects of a variable (x_j) in the first stage could be expressed as follows:

$$\frac{\delta p(W > 0 / x_i)}{\delta x_j} = \beta_{ij}\phi(x_1\beta_1) \tag{6.4}$$

where β_{1j} is the maximum likelihood estimated coefficient of x_j from the probit and ϕ is the standard normal probability density function (pdf).

The conditional partial effects of a variable (x_j) in the second stage could be expressed as:

$$\frac{\delta p(W_i / W_i > 0, x_{2i})}{\delta_{xj}} = \beta_{2j}(1-\lambda)\left(\frac{x_2\beta_2}{\sigma}\right)\left(\frac{x_2\beta_2}{\sigma} + \lambda\left(\frac{x_2\beta_2}{\sigma}\right)\right) \tag{6.5}$$

where λ represents the inverse mills ratio, β_{2j} is the estimated coefficient of x_j from the truncated regression, and σ is the estimated variance from the truncated regression.

Calculating the unconditional partial effects from the two estimation stages is usually more complicated, and can be expressed as a single equation with two parts as follows:

$$\frac{\delta p(W_i / x_1 x_2)}{\delta_{xj}} = \beta_{1j}\varphi(x_1\beta_1).(x_2\beta_2 + \sigma.\lambda)\left(\frac{x_2\beta_2}{\sigma}\right) + \\ \phi(x_1\beta_1).\beta_{2j}\left(1 - \lambda\left(\frac{x_2\beta_2}{\sigma}\right)\left(\frac{x_2\beta_2}{\sigma} + \lambda\left(\frac{x_2\beta_2}{\sigma}\right)\right)\right) \tag{6.6}$$

where the inverse mills ratio (IMR) is the probability density function, divided by the cumulative density function (pdf / cdf) and φ is the cumulative density function. The average partial effects (APEs) in the model are obtained by averaging x_j*'s* partial effects across all observations.

The empirical adoption model estimated was as follows:

$$\begin{aligned} ADPTN = \beta_0 + \beta_1 AGEHHH + \beta_2 GENDERHHH + \beta_3 YRSCHHH + \beta_4 LANDSZ + \\ \beta_5 HHSIZE + \beta_6 EXTENACS + \beta_7 FGMEM + \beta_8 DSADMN + \\ \beta_9 LOGINCOME + \beta_{10} TLU + \beta_{11} RADOWNSP + \beta_{12} INTEXTDSADMN + \\ \beta_{13} FRMLBPAT + \varepsilon_i \end{aligned} \tag{6.7}$$

The dependent variable (*ADPTN*) refers to whether a farmer had practised PPT/planted IR maize and was dichotomous. The independent variables are described in Table 3.1 (chapter 3).

The intensity empirical model was estimated as follows:

$$\begin{aligned} INTEN = \beta_0 + \beta_1 AGEHHH + \beta_2 GENDERHHH + \beta_3 YRSCHHH + \beta_4 WORKFORCE + \\ \beta_5 MOBOWNSP + \beta_6 EXTENACS + \beta_7 FGMEM + \beta_8 DSPCNTR + \\ \beta_9 LOGINCOME + \beta_{10} TLU + \beta_{11} PERCPRANK + \beta_{12} INTPERCYRSC + \\ \beta_{13} FRMLBPAT + \varepsilon_i \end{aligned} \tag{6.8}$$

The dependent variable in the second tier (*INTEN*) refers to the ratio of the area put under the technologies, to the total cultivated land size owned by a household. Description of independent variables used is shown in Table 3.1. Multicollinearity test was done using VIF, and all the variables had a value of less than 10 as required (Maddala, 1993). This is shown in appendices 1, 2, 3 and 4. Each DH model was fitted separately for PPT and IR sub-populations.

6.4 Results and discussion

6.4.1 Determinants of PPT and IR maize technology adoption

In table 6.1, the results of the determinants of PPT and IR maize technology adoption are presented.

The coefficient for *GENDERHHH* (gender of the household head) was positive (1.187) and significant at 5% level for PPT. This implies that, male-headed households were more likely to adopt PPT unlike their female counterparts. This could be attributed to the fact that, most cultures favour men and bestows them with the rights to own property especially land. It could also be that females are more risk averse to adopting a new technology which appears to affect the known equilibrium of food security. This is consistent to findings by several studies (Kaliba *et al.*, 2000; Yesuf and Bluffstone, 2009). In fact, Kaliba *et al.* (ibid) established that, male headed households, have a greater access to resources and information and therefore, they have a higher probability of adopting new technologies, as compared to the female headed households. Furthermore, Yesuf and Bluffstone (ibid) established that, male headed households are less risk averse than female headed households. However, several studies have established contradicting findings (Nguezet *et al.,* 2010: Jamala *et al.,* 2011).

The coefficient for *AGEHHH* (age of the household head) was positive and significant at 5% level (0.067). As the age of a farmer increases, there is a probability increase in adoption of PPT. Older farmers are more likely to adopt PPT, a fact that could be pegged on farming experience. Several studies have observed similar results (e.g. Adesina and Baidu-Forson, 1995; Sall *et al.,* 2000; Khan *et al.,* 2008c; Nguezet *et al.,* 2010; Ebojei *et al.,* 2012). However, inverse relationship between age and adoption of technologies has been observed (Neupane *et al.,* 2002; Mignouna *et al.,* 2011b). This was not surprising, since the direction of age has always been mixed in literature owing to the technology characteristics. The variable was insignificant in adoption of IR maize technology.

The coefficients for *HHSIZE* (household size) of PPT (0.468) and IR maize technology (0.212) were positive and significant at 1% and 5% levels respectively. The probability of adopting PPT and IR maize technology was higher in households which had more members. This could be attributed to the fact that, availability of labour is essential especially for PPT which is said to be labour intensive in its initial stages (Khan *et al.,* 2008c). Household size is used as a proxy of labour availability (Udensi *et al.,* 2012), but also as an opportunity for farmers to engage in off farm activities, thereby getting extra income to ease the consumption pressure imposed by a large family size (Yirga, 2007).

Table 6.1: DH coefficients of factors influencing adoption of PPT and IR maize technology

Variable	PPT		IR maize technology	
	Coefficient	Std. error	Coefficient	Std. error
AGEHHH (age of a household head)	0.067**	0.030	0.020	0.015
GENDERHHH (gender of a household head)	1.187**	0.574	0.128	0.338
YRSCHHH (years of formal schooling attained by a household head)	0.163*	0.086	0.169***	0.044
LANDSZ (total land owned by a household)	0.264*	0.151	0.143*	0.086
HHSIZE (household size)	0.468***	0.136	0.212**	0.099
EXTENACS (access to extension services)	-0.384	1.275	0.856	0.549
FGMEM (farmer group membership)	1.529***	0.561	1.605***	0.360
DSADMN (distance to the nearest administration centre)	-0.621**	0.290	-0.074	0.082
LOGINCOME (income level of a household)	0.742*	0.403	1.085***	0.420
TLU (tropical livestock units)	0.246**	0.126	-0.063	0.070
RADOWNSP (radio ownership)	-0.727	0.689	0.932**	0.407
INTEXTDSADMN (extension access*distance to the nearest administration centre)	0.215	0.354	-0.218	0.152
FRMLBPAT (farm labour participation)	0.068	0.581		
N	175		151	
Wald chi2(13)	28.36		41.09	
Prob > chi2	0.008		0.0000	

$^{***}P < 0.01$, $^{**}P < 0.05$ and $^{*}P < 0.10$ mean significant at 1%, 5% and 10% probability levels, respectively.

Source: Survey data, 2012.

The coefficient for *YRSCHHH* (years of schooling of a household head) was positive and significant at 10% level (0.163) for PPT. The coefficient was also positive (0.169) and significant at 1% level for IR maize technology. This is line with findings by several studies (Feleke and Zegeye, 2006; Salasya *et al.*, 2007; Khan *et al.*, 2008a; Ajewole, 2010 and Ebojei *et al.*, 2012) which established a positive relationship, between education level of a household head and the decision to adopt a new technology promoted. Educated farmers are more informed and therefore able to understand the benefits of a technology, since they are in a position to effectively use the information provided. Education creates a favourable mental attitude for the acceptance of new technologies especially which require intensive information. The ability of a farmer to read and understand sophisticated information, which might be contained in a technological package, is an important aspect of adoption. Therefore, less educated farmers have a low probability of adopting PPT and IR maize technology, since they may not been able to understand the information usually presented inform of print, pamphlets, brochures etc. In fact, Khan *et al.* (ibid) indicated that, PPT is relatively knowledge intensive.

This study established a positive relationship between *TLU* (tropical livestock units) owned by a household, and the adoption of PPT. This is consistent with findings by Zegeye *et al.* (2001) and Salasya *et al.* (2007) who established a positive relationship, between *TLU* owned and the decision to adopt PPT. This variable is often regarded as a sign of wealth where a farmer with more *TLU* can be considered wealthier, and thus the more likely it is for him/her to adopt PPT. The technology (PPT) is often regarded to offer farmers who own livestock a solution in form of fodder through the cultivation of *desmodium* and Napier grass planted along the perimeter of the PPT plots (Khan and Pickett, 2004; Khan *et al.,* 2008a).

The farmers who were members of producer groups, had a higher probability of adopting PPT (1.529) and IR maize technology (1.605) as *Striga* control measures. This is so because, most of the farmers adopting the technology sampled in the area were in groups. While in groups farmers are expected to cut down on cost of searching for information as well as transformation costs. Several studies have observed similar findings (Shiferaw *et al.,* 2009; Tura *et al.,* 2010; Simtowe *et al.,* 2010). However, some studies have differed (Bayard *et al.,* 2006; Murage *et al.*, 2011a), and indicated a negative relationship between adoption decision and a farmer being a member of a group. Collective action is one of the effective ways of overcoming high transaction costs by smallholder farmers (Kherallah and Kirsten, 2001). In fact, Dorward *et al.* (2005) argues that, poor infrastructure linking farmers to the input and output markets leads to high transaction costs, which could be lowered through group membership. Wambugu *et al.* (2009) reported a positive influence of social capital on the performance of producer groups.

The coefficients for *LOGINCOME* (income level of a household) were both positive for PPT (0.742) and IR maize technology (1.085). This showed that, households who had higher levels of income annually were more likely to adopt PPT and IR maize technology, as compared to low level income households. This could be attributed to the fact that, PPT is capital intensive particularly when it comes to accessing *desmodium* seeds (Amudavi *et al.,* 2008). On the other hand, IR seed is expensive and not available thus requires farmers to walk for long distances to get the seed (Woomer and Savala, 2007). It could also be due to the fact that, a new technology is a risky undertaking and that the more income a farmer has, risk loving one becomes hence a U-shaped relationship between income level and risk (Rosenzweig and Binswanger, 1993). Similar findings have been reported (Tura *et al.,* 2010; Ebojei *et al.,* 2012).

Distance to the nearest administration centre which was used as a proxy of information access in this study, was inversely related to adoption of PPT (-0.621). This is in line with findings from several studies (Feleke and Zegeye, 2006; Murage, 2011; Murage *et al.,* 2012). In fact, Murage (ibid) indicated that, an increase in distance of the household from tarmac, reduced the proportion of land put under PPT. This is due to the fact that, as distance from a household to the nearest agricultural centre increases, the transaction and transformation cost are bound to increase which discourage farmers to adopt a new technology. This indicates that, as the distance between a household and the nearest administration centre increased the probability of adopting PPT decreased. This would be expected due to time and cost spent to access information from agricultural offices. However, some studies have indicated an unexpected positive sign (Zegeye *et al.,* 2001; Salasya *et al.,* 2007). The variable was insignificant in the adoption of IR maize technology.

The farmers who owned radio were more likely to adopt IR maize technology (0.932) as shown in Table 6.1. The technology promoters usually advertised and run programmes of IR maize technology in vernacular FM stations e.g. West FM and Ramogi FM. Those farmers, who had access to a radio, had a higher probability of adopting the technology, compared to those who did not due to the fact that, they could easily access information. This is line with findings by Simtowe *et al.* (2010) who established that, radio is a very important dissemination pathway of availing information to farmers. The variable had no significant influence on the adoption of PPT.

6.4.2 Determinants of PPT and IR maize technology extent of adoption

In Table 6.2, the determinants of PPT and IR maize technology extent of adoption are presented.

The coefficient for *FGMEM* (group membership) was positive (0.027) and significant at 5% level for PPT. If a household head was a member of a farmer group, the probability of expanding the area under PPT increased. This is consistent to findings by Amudavi (2007) who established that, farmer groups once properly managed can enable members to access resources and overcome short-run liquidity constraints, thus reducing the risk associated with new innovations. This could be due to the fact that while in groups, farmers are able to cut on transaction costs, and in turn direct the saved cash to the expansion of the area allocated to PPT. On the other hand, the variable was insignificant in the adoption of IR maize technology.

The coefficient for *TLU* (tropical livestock unit) was positive for PPT (0.004) and IR maize technology (0.031). The farmers with a larger livestock unit were more likely to intensify the use of PPT and IR maize technology, as compared to the ones who owned fewer units. This is because initially, PPT was a target for farmers who had livestock, as they could benefit from increased fodder and was the entry point (Khan *et al.*, 2008a; Khan *et al.*, 2011). Since *TLU* is regarded as a sign of wealth, the more units a farmers owns, the higher the probability of putting more land under both technologies.

Table 6.2: DH coefficients of factors influencing the intensity of use of PPT and IR maize technology

Variable	PPT		IR maize technology	
	Coefficient	Std. error	Coefficient	Std. error
AGEHHH (age of a household head)	0.000	0.000	0.001	0.004
GENDERHHH (gender of a household head)	-0.002	0.009	-0.098	0.114
YRSCHHH (years of formal schooling attained by a household head)	0.002	0.004	0.066	0.047
WORKFORCE (labour force in a household)	0.025	0.002	0.017	0.013
EXTENACS (access to extension services)	-0.011	0.010	0.223^{*}	0.126
FGMEM (farmer group membership)	0.027^{**}	0.013	0.097	0.147
DSPCNTR (distance to the nearest shopping centre)	-0.001	0.002	0.010	0.015
LOGINCOME (income level of a household)	0.004^{*}	0.003	-0.063	0.056
PERCPRANK (perception)	0.031^{*}	0.017	0.382^{**}	0.190
TLU (tropical livestock units)	0.004^{**}	0.002	0.031^{*}	0.016
MOBOWNSP (mobile phone ownership)	-0.001	0.009	0.087	0.156
INTPERCYRSC (perception*years of schooling of a household head)	0.000	0.001	-0.024	0.016
FRMLBPAT (farm labour participation)	0.013	0.008		
SIGMA	0.027^{***}	0.003	0.241^{***}	0.033

$^{***}P < 0.01$, $^{**}P < 0.05$ and $^{*}P < 0.10$ mean significant at 1%, 5% and 10% probability levels, respectively.

Source: Survey data, 2012.

Another factor which positively (0.004) influenced the decision of expanding the use of PPT was *LOGINCOME* (income level of a household). The higher the level of income a farmer has, the higher the probability of putting more land under PPT. This could assist the individual cover related increase costs, since more *desmodium* seed and Napier grass would probably be required. Furthermore, more income and especially that which is over and above food expenditure and other social expenditures, as well would enable a farmer to expand investments into more agricultural activities including complimentary *desmodium* seed purchases. This in line with findings by Rosenzweig and Binswanger (1993), who established that, wealthier farmers are more risk loving compared to their poorer counterparts who are more risk averse. However, the variable insignificantly influenced the decision to expand the use of IR maize technology.

The coefficient for perception (*PERCPRANK*) positively influenced the decision to intensify the use of PPT (0.031) and IR maize technology (0.382). Higher perceptions ("very good") show that, farmers are contented with the respective technology's effectiveness in *Striga* control. Positive perception increases the probability of expanding the area under both technologies and vice versa. This is consistent to the findings of several studies (Adesina and Baidu-Forson, 1995; Negatu and Parikh, 1999; Sall *et al.,* 2000), which established a positive relationship between perception and decision to adopt and expand the use of a new technology being promoted. In this study, farmers are expected to intensify the cultivation areas considering that, through the adopted technology (PPT or IR maize technology), the *Striga* weed effects would have been mitigated or abated. However, Mignouna *et al.* (2011b) differed and observed an unexpected negative influence, which was attributed to the possibility of farmers' positive perception about IR maize being distorted by other attitudes.

Farmers who accessed extension services, positively (0.223) influenced the decision of farmers to expand the amount of land put under IR maize technology (Table 6.2). They had a higher probability of expanding the area planted with IR maize, as compared to those who did not access extension services. This is consistent to the findings by several studies (Alene *et al.,* 2000; Tura *et al.,* 2010; Ouma and De Groote, 2011). In fact, Alene *et al.* (ibid) established that farmers, who had accessed extension services, had a high probability of adopting and intensifying the use of improved maize varieties in Ethiopia. However, the variable had no significant influence on expansion of PPT.

6.4.3 The unconditional average partial effects (APE) results of PPT and IR maize technology

Table 6.3 indicates the observed coefficients and bootstrapping error estimated after using 100 replications. Bootstrapping was conducted since it gives the statistical significance of the APE (P value) and the confidence intervals.

The coefficient for *FGMEM* (farmer group membership) was positive for PPT (APE = 0.010) and IR maize technology (APE = 0.076) and significant at 10% level. The household heads, who were members of farmer groups, were more likely to intensify the use of PPT and IR maize technology though the magnitude differed. This was in line with findings by Amudavi *et al.* (2008), who indicated a positive relationship between the decision to intensity the use of PPT, and an individual being a member of a farmer group. For example, if a household head was a member of a farmer group, he/she was expected to expand on average the area under PPT by 0.010 acres as opposed to 0.076 acres for IR maize technology. Thus, more land would be put into IR maize technology use compared to PPT, if a farmer was in a group. While in groups, farmers are expected to reduce costs of searching information and also transformation costs. Social capital which includes the interactions of individuals, norms and values positively influences the performance of group membership (Wambugu *et al.,* 2009).

The average partial effect coefficient for *LOGINCOME* (income level of a household), was positive for PPT (APE = 0.003). The higher the income level for farmers, the more the likelihood of expanding the land put under PPT. In fact, if income of a household increased by 100 KES, the area put under PPT was expected to increase by 0.3 acres on average. The wealthier a household is, the more likelihood of expanding the area allocated to PPT. This is in line to findings by Alene *et al.* (2000) who established that, wealthier farmers were more likely to adopt and expand the use of improved maize varieties. This could be due to the fact that, they are able to cope with risks and shocks as well as covering related costs, since they are more risk loving than their poorer counterparts (Rosenzweig and Binswanger, 1993). The study however, found no significant influence of income level of a farmer to the decision of expanding the area under IR maize.

Table 6.1: Unconditional Average Partial Effects (APE) results of PPT and IR maize technology

Variable	PPT		IR maize technology	
	Observed coefficient	Std. error	Observed coefficient	Std. error
AGEHHH (age of a household head)	0.000	0.000	0.001	0.001
GENDERHHH (gender of a house hold head)	0.002	0.003	-0.016	0.033
YRSCHHH (years of formal schooling attained by a household head)	0.001	0.001	0.020	0.012
EXTENACS (access to extension services)	-0.004	0.004	0.077	0.050
FGMEM (farmer group membership)	0.010*	0.006	0.076*	0.044
LOGINCOME (income level of a household)	0.003**	0.001	0.024	0.021
TLU (tropical livestock unit)	0.002**	0.007	0.004	0.006
FRMLBPAT (farm labour participation)	0.004	0.003		

$^{***}P < 0.01$, $^{**}P < 0.05$ and $^{*}P < 0.10$ mean significant at 1%, 5% and 10% probability levels, respectively.

Source: Survey data, 2012.

Livestock ownership significantly influenced the expansion of the area under PPT (APE = 0.002), but was insignificant for IR maize technology. The higher the number of livestock units owned by a household, the more likely it is to expand the area under PPT. In fact, an addition livestock unit in a household is likely to increase the probability of expanding the area under PPT on average by 0.002 acres. This is due to the fact that, the farmers are bound to benefit with livestock fodder from PPT (Khan *et al.,* 2001).

6.5 Conclusion

This chapter assessed the factors influencing adoption and intensity of use of PPT and IR maize technology. Nine (9) variables significantly influenced the decision of a household head to adopt PPT namely: *AGEHHH* (age of the household head), *GENDERHHH* (gender of the household head), *YRSCHHH* (years of schooling of a household head), *LANDSZ* (total land size), *LOGINCOME* (income level of a household), *DSADMN* (distance to the nearest administration centre), *TLU* (tropical livestock unit) and *FGMEM* (farmer group membership) while four (4) variables influenced the decision to expand the area put under PPT namely: *FGMEM* (farmer group membership), *LOGINCOME* (income level of a household), *PERCPRANK* (perception on the effectiveness of the technology towards *Striga* control) and *TLU* (tropical livestock unit).

On the other hand, six (6) variables significantly influenced the adoption of IR maize technology namely: *FGMEM* (farmer group membership), *YRSCHHH* (years of schooling of a household head), *LOGINCOME* (income level of a household), *RADOWNSP* (radio ownership), *HHSIZE* (household size) and *LANDSZ* (household total land size) while three factors (3) influenced the technology's extent of adoption namely: *EXTENACS* (access to extension), *PERCPRANK* (perception) and *TLU* (tropical livestock unit).

Farmers experience and whether a farmer is male matters in the adoption of PPT. Therefore, efforts in the adoption of the technology should target older farmers and male headed households. On the other hand, IR maize technology promoters should focus on large households and those who own radios since they are able to easily access information. In order to expand the use of PPT, promoters should target farmers who are organized in groups and with higher income levels. The IR maize technology counterparts should target farmers who usually access extension services and own livestock.

These results lead to the conclusion that, any efforts to the promotion of PPT and IR maize technology should target different strategies. Therefore the second hypothesis which stated that, there is no significant difference between factors influencing adoption and intensity of use of PPT and IR maize technology was rejected.

CHAPTER SEVEN

ESTIMATION OF ACTUAL AND POTENTIAL ADOPTION RATES AND THEIR DETERMINANTS OF PPT AND IR MAIZE TECHNOLOGY

7.1 Introduction

Most studies have assessed adoption rates of new technologies by simply using classical "adoption" models. This approach has been proved to suffer either from non-exposure bias or from selection bias. As a consequence, they generally yield biased and inconsistent estimates of population adoption rates even when based on a randomly selected sample. This therefore shows that, the causal effects of the determinants of adoption cannot also be consistently estimated using simple probit, logit or tobit adoption models that do not control for exposure (Diagne, 2009). The non-exposure bias occurs due to the fact that farmers who have not been exposed to a new technology cannot adopt it if they had not known about it (Diagne and Demont, 2007). Therefore, the observed sample adoption rate will always underestimate the true population adoption rate, when exposure of the population to the new technology is incomplete (Diagne, 2006).

The adoption rate of the sub sample of farmers exposed to the technology is also not a consistent true estimate of the population adoption rate even if the sample was random. This is due to the positive population selection bias, which arises due to farmers self-selecting themselves into exposure and technology promoters targeting progressive farmers in a village, who have a higher propensity to adopt (Diagne, 2006). This therefore, may overestimate the true population adoption rate (Diagne and Demont, 2007). This shows the need for researchers to turn to ATE framework and shun from using classical approaches in estimating the adoption rates, since it caters for selectivity bias and brings out the aspect of counterfactual (Diagne, 2009).

This framework has been used widely by various authors (e.g. Diagne and Demont, 2007; Diagne, 2009; Nguezet *et al.,* 2010; Simtowe *et al.,* 2010). This method assists in estimating ATE, which refers to the potential population adoption rate that represents the adoption rate, when all members of the population have been exposed to the technology. The difference between the potential and actual adoption rate, gives rise to unmet demand. This is usually referred to as the "adoption gap", which occurs solely due to incomplete diffusion of the technology in the population. This chapter uses ATE framework, to compare the adoption rates of PPT and IR maize technology using exposure as the treatment.

7.2 Data

For the results of any econometric analysis conducted to be robust and reliable, appropriate data must be collected. While using structured questionnaire administered by trained enumerators, during a survey carried out between February and March 2012, data on covariates for exposure and adoption models were collected. They included: age, gender and years of schooling of a household head, total land size owned by a household, size of the household, extension access, farmer group membership, distance to the nearest administration centre, income level of a household, tropical livestock unit owned by a household and whether a household head owned a radio. Furthermore, data on whether the household head was aware of the existence of PPT or IR maize technology (exposed) were also collected. Exposure was used a treatment variable in the ATE estimation framework.

7.3 Model specification and analysis

Following Diagne (2006) and Diagne and Demont (2007), ATE (average treatment effect) provides appropriate framework to estimate the PPT and IR maize technology adoption rates and their determinants. A counterfactual outcome framework is used where every farmer in the population has two potential outcomes: with and without exposure to a technology. If we let y_1 be the potential adoption outcome of a farmer when exposed to PPT and IR maize technology and y_0 be the potential adoption outcome when not exposed to them. The potential adoption outcome can be either adoption status (a dichotomous 0, 1 variable) or a measure of intensity of adoption such as the total land area allocated to the technologies. The treatment effect for farmer i is measured by the difference $y_{i1} - y_{i0}$. Thus, the expected population adoption impact of exposure to these technologies is given by the expected value which is $E(y_1 - y_0)$ called ATE. But, the inability to observe both an outcome and its counterfactual makes it impossible to measure $y_1 - y_0$ for any given farmer. However, since exposure to a new variety is a necessary condition for its adoption, we have $y_0 = 0$ for any farmer whether exposed to the set of new technologies or not. Hence the adoption impact of a farmer i is given by y_{i1} and the average adoption impact is given by $ATE = Ey_1$.

Unfortunately, we observe y_1 only for farmers exposed to these technologies. Hence, we cannot estimate the expected value of y_1 by the sample average of a randomly drawn sample, since some of the y_1 in the sample would be missing. If we let the binary variable W be an indicator for exposure to PPT and IR maize technologies, where *W*= 1 denotes exposure and *W*= 0 otherwise.

The ATE estimators are classified under two broad classes based on the assumption they require to be consistent. The first class of estimators is based on the conditional independence assumption which states that: the treatment status (*W*) is independent of the potential outcomes y_1 and y_0 conditional on an observed set of covariates *x*. The second class of estimators is based on instrumental variable methods and assumes the existence of at least one instrument (*Z*) that explains treatment status but is redundant in explaining the outcomes y_1 and y_0, once the effects of the covariates *x* are controlled for. The estimators using the conditional independence assumption are either a pure parametric regression-based method where the covariates are interacted with treatment status variable, or they are based on a two-stage estimation procedure where the conditional probability of treatment $P(W=1/x)=P(x)$ called the propensity score, is estimated in the first stage and ATE as well as ATE1 are estimated in the second stage by parametric regression-based methods or by non-parametric methods.

The inverse probability weighting (IPW) estimator of ATE (nonparametric)

The weighting estimator is based on a two-stage estimation procedure where the conditional probability of treatment $P(W=1/Z)=P(Z)$ called the propensity score (PS), is estimated in the first stage and ATE, ATE1 and ATE0 are estimated in the second stage using the following probability weighting estimators, which are special cases of the general weighting estimators of ATE, ATE1 and ATE0 when y_0= 0 are expressed as follows:

$$A\hat{T}E=\frac{1}{n}\sum_{i=1}^{n}\frac{\mathrm{y}_1}{\hat{\mathrm{p}}(\mathrm{Z}_\mathrm{i})} \tag{7.1}$$

$$A\hat{T}E1=\frac{1}{n_e}\sum_{\mathrm{i}=1}^{n_e}y_i \tag{7.2}$$

$$A\hat{T}E0=\frac{1}{n-n_e}\sum_{\mathrm{i}=1}^{n}\frac{(1-\hat{\mathrm{p}}(\mathrm{Z}_\mathrm{i}))}{\hat{\mathrm{p}}(\mathrm{Z}_\mathrm{i})}y_1 \tag{7.3}$$

where $\hat{p}(Z_i)$ is a consistent estimate of the propensity score evaluated at Z and $n_e = \sum_{i=1}^{n} W_i$ is the number of exposed farmers.

Parametric estimation of ATE

The parametric estimation procedure of ATE which holds under the conditional independence assumption is given by:

$$ATE_X = E(y_1 / x) = E(y / x, W = 1) \tag{7.4}$$

The parametric estimation first specifies a parametric model for the conditional expectation in the right hand side of the second equality of the above equation which involves the observed variables *y, x* and *W*:

$$E(y / x, W = 1) = g(x, \beta) \tag{7.5}$$

where *g* is a known (possibly nonlinear) function of the vector of covariates *x* and the unknown parameter vector *β,* which is to be estimated using standard Least Squares or maximum likelihood estimation (MLE) procedures. This is done using the observations from the sub-sample of aware farmers only, with *y* as the dependent variable and *x* the vector of explanatory variables. With an estimated parameter $\hat{\beta}$, the predicted values $g(x_i, \hat{\beta})$ are computed for all the observations *i* in the sample (including the observations in the non-aware sub-sample) and ATE, ATE1 and ATE0 are estimated by taking the average of the predicted $g(x_i, \hat{\beta})\, i$ = 1.....,n across the full sample (for ATE) and respective sub-samples (for ATE1 and ATE0):

$$A\hat{T}E = \frac{1}{n}\sum_{i=1}^{n} g(x_i, \beta) \tag{7.6}$$

$$A\hat{T}E1 = \frac{1}{n_e}\sum_{i=1}^{n_e} W_i g(x_i, \beta) \tag{7.7}$$

$$A\hat{T}E0 = \frac{1}{n - n_e}\sum_{i=1}^{n} (1 - W_i) g(x_i, \beta) \tag{7.8}$$

The effects of the determinants of adoption, as measured by the marginal effects of the k dimensional vector of covariates x, at the average point ($\bar{x}$) are estimated as:

$$\frac{\partial E(y_1 / \bar{x})}{\partial x_k} = \frac{\partial g(\bar{x}, \hat{\beta})}{\partial x_k} k = 1, \ldots\ldots\ldots, k \tag{7.9}$$

where x_k is the k^{th} component of x. To test for multicollinearity, VIF was used where all variables registered values less than 10 as required (Maddala, 1993). These are indicated in appendices 7 and 8. Each ATE model was fitted separately for PPT and IR sub-populations.

7.4 Results and discussion

7.4.1 Actual and potential adoption rates estimates of PPT and IR maize technology

Table 7.1 indicates the estimates of PPT and IR maize technology adoption rates and their standard errors. The actual adoption rates (AAR) of PPT and IR maize technology, were estimated at 36.3% and 37.0% respectively and significant at 1% level. This indicated that on average, the two technologies recorded almost similar adoption rates even though IR maize technology had a slightly higher uptake level (37.0%). However, the potential adoption rates (ATE) which inform on the demand of PPT and IR maize technology by the target population, was estimated at 56.3% and 46.0% respectively and was significant at 1% level. This showed that on average, PPT had a higher potential to be adopted (56.3%), compared to IR maize technology (46.0%) once the whole population was made aware (exposed). In fact, the potential adoption rate of PPT was higher than that of IR maize technology by 10.3%.

The population adoption rates (ATE) could be interpreted to mean that, PPT and IR maize technology adoption rates could have been 56.3% and 46.0% respectively, instead of the actually observed 36.3% and 37.0% joint exposure and adoption rates in 2012. This was possible if the whole population was exposed to the two technologies in 2012 or before. These results indicated that, even though IR maize technology had a slightly higher uptake level by a margin of 0.7%, PPT recorded a higher potential of adoption shown by 10.3% difference (Table 7.1).

Table 7.1: Estimates of PPT and IR maize technology adoption rates (actual and potential) according to the attributes (covariates)

Attributes (Covariates)	ATE parametric (Probit) estimates	
	PPT	IR maize technology
	Parameter	Parameter
PPT and IR maize technology adoption rates (Probability of adopting PPT or IR maize technology):		
In the full population (ATE)	0.563 (0.043) ***	0.460 (0.035) ***
Within the PPT or IR maize technology exposed sub-population (ATE1)	0.723 (0.030)***	0.508 (0.033)***
Within the sub-population not exposed to the PPT or IR maize technology (ATE0)	0.401 (0.065) ***	0.329 (0.050)***
Actual adoption rate (AAR)	0.363 (0.015)***	0.370 (0.024)***
Estimated population adoption gap (GAP)	-0.200 (0.032)***	-0.089 (0.013)***
Expected population selection bias (PSB)	0.160 (0.026)***	0.048 (0.010)***

Note: Figures in the parentheses are the standard errors associated with the coefficients and marginal effects.

$^{***}P < 0.01$, $^{**}P < 0.05$ and $^{*}P < 0.10$ mean significant at 1%, 5% and 10% probability levels, respectively.

Source: Survey data, 2012.

The adoption rates of PPT and IR maize technology within the exposed sub-population (ATE1), were estimated at 72.3% and 50.8% respectively using ATE parametric (probit) model. Thus, PPT had a higher adoption rate within the sub-population that was aware (exposed) to the technology, as compared to IR maize technology by a margin of 21.5%. The margin (21.5%) was calculated as the difference between ATE1 adoption rates of the two technologies (72.3% and 50.8%). The adoption rates within the sub-population which was not exposed to PPT and IR maize technology (ATE0) were estimated at 40.1% and 32.9% respectively and were significant at 1% level. The PPT sub-population indicated a higher adoption rate, compared to IR maize technology by 7.2% margin. However, ATE1 and ATE0 cannot be used as true estimates of adoption rates due to biasness, and therefore ATE was used for estimating potential adoption rates (Diagne and Demont, 2007).

The expected population selection bias (PSB) was calculated as adoption rate within the exposed sub-population minus the potential adoption rate (ATE1-ATE). This showed the bias of using ATE1 (for exposed sub-population) rather than the ATE (for the whole population). The PSB for PPT was higher (16%), as compared to that of IR maize technology (4.8%) and was significant at 1% level. The biasness (PSB), could occur due to progressive farmers usually being targeted by technology developers and promoters, or farmers self-selecting themselves into exposure (Diagne and Demont, 2007). This therefore explains why ATE1 estimates are not usually used, since they can overestimate or underestimate the true population adoption rates. In fact, had the study used ATE1 to estimate the potential adoption rates of PPT and IR maize technology, the results would have been 16% and 4.8% higher for PPT and IR maize technology respectively.

Population adoption gap (GAP) was estimated as actual adoption rate minus potential adoption rate (AAR - ATE) for both technologies. This explained the adoption gap (unmet demand once the whole population is made aware) which was the difference between the actual and potential adoption rates. The adoption gap for PPT (20.0%) was higher as compared to IR maize technology (8.9%) and significant at 1% level (Table 7.1). This explained that, had the technology promoters ensured complete population exposure of PPT in 2012 or before, the adoption rate could have been 56.3% instead of 36.3%. On the other hand, IR maize technology registered a much lower adoption gap (8.9%). Therefore, in case of complete population awareness, adoption rate could have been 46.0% instead of currently observed 37%. Therefore, PPT indicated a higher adoption gap, as compared to IR maize technology by 11% margin.

7.4.2 Determinants of the probability of exposure to PPT and IR maize technology

The coefficients and marginal effects of factors which determined the probability of being exposed to PPT and IR maize technology are presented in Table 7.2 and Table 7.3.

The marginal effect for *AGEHHH* (age of the household head) was positive (ME = 0.015) for PPT and statistically significant at 1%. Older farmers had a higher probability of being exposed, as compared to their younger counterparts. This could be due to their enormous farming experience acquired overtime. This was inconsistent to the findings by Adesina and Baidu-Forson (1995) and Rahelizatovo and Gillespie (2004) who established that, older farmers are less risk takers (risk averse) than younger farmers. Therefore they have less likelihood of being exposed to new technologies. On the other hand, the variable had no significant effect on the probability of being exposed to IR maize technology.

Table 7.2: Coefficients and marginal effects of estimated parametric models for PPT exposure and adoption

Variable	Exposure probit model		ATE probit adoption model		Classic probit joint exposure and adoption model	
	Coefficient	Marginal effects (dy/dx)	Coefficient	Marginal effects (dy/dx)	Coefficient	Marginal effects (dy/dx)
AGEHHH	0.037 (0.011)***	0.015 (0.005)***	0.053 (0.172)***	0.020 (0.007)***	0.020 (0.011)*	0.006(0.003)*
GENDERHHH	-0.071 (0.273)	-0.028 (0.108)	1.212(0.452)***	0.433 (0.148)***	0.636 (0.304)**	0.198 (0.091)**
HHSIZE	0.089 (0.045)**	0.035 (0.018)**	0.260 (0.761)***	0.100 (0.031)***	0.192 (0.050)***	0.059 (0.015)***
EXTENACS	0.513 (0.276)*	0.202 (0.106)*	- 0.385 (0.462)	-0.145 (0.172)	0.277 (0.263)	0.084 (0.081)
RADOWNSP	-0.192 (0.269)	-0.076 (0.106)	0.120 (0.376)	0.046 (0.144)	-0.357 (0.269)	-0.109 (0.082)
FGMEM	0.489 (0.271)*	0.192 (0.104)*	0.823 (0.470)*	0.307 (0.164)*	0.704 (0.292)**	0.214 (0.089)**
YRSCHHH	0.060 (0.037)	0.024 (0.015)	- 0.008 (0.065)	-0.003 (0.025)	0.041 (0.038)	0.013 (0.012)
DSADMN	-0.312 (0.067)***	-0.124 (0.027)***	- 0.271 (0.108)**	-0.103 (0.046)**	-0.524(0.073)***	-0.161(0.018)***
LOGINCOME	0.439 (0.213)**	0.174(0.083)**	- 0.280 (0.090)	-0.011 (0.034)	-0.111 (0.095)	-0.034 (0.029)
TLU	0.070 (0.062)	0.028 (0.025)	0.182 (0.086)**	0.070 (0.033)**	0.139 (0.061)**	0.043 (0.019)**
LANDSZ			0.167 (0.086)*	0.064 (0.032)**	0.032 (0.061)	0.010 (0.019)
Constant	-4.179 (1.138)***					
N	175		175		175	
Wald chi2(11)	121.40		34.11		75.89	
Prob > chi2	0.0000		0.0003		0.0000	
Pseudo R^2	0.5004					

Note: Figures in the parentheses are the standard errors associated with the coefficients and marginal effects. $^{***}P < 0.01$, $^{**}P < 0.05$ and $^{*}P < 0.10$ mean significant at 1%, 5% and 10% probability levels, respectively.

Source: Survey data, 2012.

Male household heads were more likely to be exposed to IR maize technology (ME = 0.224) unlike their female counterparts. This could be due to the fact that, males have greater access to information and resources unlike their female counterparts (Kaliba *et al.,* 2000). This is contrary to findings by Nguezet *et al.* (2010) who observed that, female headed households are more likely to be exposed to Nerica rice varieties. However, no significant influence on the probability of being exposed to PPT was observed.

The marginal effect for *HHSIZE* (household size) was positive (ME = 0.035) for both PPT and IR maize technology. This showed that, the more members a household had, the higher its probability of being exposed to PPT and IR maize technology. This could be attributed to the fact that, many members in a household provide diverse avenues from which they can access and share information and ideas.

The farmers who were members of producer groups had a higher probability of being exposed to PPT (ME = 0.192). This could be because while in groups, the farmers have an opportunity to be trained and thus access vital information easily and cheaply. Several studies agree with these findings (Tura *et al.,* 2010). This study however, found no significant influence of farmer group membership on the probability of being exposed to IR maize technology.

The marginal effect for *YRSCHHH* (years spent in school by a house head) was positive (ME = 0.016) for IR maize technology. Educated individuals have a higher probability of being exposed to IR maize technology, since they are able to effectively search and interpret information accessed (Zhang *et al.,* 2010).

Distance of the household from the nearest administration centre, had a negative marginal effect (ME = -0.124) on its probability of being exposed to PPT. This could be interpreted to mean that, the further away the household location is from the agricultural offices, the lower the probability of being exposed to PPT. In fact, as distance from agricultural offices increases by 1 km, probability of a household becoming exposed decreases by 12.4%. Some studies are in agreement with these findings (Feleke and Zegeye, 2006; Murage *et al.,* 2012).

Wealthier farmers were more likely to be exposed to PPT (ME = 0.174), since they are more risk loving than their poorer counterparts. This is in line to findings by Ebojei *et al.* (2012) who established that, wealthier farmers have a higher probability of adopting a new technology, compared to the less income households who are more risk averse. On the other hand, the variable had no significant effect on the probability of being exposed to IR maize technology.

7.4.3 Factors influencing the adoption of PPT and IR maize technology

Table 7.2 and Table 7.3 shows the coefficients and marginal effects of the factors influencing the adoption of PPT and IR maize technology, using ATE adoption model and classical probit joint exposure model.

Marginal effect for *AGEHHH* (age of a household head) was positive (ME = 0.020) for PPT and indicated that, older farmers were more likely to adopt the technology, as compared to their younger counterparts. This is inconsistent to findings by Simtowe *et al.* (2010) who indicated that, younger farmers were more likely to adopt improved groundnut varieties. The variable was insignificant for IR maize technology adoption.

The marginal effect for *TLU* (tropical livestock unit) was positive (0.070) for PPT and significant at 5% level. The variable was used as a proxy of wealth and indicated that, as the livestock units of a household increases, the probability of adopting PPT would increase. Thus, the wealthier a household was in terms of TLU ownership, the more likelihood of adopting the technology. Several studies concur with these findings (Zegeye *et al.,* 2001; Salasya *et al.,* 2007). However, TLU had no significant influence on IR maize technology adoption.

Educated individuals were more likely to adopt IR maize technology (ME = 0.045), as compared to their less educated counterparts, since they could interpret information easily. This is consistent to findings from several studies (e.g. Alene *et al.,* 2000; Mwabu *et al.,* 2006; Salasya *et al.,* 2007; Ouma and De Groote, 2011). Salasya *et al.* (ibid) established that, educated farmers were more likely to adopt IR maize technology in western Kenya. The variable had no significant influence on the decision to adopt PPT.

Table 7.3: Coefficients and marginal effects of estimated parametric models for IR maize technology exposure and adoption

Variable	Exposure probit model		ATE probit adoption model		Classic probit joint exposure and adoption model	
	Coefficient	Marginal effects (dy/dx)	Coefficient	Marginal effects (dy/dx)	Coefficient	Marginal effects (dy/dx)
AGEHHH	0.005 (0.010)	0.001 (0.003)	-0.007 (0.009)	-0.003 (0.004)	-0.013 (0.008)	-0.005 (0.003)
GENDERHHH	0.804 (0.269)***	0.224 (0.069)***	-0.538 (0.325)*	-0.207 (0.123)*	-0.198 (0.262)	-0.068 (0.090)
HHSIZE	0.147 (0.080)*	0.035 (0.018)**	-0.049 (0.089)	-0.019 (0.035)	-0.017 (0.069)	-0.006 (0.024)
EXTENACS	0.290 (0.281)	0.083 (0.078)	0.107 (0.331)	0.042 (0.130)	0.164 (0.272)	0.057 (0.095)
RADOWNSP	0.414 (0.253)	0.128 (0.081)	0.120 (0.376)	0.101 (0.111)	0.337 (0.250)	0.112 (0.081)
FGMEM	0.093 (0.264)	0.027 (0.076)	1.482 (0.359)***	0.540 (0.110)***	1.202 (0.273)***	0.414 (0.090)***
YRSCHHH	0.056(0.031)*	0.016 (0.009)*	0.115 (0.037)***	0.045 (0.014)***	0.124 (0.034)***	0.043 (0.011)***
DSADMN	-0.071 (0.043)	-0.020 (0.013)	-0.199 (0.068)***	-0.078 (0.026)***	-0.216 (0.066)***	-0.075 (0.020)***
LOGINCOME	0.145 (0.171)	0.042 (0.050)	-0.055 (0.010)	-0.021 (0.039)	-0.100 (0.108)	-0.035 (0.037)
TLU	-0.015 (0.053)	-0.005 (0.015)	-0.027 (0.059)	-0.011 (0.023)	-0.007 (0.049)	-0.002 (0.017)
LANDSZ			0.056 (0.071)	0.022 (0.028)	-0.000 (0.068)	-0.000 (0.024)
Constant	-1.806 (1.106)					
N	175					
Wald chi2(11)	32.85		44.87		52.52	
Prob > chi2	0.0003		0.0000		0.0000	
Pseudo R^2	0.1860					

Note: Figures in the parentheses are the standard errors associated with the coefficients and marginal effects.
$^{***}P < 0.01$, $^{**}P < 0.05$ and $^{*}P < 0.10$ mean significant at 1%, 5% and 10% probability levels, respectively.
Source: Survey data, 2012.

The marginal effect for *FGMEM* (farmer group membership) was positive for PPT (0.307) and IR maize technology (0.540). The farmers who are members of a group had a higher probability of adopting PPT and IR maize technology. Group membership leads to lower transaction and transformation costs of searching for information, which in turn helps farmers to cheaply access information (Amudavi *et al.,* 2008). Grootaert (2001) argues that, social capital which are the networks, values and norms that govern interactions among people are crucial in reducing the transaction costs incurred by farmers. However, these results differs to those by Murage *et al.* (2011a) who established that, farmers who belonged to organized groups were likely to take longer time to adopt PPT than non-members. This could be due to being exposed to a wide range of ideas, which may either make them form a positive or negative attitude towards a new technology being promoted.

The closely located households to the nearest administration centre had a higher probability of adopting PPT (ME = -0.103) and IR maize technology (ME = -0.078) as shown in Table 7.2 and Table 7.3. This is consistent to findings by Dorward *et al.* (2005) who established that, poor infrastructure linking farmers to the input and output markets leads to high transaction costs, which could hinder the adoption of new technologies being promoted. However, the results were inconsistent to the findings by Simtowe *et al.* (2010) who noted an unexpected positive relationship, and attributed it to the fact that, agricultural extension in Malawi could be irrelevant in disseminating information to the farmers.

Male headed households were more likely to adopt PPT (ME = 0.433), while female headed households had a higher probability of adopting IR maize technology (ME = -0.207). The findings are consistent to those of several studies (e.g. Kaliba *et al.,* 2000; Diagne, 2009; Jamala *et al.,* 2011). In fact, Kaliba *et al.* (ibid) established that, male headed households have a greater access to resources and information. They therefore have a higher probability of adopting new technologies, as compared to the female headed households. However, the findings are contrary to those by Khan *et al.* (2008c), who indicated that, female headed households were more likely to adopt PPT.

7.5 Conclusion

This chapter used average treatment effect estimation framework, to consistently estimate the PPT and IR maize technology adoption rates and their determinants in Siaya county. It highlighted the importance of controlling for exposure and selection bias, when estimating the adoption rates and their determinants. The decision to adopt PPT and IR maize technology and probability of farmers being exposed to the two technologies was influenced by different factors. This implies that, different strategies should be targeted in up scaling the uptake of the two *Striga* eradicating technologies.

Despite the actual adoption rates of the two technologies being relatively equal, PPT had a higher potential adoption rate compared to IR maize technology. The potential adoption rate would be realized when the whole population was made aware/exposed to the two technologies. This therefore calls for re-evaluation of the dissemination pathways used by the technology promoters so as to bridge the unmet demand (adoption gap). Since PPT had the highest potential adoption rate as compared to IR maize technology, it should be given priority in dissemination as a *Striga* control strategy.

These results lead to the conclusion that, the actual and potential adoption rates and their determinants of PPT and IR maize technology are different. Therefore, the third hypothesis which stated that there is no significant difference between estimates of actual and potential adoption rates of PPT and IR maize technology and their determinants was rejected. All the estimations and inferences in this chapter were done using Stata version 11.2. The Stata add-on adoption command which was developed to automate the estimation of ATE adoption models was specifically used, as indicated by Diagne and Demont (2007).

CHAPTER EIGHT

SUMMARY, CONCLUSIONS AND IMPLICATIONS

8.1 Introduction

Pests, weeds and insects are some of the serious challenges facing maize farmers in western Kenya and pose a threat to food security. *Striga* weeds in particular are a menace that farmers to date still struggle to control and lead to huge maize losses. In trying to control the witch weeds, farmers have been using conventional methods such as: hand weeding and uprooting to no success and this led to the development of two modern technologies namely: PPT and IR maize technology. Khan and Pickett (2004) termed PPT as a novel tool for integrated pest management programs, used to control both stemborers and *Striga* weeds simultaneously while IR maize technology involves coating maize seeds with a systemic herbicide called *Imazapyr* (Kanampiu *et al.,* 2002).

For Kenya to experience an increase in maize production, these technologies must register high adoption rates. Many PPT studies have been carried out in Kenya (Khan *et al.,* 2001; 2007; 2008a; 2008b; 2011; Amudavi *et al.,* 2008), but very few have investigated the factors which influence the decision of the farmers to adopt the technology (Amudavi *et al.,* 2008). Similarly, among the many studies that have been conducted on IR maize technology (Odhiambo and Woomer, 2005; Kabambe *et al.,* 2007; Manyong *et al.,* 2008; Mignouna *et al.,* 2010; 2011a), only a few have analysed the determinants of the technology's adoption and intensity of use (Mignouna *et al.,* 2010; 2011a).

These numerous publications from PPT and IR maize technology show that, effort has been devoted in understanding these innovations, but very few have compared the two technologies in terms of the actual and potential adoption rates. Therefore, this study purposed to compare the adoption rates (both actual and potential) of PPT and IR maize technology using ATE estimation framework unlike many adoption studies, which estimate the adoption rates using classical adoption models. This method is superior due to the fact that, it does not suffer from selectivity bias and brings out the aspect of counterfactual.

The study also attempted to assess the factors which determined the adoption and intensity of use of the two technologies using Cragg's double hurdle model. Whereas many studies that have used this model only limit themselves to just estimating the coefficients only, this study moved a step further and estimated the "unconditional" average partial effects for PPT and IR maize technology.

While evaluating the farmers' perceptions on the effectiveness of the two technologies in controlling *Striga*, this study unlike other perception studies used index approach to calculate the respective demand, supply and attainment indices. This would assist the technology developers of both technologies in identifying the characteristics that farmers consider important to them, and how the technology package addresses them. Although several studies have been carried out on adoption of PPT and IR maize technology, none that this study is aware of has compared the two. This study aimed to fill this gap.

8.2 The determinants of PPT and IR maize technology adoption and intensity of use in *Striga* control.

For newly developed innovations to be adopted in large numbers, they must be effective and affordable. The speed of their uptake is very important if the farmers are to realize maximum benefits, and calls for an effective and efficient dissemination pathway which ensures information is readily available (Murage, 2011). To realize high adoption rates, PPT and IR maize technology must convince the farmers of their effectiveness in *Striga* control. The PPT has been adopted by over 30,000 farmers in East Africa (Khan *et al.,* 2011), but IR maize technology adoption is not clear. The adoption levels of the two technologies could be expected to be influenced by several factors among them: socio-economic, institutional and technological. This led to the formulation of the second objective of this study, which aimed at analyzing the factors which influenced the adoption and intensity of use of PPT and IR maize technology.

Several studies have analyzed the determinants of adoption and intensity of use separately (Jamala *et al.,* 2011), while very few have studied the determinants of both decisions together (Olwande *et al.,* 2009; Burke, 2009 and Mignouna *et al.,* 2010). The results of DH model described in chapter 6 (Table 6.1; 6.2 and 6.3) indicated that, factors influencing the decision of farmers to adopt and intensify the use of PPT and IR maize technology were different and differed in magnitude.

Following these results, Tobit model which assumes that the determinants of adoption and intensity decisions are the same, was not appropriate and therefore, this shows the superiority of DH model. This is because, it assumes that, the factors which influence the decision to adopt and how much to adopt are not necessarily the same. For example, the factors which differed for the adoption decisions of PPT and IR maize technology included: age and gender of a household head, tropical livestock units owned and distance to the nearest agricultural offices for PPT and income level of a household and radio ownership for IR maize technology (Table 6.1). On the other hand, farmer group membership and income levels of a household significantly influenced the decision to intensify the use of PPT, but was insignificant in deciding to intensify the use of IR maize technology.

The results generally indicated that, PPT promoters should target male headed households who are old. On the other hand, educated farmers who own radios and are members of groups should be targeted in efforts of up-scaling IR maize technology uptake. It is important to note that, farmers' perception on the effectiveness of both technologies in *Striga* control significantly influenced the extent of PPT and IR maize technology adoption. This indicated the importance of farmers' perception inclusion in adoption studies, as highlighted by Adesina and Baidu-Forson (1995).

8.3 The determinants of farmers' perception towards the effectiveness of PPT and IR maize technology in *Striga* control.

A farmer is expected to have positive, negative or no perceptions towards a new technology promoted. This is largely attributed to many factors among them: farm and farmer characteristics as well as technology's features. As argued by Sall *et al.* (2000), understanding farmers' perception on technology-specific characteristics, is fundamental in eliciting which ones are highly regarded by farmers as important, and how well they are supplied by the technology in question. Information available to a farmer may positively or negatively influence their perception, and thus credibility of an information source is critical in shaping farmer's perception towards a new technology being promoted. Technology developers and scientists are likely to perceive a new technology differently from the farmers, and since they are the end users of the innovation, their view is very important. Few studies have been carried out to determine the factors which influence farmers' perception (Bagheri *et al.,* 2008). Thus, the first objective which attempted to analyze the determinants of farmers' perception of the effectiveness of PPT and IR maize technology in *Striga* control was formulated to fill this gap. The farmers rated these characteristics against the conventional control methods that they had been using, before CIMMYT and ICIPE introduced IR maize technology and PPT to the area.

Farmers' perception on PPT and IR maize technology characteristics was evaluated using index approach which involved calculation of demand, supply and attainment indices. These indices assisted in assessing how important inbuilt characteristics of both technologies were to farmers, and how well they were satisfied with the manner the respective technologies supplied them. Generally, although PPT seemed to have satisfied the farmers with many of its characteristics, some of them were poorly supplied e.g. intercropping of maize with beans. On the other hand, IR maize technology seemed to struggle in supplying most of the characteristics which were important to farmers, particularly intercropping of maize with other leguminous crops especially beans (Table 5.1).

In general, the factors which influenced farmers' perception of the effectiveness of PPT and IR maize technology in *Striga* control were different (Table 5.2 and 5.3). For instance, age influenced farmers' perception of PPT but was insignificant for IR maize technology. On the other hand, IR maize technology's perception was influenced by several factors among them: education level of a household head, access to extension services and radio ownership, but these factors had no influence on the PPT sub-population.

8.4 Role of exposure in adoption of new technologies

A farmer will only adopt a new technology if the individual is exposed to it (aware of it). This therefore, stresses the need to remove non exposure bias in order to spur adoption. In order to realize increased levels of adoption, information should be made available and affordable to farmers. Several adoption studies have indicated the importance of exposure to the new technology being promoted (Diagne and Demont, 2007; Simtowe *et al.,* 2010; Nguezet *et al.,* 2012). Most farmers fail to adopt a technology mainly due to lack of information about its existence and therefore, dissemination pathway chosen by technology promoters should be effective. In this light, the third objective which aimed at estimating the actual and potential adoption rates of PPT and IR maize technology, using exposure as the treatment was formulated. The main aim was to identify the technology with the highest potential, so as to direct the meagre agricultural investment.

The adoption rates estimations were carried out using ATE which unlike classical 'adoption' models caters for selectivity bias and brings out the aspect of counterfactual (Diagne and Demont, 2007). In fact, the counterfactual question was: "what would have happened to the farmers who did receive treatment, if they had not received treatment (or the converse)?" A comparison of ATE and classical adoption rates was carried out, in an effort to show the superiority of the former. In general, the marginal effects of ATE adoption model were larger (absolute values) than those of classical adoption model. Some variables were significant in ATE adoption model but insignificant in classical adoption model and this showed its superiority. This was in tandem with the theoretical explanation by Diagne and Demont (2007).

Generally, IR maize technology had a higher actual adoption rate as compared to PPT though below 50%. On the other hand, PPT had a higher potential adoption rate as well as unmet demand (Table 7.1). Many studies which have attempted to estimate the adoption rates of technology conditioned on exposure to all population have found similar results (Diagne, 2009; Nguezet *et al.,* 2010). These studies have found a huge adoption gap, which could be realized if the whole population was to be made aware of the existence of respective technologies. In general, exposure is very fundamental in shaping the adoption decisions of farmers. Therefore, the results of this study adds weight to the findings of other studies, which have estimated the adoption rates using ATE as earlier indicated in this chapter.

8.5 Policy implications

Farmers' perception towards the characteristics of PPT and IR maize technology, have been identified as very critical in shaping their decision to adopt and intensify the use of both technologies. Therefore, in addition to farm and farmer characteristics, focus needs to be changed to also include farmers' perceptions on technological characteristics. Technology developers need to involve farmers in the development process of *Striga* eradication technology so as to take into account the characteristics they desire.

The fact that awareness has a huge impact on the potential adoption rates of PPT and IR maize technology means that, technology promoters need to re-evaluate the existing dissemination pathway, in order to be more effective and efficient in exposing the whole population, thus up scaling adoption.

Farmer group membership has been identified as a fundamental factor influencing the adoption and intensification of PPT and IR maize technology. Therefore, technology promoters should promote the formation of farmer groups, and focus more to those farmers who are members of groups. This is because, the effectiveness of the *Striga* control technology, seems to be more prominent to those farmers who were in groups.

Finally, based on the estimates of potential adoption rate, adoption gap and farmers' perception towards PPT and IR maize technology characteristics, PPT seems to be the technology which meets the maize producers' expectations. Given the limitation of agricultural resources, the focus should be more on promotion of PPT and less on IR maize technology as a *Striga* control measure in the study area.

8.6 Suggestions for further research

The study was only undertaken in Siaya county and since *Striga* is prevalent in many other regions in Kenya and some parts of Africa, further research should be carried out in those areas where PPT and IR maize technology has been promoted, to validate the results in this study.

The ability of PPT improving soil fertility is one of the benefits farmers realize after adopting the technology (Khan *et al.,* 2011). This study however, did not determine to what extent does PPT improve soil fertility and therefore a study needs to be carried out to ascertain this.

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APPENDICES

Appendix 1: Variance inflation factor (VIF) multicollinearity test results for the ordered probit model of PPT

Variable	VIF	1/VIF
WORKFORCE	1.82	0.55
YRSCHHH	1.43	0.70
TLU	1.36	0.73
LOGINCOME	1.28	0.78
LANDSZ	1.24	0.81
EXTENACS	1.22	0.82
AGEHHH	1.22	0.82
DSADMN	1.21	0.83
FGMEM	1.18	0.85
GENDERHHH	1.06	0.94
RADOWNSP	1.06	0.95
Mean VIF	1.28	

Appendix 2: Variance inflation factor (VIF) multicollinearity test results for the ordered probit model of IR maize technology

Variable	VIF	1/VIF
EXTENACS	1.33	0.75
YRSCHHH	1.27	0.78
FGMEM	1.27	0.79
WORKFORCE	1.26	0.80
TLU	1.15	0.87
AGEHHH	1.12	0.89
DSADMN	1.12	0.89
GENDERHHH	1.12	0.89
LOGINCOME	1.10	0.91
RADOWNSP	1.05	0.95
LANDSZ	1.04	0.96
Mean VIF	1.17	

Appendix 3: Variance inflation factor (VIF) multicollinearity test results for the double hurdle model (1st hurdle) of PPT

Variable	VIF	1/VIF
INTEXTDSADMN	4.21	0.24
EXTENACS	3.88	0.26
DSADMN	2.32	0.43
HHSIZE	1.64	0.61
YRSCHHH	1.46	0.68
TLU	1.34	0.75
AGEHHH	1.29	0.77
LOGINCOME	1.28	0.78
LANDSZ	1.27	0.79
FGMEM	1.17	0.85
FRMLBPAT	1.16	0.86
RADOWNSP	1.10	0.91
GENDERHHH	1.06	0.94
Mean VIF	1.78	

Appendix 4: Variance inflation factor (VIF) multicollinearity test results for the double hurdle model (2nd hurdle) of PPT

Variable	VIF	1/VIF
INTPERCYRSC	7.23	0.14
PERCPRANK	7.17	0.14
WORKFORCE	2.24	0.45
YRSCHHH	2.12	0.47
TLU	1.52	0.66
FGMEM	1.42	0.70
AGEHHH	1.40	0.72
LOGINCOME	1.32	0.76
EXTENACS	1.25	0.80
LANDSZ	1.25	0.80
FRMLBPAT	1.19	0.84
MOBOWNSP	1.14	0.88
DSPCNTR	1.13	0.88
GENDERHHH	1.11	0.90
Mean VIF	2.25	

Appendix 5: Variance inflation factor (VIF) multicollinearity test results for the double hurdle model (1st hurdle) of IR maize technology

Variable	VIF	1/VIF
EXTENACS	2.88	0.35
INTEXTDSADMN	2.74	0.37
DSADMN	1.76	0.57
FGMEM	1.22	0.82
YRSCHHH	1.22	0.82
TLU	1.21	0.82
HHSIZE	1.13	0.88
GENDERHHH	1.13	0.89
AGEHHH	1.13	0.89
LOGINCOME	1.09	0.91
RADOWNSP	1.04	0.96
LANDSZ	1.04	0.96
Mean VIF	1.47	

Appendix 6: Variance inflation factor (VIF) multicollinearity test results for the double hurdle model (2nd hurdle) of IR maize technology

Variable	VIF	1/VIF
INTPERCYRSC	6.25	0.16
PERCPRANK	4.96	0.20
YRSCHHH	2.28	0.44
FGMEM	1.60	0.62
EXTENACS	1.37	0.73
WORKFORCE	1.37	0.73
MOBOWNSP	1.21	0.82
AGEHHH	1.20	0.83
DSPCNTR	1.20	0.83
LOGINCOME	1.16	0.86
TLU	1.16	0.86
GENDERHHH	1.12	0.90
LANDSZ	1.07	0.93
Mean VIF	2.00	

Appendix 7: Variance inflation factor (VIF) multicollinearity test results for the average treatment effect of PPT

Variable	VIF	1/VIF
HHSIZE	1.61	0.62
YRSCHHH	1.45	0.69
TLU	1.34	0.75
LOGINCOME	1.26	0.79
AGEHHH	1.26	0.79
LANDSZ	1.23	0.81
EXTENACS	1.22	0.82
DSADMN	1.18	0.84
FGMEM	1.17	0.86
RADOWNSP	1.09	0.92
GENDERHHH	1.07	0.93
Mean VIF	1.26	

Appendix 8: Variance inflation factor (VIF) multicollinearity test results for the average treatment effect of IR maize technology

Variable	VIF	1/VIF
EXTENACS	1.34	0.75
FGMEM	1.22	0.82
YRSCHHH	1.22	0.82
TLU	1.21	0.83
AGEHHH	1.13	0.89
HHSIZE	1.12	0.89
GENDERHHH	1.12	0.90
DSADMN	1.11	0.90
LOGINCOME	1.09	0.92
LANDSZ	1.04	0.96
RADOWNSP	1.04	0.96
Mean VIF	1.15	

Appendix 9: Questionnaire

STRIGA CONTROL TECHNOLOGIES (PPT AND IR MAIZE) HOUSEHOLD SURVEY 2012

This study is being carried out by a student pursuing a Master of Science degree from Egerton University. The questionnaire is aimed at gathering information on an analysis of PPT and IR Maize technology adoption for *Striga* control. I, therefore kindly request you to feel free to answer the questions asked, because the information will strictly be used for academic purposes and the necessary confidentiality will be maintained.

Questionnaire No (QNO) ______ Date: (ddmmyy) __________

Household Name ____________________ Respondent Name (Household head) ________________

Identifying Variables:

Enumerator: __________________ Telephone number : _____________

County: __________________

District: __________________

Division: __________________

Location: __________________

Sub-Location: __________________

Village: __________________

SECTION A

1.0 PUSH PULL TECHNOLOGY (PPT) ADOPTER

1.1 Are you aware of PPT? 1=**Yes** [ ] 0=**No** [ ] **If Yes**, when was the first time you heard about it ?......................... yr.

If No, go to part 2.0

1.2 Which were your first three (3) sources of information about PPT?

Source 1	**Source 2**	**Source 3**

1=Radio [ ] 2=Extension agents (government) [ ] 3=Extension agents (ICIPE) [ ] 4=Demonstration sites/on-farm trials [ ]

5=Public barazas [ ] 6=Fellow farmer (neighbour) [ ] 7=Field day [ ] 8=NGO (specify) [ ] 9= Others (specify) [ ]

1.3 Have you ever adopted (practiced) PPT? 1=**Yes** [ ] 0=**No** [ ] **If Yes, go to the next question, if No, go to question 1.12**

1.4When was the first time you adopted? ……………. yr

1.5What was the acreage under PPT at the time you first adopted? .... acres

1.6 What is the status of area under PPT since you first adopted?

1= Increasing [ ] 2= Decreasing [ ] 3= Constant [ ]

1.7 Did you practice PPT in year 2011? 1=**Yes** [ ] 0=**No** [ ] **If Yes, go to the next question and If No, go to question 1.9**

1.8 How many acres/area did you put under PPT? ……………. Acres

1.9 Why didn't you practice PPT in year 2011? Tick as many as possible

1=Desmodium seed was not available [ ] 2=Desmodium seed was expensive [ ]3=Technology is not effective in *Striga* control [ ]

4=Poor desmodium seed germination rate [ ] 5=Does not allow intercropping with other crops especially beans [ ]

6= Technology requires a lot of labour [ ] 7= Technology requires a lot of capital [ ] 8= Napier grass was not available [ ]

9= Napier grass was expensive [ ] 10= Napier grass stunted disease [ ] 11=Others (specify) [ ]

1.10 Which year did you stop using PPT…………………... yr

1.11 Why did you stop using PPT? Tick as many as possible

1= Desmodium seed was not available [ ] 2= Desmodium seed was expensive [ ] 3=Technology is not effective in the control of *Striga* [ ]

4=Poor desmodium seed germination rate [ ] 5=Does not allow intercropping with other crops especially beans [ ]

6= Technology requires a lot of labour [ ] 7= Technology requires a lot of capital [ ] 8= Napier grass was not available [ ]

9= Napier grass was expensive [ ] 10= Napier grass stunted disease [ ] 11=Others (specify) [ ]

1.12 If you have never adopted PPT, give reasons why? Tick as many as possible

1= Desmodium seed was not available [ ] 2= Desmodium seed was expensive [ ] 3=Technology is not effective in *Striga* control [ ]

4=Poor desmodium seed germination rate [ ] 5=Does not allow intercropping with other crops especially beans

6= Technology requires a lot of labour [ ] 7= Technology requires a lot of capital [ ] 8= Napier grass was not available [ ]

9= Napier grass was expensive [ ] 10= Napier grass stunted disease [ ] 11=Others (specify) [ ]

1.13. Have ever been involved in on farm trials or experiments on PPT? **1=Yes [ ] 0=No [ ]**

If Yes, go to the next question and If No, go to question 1.15

1.14 Which year(s) were you first and last involved in the farm trials or experiment?..... ...., (First yr) …………………. (Last yr)

1.15 If you compare PPT and conventional methods that you have been using, how do you rate its effectiveness in *Striga* control?

4= Very good [ ] 3= Good [ ] 2= Poor [ ] 1= No perception [ ]

1.16 FARMERS' PERCEPTION ON PUSH PULL TECHNOLOGYCOMPARED TO CONVENTIONAL METHODS.

No	**Technology characteristic**	**How is the characteristic important to the farmer? (3=Very important 2=Important 1=Not important)**	**How well does the technology supply (address) the characteristic to the farmer? (3=Very Good 2= Good 1= Poor)**
1	Capital required to adopt the technology		
2	Labour required by the technology		
3	Effectiveness in the control of *Striga*		
4	Availability of *desmodium* seed		
5	Affordability of *desmodium* seed		
6	Amount of land required by the technology		
7	Intercropping of maize and other crops especially beans		
8	Improvement of soil fertility		
9	Production of livestock fodder		
10	**Others**		

2.0 IR Maize Technology Adopter

2.1 Are you aware of IR maize technology? 1=**Yes [ ] 0=No [ ]**

If Yes, when was the first time you heard about IR maize ………………… yr. **If No, go to part 3.0**

2.2 Which were your first three (3) sources of information about IR maize? Tick three

Source 1	Source 2	Source 3

1=**Radio [ ] 2=Extension agents (government) [ ] 3=Extension agents (western seed) [ ] 4=Demonstration sites/on-farm trials [ ] 5=Public barazas [ ] 6=Fellow farmer (neighbour) [ ] 7=Field day [ ] 8=NGO (specify) [ ] 9= Others (specify) [ ]**

2.3 Have you ever adopted IR maize technology? 1=**Yes [ ] 0=No [If Yes, go to next question,** If **No, go to question 2.12**

2.4 When was the first time you adopted? …………………. yr

2.5 What was the acreage planted IR maize at the time you first adopted? .... acres

2.6 What is the status of area planted IR maize since you first adopted?

1= Increasing [ ] 2= Decreasing [ ] 3= Constant [ ]

2.7 Did you Plant IR Maize in year 2011? 1=**Yes [ ] 0=No [ ]If Yes, go to the next question** and if **No, go to question 2.9**

2.8 How many acres/area were planted IR maize? ....

2.9 Why didn't you plant IR maize in year 2011? Tick as many as possible

1= IR seed was not available [ ] 2= IR seed was expensive [ ] 3=IR maize Technology is not effective in the control of *Striga* [ ] 4=Poor IR seed germination rate [ ] 5=Chemical used is harmful to farmer's health and other seeds [ ] 6=Others (specify) [ ]

2.10 Which year did you stop using IR maize technology?………………….. yr

2.11 Why did you stop planting IR maize? Tick as many as possible

1= IR seed was not available [ ] 2= IR seed was expensive [ ] 3=IR maize technology is not effective in the control of *Striga* [ ] 4=Poor IR seed germination rate [ ] 5=Chemical used is harmful to farmer's health and other seeds [ ] 6=Others (specify) [ ]

2.12 If you have never adopted IR maize technology (planted IR maize), give reasons why? Tick as many as possible

1=IR seed was not available [ ] 2=IR seed was expensive [ ] 3=IR maize technology is not effective in the control of striga [ ]

4=Poor IR seed germination rate [ ] 5=Chemical used is harmful to farmer's health and other seeds [ ]

6=Low yielding variety [ ] 7=Can't get credit [ ] 8=Lack of cash to buy the IR maize seed [ ] 9=Others (specify) [ ]

2.13 Have ever been involved in on farm trials or experiments on IR maize technology? 1=**Yes [ ] 0=No [ ]**

If Yes, go to the next question and If No, go to question 2.15

2.14 Which year(s) were you first and last involved in the farm trials or experiment? ...., (First yr) .... (Last yr)

2.15 If you compare IR maize technology and conventional methods that you have been using, how do you rate its effectiveness in *Striga* control?

4= Very good [ ] 3= Good [ ] 2= Poor [ ] 1= No perception [ ]

2.16 FARMERS' PERCEPTION ON IR MAIZE TECHNOLOGY COMPARED TO CONVENTIONAL METHODS

No	Technology characteristic	How important is the characteristic to the farmer? (3=very important 2=important 1=Not important)	How does the technology supply (address) the characteristic to the farmer? (3= Very Good 2=Good 1= Poor)
1	Capital required to adopt the technology		
2	Labour required by the technology		
3	Effectiveness in the control of *Striga*		
4	Affordability of IR maize seed		
5	Availability of IR maize seed		
6	Chemicals used being safe to humans and other seeds		
7	Maize seed germination rate		
8	Technology does not allow intercropping of maize and other crops especially beans		
9	Maize seed being a hybrid		
10	Others		

3.0 PPT PRODUCTION INPUTS AND OUTPUT IN LONG/SHORT RAIN SEASON 2011 [APPLICABLE TO A PPT ADOPTER]

Season	Proportion of land planted	Manure					Fertilizer						desmodium seed			Hired oxen (KES								
		Own		Bought			DAP			CAN			Own saved/gift (Kg	Bought			Ploughing, harrowing & planting	Weeding (1st & 2nd	Chemical application	Harvesting	Shelling	Total hired labour (man days)	Prodn See codes below	selling Price (KES)
		Quantity	Unit	Quantity	Unit	Cost/unit	Quantity	Unit	Cost/unit	Quantity	Unit	Cost/unit	Amt Kg	Amount kg	Cost (KES/kg)									
Long Rain (April-Aug 2011)																								
Short Rain (Sept – Dec 2011)																								

Unit codes:

1=90 kg bag 2=50 kg bag 3=kgs 4=gorogoro 5=debe

6=wheelbarrow 7=cart 8=canter 9=pickup

3.1 If you bought desmodium seed, was the amount enough for your needs? **1=Yes [ ] 0=No [ ]**

If Yes, go to the 4.0. If No, go to question 3.2

3.2 How many kilograms of desmodium seed had you wanted to buy? ______________ (kg)

3.3 Why didn't you buy enough desmodium seed? Tick as many reasons as possible

1=Desmodium seed was expensive [ ] 2=Desmodium seed was not available [ ] 3=Lack of enough money [ ] 4=No credit [ ]

5=Others (specify) [ ]

4.0 LONG /SHORT 2011 SEASON (APPLICABLE TO AN IR MAIZE TECHNOLOGY ADOPTER)

[Knowledge of IR Maize technology, source of information and input source]

		First Seed			
IR Variety Known **WS 303(western seed) = 1** **Others (specify) = 0**	Main source of Variety Information. **(Codes A)**	Source of 1st seed **(Codes B)**	Year acquired	Qty (Kg)	Means of acquiring seed **(Codes C)**

Codes

A

1.Government extension

2.Western seed extension

3. Farmer club

4. on-farm trials/demos/ field days

B

1. Extension demo plots

2. Farmer club

3. Bought from local trader or agro-dealers(stockists)

4. Farmer to farmer seed

C

1. Gift/free

2. Borrowed seed

3. Bought with cash

4. Payment in kind

5. Exchange with

5. Seed/grain stockist 6.Another farmer/neighbor 7. Radio/newspaper/TV 8 Other, specify…......…	exchange (relative, friend, etc) 5.Provided free by Western seed company 6. Provided free by other govt agency	other seed 6. Other, specify…..

4.1 If you bought IR seed, was the amount enough for your needs? **1=Yes [ ] 0=No [ ]** If **Yes go to part 5.0, If No, go to question 4.2**

4.2 How many kilograms of IR seed had you wanted to buy? _______________ (kg)

4.3 Why didn't you buy enough IR seed?

1=IR seed was expensive [ ] 2=IR seed was not available [ ] 3=Lack of enough money [ ] 4=No credit [ ]

5=Others (specify) [ ]

5.0 IR MAIZE PRODUCTION INPUTS AND OUTPUT IN LONG/SHORT RAIN SEASON 2011

Season	Proportion of land planted	Manure					Fertilizer						IR maize Variety	IR maize Seed			Hired oxen (KES								
		Own		Bought			DAP			CAN				Own saved/gift	Bought			Ploughing, harrowing & planting	Weeding (1^{st}& 2^{nd}	Chemical application	Harvesting	Shelling	Total hired labour (man days)	Prod *See codes below*	selling Price (KES)
		Quantity	Unit	Quantity	Unit	Cost/unit	Quantity	Unit	Cost/unit	Quantity	Unit	Cost/unit		Amt (Kg)	Amount kg	Cost (KES/kg)									
Long Rain (April-Aug 2011)																									
Short Rain (Sept – Dec 2011)																									

Unit codes:

1=90 kg bag	2=50 kg bag	3=kgs	4=gorogoro
5=debe	6=wheelbarrow	7=cart	8=canter
9=pickup			

SECTION B [NON-ADOPTERS-CONTROL GROUP]

6.0 Are you aware of PPT? 1=**Yes [ ]** 0=**No [ ]** [Control of PPT)

6.1 Are you aware of IR maize technology? 1=**Yes [ ]** 0=**No [ ]** [Control of IR maize technology]

6.2 How do you rate the effectiveness of PPT/IR maize technology in *Striga* control compared to the conventional methods?

4= Very good [ ] 3= Good [ ] 2= Poor [ ] 1= No perception [ ]

6.3 NON PPT/IR MAIZE ADOPTER PRODUCTION INPUTS AND OUTPUT IN LONG/SHORT RAIN SEASON 2011

Season	Proportion of land planted	Manure					Fertilizer						Maize Seed			Hired oxen (KES								
		Own		Bought			DAP			CAN			Own saved/gift	Bought			Ploughing, harrowing & planting	Weeding (1st & 2nd etc	Chemical application	Harvesting	Shelling	Total hired labour (man days)	Prodn *see codes below*	selling Price (KES)
		Quantity	Unit	Quantity	Unit	Cost/unit	Quantity	Unit	Cost/unit	Quantity	Unit	Cost/unit	Amt Kg	Amount	Cost (KES/Kg)									
Long Rain (April-Aug 2011)																								
Short Rain (Sept - Dec 2011)																								

Unit codes:

1=90 kg bag 2=50 kg bag 3=kgs 4=gorogoro
5=debe 6=wheelbarrow 7=cart 8=canter
9=pickup

7.0 INDICATE HOUSEHOLD SOURCES OF INCOME IN THE LAST ONE YEAR (2011)

Source	**Amount per month (KES)**	**Total per year(KES)**
Sale of crop from the farm		
Sale of livestock		
Petty trade		
Employment as casual labour		
Formal employment		
Remittances from relatives		
Government pensions		
Dividend on shares		
Interest on savings		
Renting out houses		
Self employment		
Others specify		

8.0 MARKET AND INSTITUTIONAL FACTORS

8.1 Did any household member access any type of credit for farming (agricultural) purposes in year (2011)? **1=Yes [ ] 0=No [ ]**
If **Yes,** fill the table below and if **No go to the next question 8.2**

Household Member	Item of credit: 1 = cash 2 = kind	Type of provider: 1 = bank 2 = cooperative 3 = trader / shop 4 = money lender 5 = friends and relatives 6 = merry-go-rounds 7= other:	Amount (ksh) (if kind estimate value)	Borrowing date (month and year)	Repayment period (months)	Borrowing conditions	
						Interest rate in %	**Per:**1=day 2=Week 3=Month 4= Year

8.2 If you did not seek any form of credit, what was the reason? Tick as many as possible

1=No collateral [ ] 2=Had outstanding loan [ ] 3=Didn't know the sources of credit [ ] 4=Didn't have an account [ ]
5=Lender lacked cash [ ] 6=No need [ ] 7=Other, (specify) [ ]

9.0 ACCESS TO EXTENSION SERVICES

9.1 Did you actively seek advice on crop farming (maize) between Jan–Dec 2011? **1=Yes [ ] 0=No [ ]**

If **Yes, go to question 9.2, if No go to question 9.4**

9.2 Who did you approach for the advice? **Tick first three [Advice 1 ………. Advice 2 ……….. Advice 3 ………..]**

1=Public extension agent [ ] 2=Private extension agent [ ] 3=Neighbour/farmer [ ] 4=ASK Shows [ ] 5=Traders/input dealers [ ] 6=Radio /television [ ] 7=Family/friend newspaper/magazines [ ] 8=Farmer organizations/cooperatives [ ] 9=Field days/demonstrations [ ] 10=NGO agent [ ] 11=Research organizations [ ] 12= Other (specify) [ ]

9.3 How many times in year 2011 did you contact the (b) above? ....

9.4 Why didn't you seek advice? **(Give up to 2 reasons) [Reason 1 …………….. Reason 2 …………………..]**

1=Long distance [ ] 2=Expensive time consuming [ ] 3=Extension agents not available [ ] 4=Don't need extension service [ ] 5=Other (specify) [ ]

9.5 Are you paying for extension services? **1=Yes [ ] 0=No [ ]**

If Yes, How much are you paying……………... KES/ **(1=day [ ] 2=month [ ] 3= year [ ]) If No, go to question 9.6**

9.6 If extension services in general were to be availed at a fee, would you be willing to pay? **1=Yes [ ] 0=No [ ]**

If Yes, go to the next question, If No, go to 9.8

9.7 How much would you be willing to compensate an extension worker who comes to train you for three hours on a new technology that you urgently need for the maize production…………………………..KES

9.8 If you are not willing to pay for extension services, why? Tick first three reasons **[Reason 1 ….. Reason 2……….Reason 3…………..]**

1=Can't afford [ ] 2=It is a government role [ ] 3=Free services available [ ] 4=Bad past experience [ ] 5=Don't need extension service [ ] 6=Other, specify [ ]

10.0 MEMBERSHIP TO FARMER GROUPS

Does any member of your family belong to any association? 1=**Yes [ ]** 0=**No [ ]** **If Yes, fill the table and if No go to 10.1**

Member ID	Name of HH member	Type of association or club you belong to. (Codes A)	Functions of the club or association (Codes B)	Role in the club (Codes C)

Codes A
1. Input supply/service association
2. Producer marketing club
3. Local administration
4. Farmers' club
5. Women's club
6. Youth club
7. Faith-based organization
8. Saving and credit group
9. Welfare/funeral club
10. Government team
11. Water user's club
12. Other, specify…………….

Codes B
1. Produce marketing
2. Input access/marketing
3. Seed production
4. Farmer research group
5. Savings and credit
6. Welfare/funeral club
7. Tree planting and nurseries
8. Soil & water conservation
9. Input credit
10. Other, specify………

Codes C
1. Chairperson
2. Vice chairperson
3. Secretary
4. Vice secretary
5. Treasurer
6. Ordinary member
7. Messenger
8. Cashier
9. Coordinator
10. Store keeper
11 Other (specify)….

10.1If household head is not a member, Why? (Give reasons)**Tick as many as possible**

1=Resigned for personal reasons [ ] 2=Resigned since the organization was not useful [ ] 3=Finished his/her term [ ]

4=Was deposed for some reason [ ] 5=Unable to pay annual subscription fee [ ] 6=Groups uses a lot of time (time wasting) [ ]

7= Group collapsed [ ] 8=Others (specify) [ ]

11.0 TRANSPORT AND COMMUNICATION INFRASTRUCTURES

11.1 Distance to the nearest market/shopping center (km)……………………………walking time to the market……………………………….(minutes/hrs)

Name of market/shopping center…………………………………

11.2 Distance to the nearest administration centre ……………………….. (Km) walking time to the market……………………………….(minutes/hrs)

11.3 Distance to the nearest big town ……………………….. (Km) walking time to the market……………………………….(minutes/hrs)

11.4 **Type of road** to village market **1=Dirt road [ ] 2=Murram road [ ] 3=Tarmac road [ ]**

Quality of road:**1=Bad [ ] 2=Good [ ] 3=Very Good [ ]**

11.5 Transport cost (per person) to the market using a bus or a boda boda ………………………………………….. (KES/person)

11.6 Do you produce enough (surplus) maize? **1=Yes [ ] 0= No [ ] If Yes, go to the next question, If No, go to part 12.0**

11.7 Do you face any problems while marketing your maize produce? **1=Yes [ ] 0= No [ ] If Yes, go to the next question, If No, go to part 12.0**

11.8 What problems do you face while marketing your maize produce?

1= Lack of market for maize produce [ ] 2=Exploitation by brokers [ ]

3= Maize price fluctuation [ ] 4= Poor roads [ ] 5= Others (specify) [ ]

12.0 OBSERVE AND ASK THE FOLLOWING QUESTIONS

12.1 Does your household own any of the following assets? 1=**Yes [ ] 0=No [ ] If Yes, fill the following table and if No, go to part 13.0**

Asset Name	**Year bought (units)**	**Unit price (year bought)**	**Current Unit value (Kes) (year bought)**	**Total Value (Kes)**
Ox-Ploughs				
Ox-cart				
Sickle				
Axe				
Spade/Shovel				
Hoes				
Sprayer/ Pump				
Wheel Barrow				
Bicycle				
Tractor				
Radio				
Mobile phone				
Television				
Other Specify				

13.0 LIVESTOCK OWNERSHIP

13.1 Does your household own any of the following livestock? 1=**Yes [ ] 0=No [ ]** **If Yes, fill the following table and if No, go to part 14.0**

Livestock	**Current number owned**	**Current average value**	**Total value**
Grade cow			
Grade bull			
Grade calves			
Local cow			
Local bull			
Local calves			
Goats			
Sheep			
Chicken-indigenous (both hens and cocks)			
Chicken-improved			
Donkeys			
Others specify			

14.0 HOUSEHOLD SOCIO-ECONOMICS AND DEMOGRAPHY

Member ID	Name of HH member (start with Household head)	Year of Birth	Age (Years)	Gender (Codes A)	Marital status (Code B)	Education level (Code C)	Years of schooling	Relationship to HH (Codes D)	Main Occupation (Codes E)	Farm labour participation (Codes F)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										

Codes A
1. Male
0. Female

Codes B
1. Monogamously married
2. Polygamously married
3. Divorced/separated
4. Widow/widower
5. Never married(single)
6. Separated
7. Other, specify……….

Codes C
1.None
2.Primary
3.Secondary
4. Tertiary
5.Adult literacy

Codes D
1. Household head
2. Spouse
3. Son/daughter
4. Parent
5. Son/daughter in-law
6. Grand child
7. Other relative
8. Hired worker
9. Other, specify………

Codes E
1. Farming (crop + livestock)
2. Salaried employment
3. Self-employed off-farm
4. Casual labourer on/off-farm
5. School/college child
6. Herdsboy/girl
7. Household chores
8. Non-school child
9. Other, specify………

Codes F
1. Full time
2. Part-time
3. Not a worker

14.1 Households head farming experience in years……………………………………………………………

14.2 Household head's maize farming experience in years……………………………………………………

14.3 Household's total land size in acres………………………… acres

14.4 Household's total cultivated land……………………………acres

15.0 BUILDING IN THE HOMESTEAD

Type of Building (codes A)	Total Number	Walling material for the building (codes B)	Roofing material for the building (codes C)	**Codes A** 1. Residential 2. Livestock pen 3. Store 4. Other, specify…………	**Codes B** 1. Bricks 2. Stone 3. Earth 4.Unburned bricks	5. Poles 6.Timber 7. Other, specify….	**Codes C** 1. Grass thatch 2. Iron sheet 3. Tiles 4. Other, specify……………