EFFICIENCY AND EFFECTIVENESS OF DISSEMINATION PATHWAYS: A CASE STUDY OF PUSH-PULL TECHNOLOGY FOR STEMBORERS AND *STRIGA* WEEDS CONTROL IN WESTERN KENYA

ALICE WARUKIRA MURAGE

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DECLARATION AND RECOMMENDATION

I declare that this thesis is my original work and has not been presented in this or any other university for the award of a degree.

Signature: .... Date: 9/8/2011...........

Alice Warukira Murage

Recommendation:

This thesis has been submitted with our approval as the candidates' supervisors

Signed: .... Date: 18/08/2011...........

Prof. Gideon Obare

Department of Agricultural Economics and Agribusiness Management

Egerton University, Kenya

Signed: .... Date: 17th August 2011...........

Dr. David Amudavi

Department of Agricultural Education and Extension

Egerton University, Kenya

Signed: Z. R. Khan .... Date: 11 August 2011...........

Prof. Zeyaur Khan

Department of Plant Health

ICIPE Mbita Point, Kenya

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DEDICATION

To my mother Mary Njeri, and my sons Steve Mbutha and Dennis Murage for their unconditional love

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ABSTRACT

Food security in Kenya is potentially challenged by increased infestation of maize fields by cereal stemborers (mainly *Chilo partellus* Swinhoe and *Busseola fusca* Füller) and parasitic *Striga* weeds (mainly *Striga hermonthica* (Del.) Benth. and *Striga asiatica* (L.) Kuntze). The conventional control measures for these pests have had limited acceptance by smallholder farmers in the region due to various socio-economic and environmental effects. The 'push-pull' technology (PPT), developed by the International Centre of Insect Physiology and Ecology (ICIPE) together with other collaborators, has been well evaluated by smallholder farmers as an effective method for controlling the two pests. However, this technology is relatively knowledge intensive, thus realization of maximum adoption will depend on how well-trained farmers are, via effective and efficient dissemination pathways. The information on efficiency and effectiveness of dissemination pathways is scanty in literature. This study therefore sought to fill this gap in order to proffer better targeting of resources in an efficient dissemination strategy. Both primary and secondary data were used in this evaluation. A total of 491 randomly selected respondents from Homabay, Kisii, Busia and Bungoma districts were interviewed, and secondary data were obtained from project records in ICIPE-Mbita. Data were analysed using: a weighted score index; an ordered probit model for pathway preference ranking; a two limit tobit for pathways' effects on adoption; a duration model for pathways' effects on the speed of adoption; and Data Envelopment Analysis (DEA) for efficiency analysis. The results from the weighted score index show that field days (FD) were the most preferred dissemination pathway, followed by farmer field schools (FFS) and farmer teachers (FT). The tobit and duration model results show that FD had the highest impact on the level and intensity, and the speed of adoption, respectively, whereas the DEA results show that FD was relatively more efficient compared to FFS and FT in the short run; but in the long run, FTs were more efficient. Considering that the pathways are not mutually exclusive, it is imperative to account for the complimentary roles of the various pathways in strengthening the uptake of PPT technology. The dissemination pathways would be more effective if the target population is well segmented and appropriate pathways utilised for the various farmer segments. The findings of this study contribute to the framework for ICIPE and other research institutions to examine both their human and financial strategies in order to invest in dissemination strategies that are relevant, efficient and effective.

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ACRONYMS

AIC	Akaike Information Criteria
ARPPIS	African Region Postgraduate Program in Insect Science
BIC	Bayesian Information Criteria
CRS	Constant Return to Scale
DAAD	German Academic Exchange Program
DEA	Data Envelopment Analysis
DMU	Decision Making Units
FAO	Food and Agriculture Organisation of the United Nations
FD	Field Day
FF	Fellow Farmers
FFS	Farmers Field School
FOOD-SEC	Food Security
FT	Farmer Teacher
GoK	Government of Kenya
ICIPE	International Centre of Insect Physiology and Ecology
IIRR	International Institute for Rural Reconstruction
IPM	Integrated Pest Management
Ksh	Kenya Shilling
ME	Marginal Effects
PPT	Push Pull Technology
RU	Random Utility
SE	Standard Error
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Unit
USD	United States Dollar
VIF	Variance Inflation Factor
VRS	Variable Returns to Scale

CHAPTER ONE
INTRODUCTION

1.1. Background information

Sustainable food production in most developing countries is faced with numerous challenges, which have the potential to upset and threaten the livelihoods of many households in rural and urban areas. Such challenges could be mitigated through setting up research agenda that target development of appropriate and effective agricultural technologies aimed at increasing production of major food crops. Agricultural research institutions, both local and international, have actively been involved in developing such technologies and formulating dissemination packages in order to enhance production and to guarantee food security. One of the major staple food crops in Eastern and Southern Africa is maize, which accounts for 40% of the calories consumed, mainly by the poor, most of who are women and children (Pingali, 2001; Nyoro, 2002; De Groote, 2002). In Kenya, maize is one of the main staple foods for many households and a major food security crop. In fact, households' food security is, in most cases, assessed in terms of the quantity of maize available relative to other cereals. Maize covers nearly 80% of the total cereal area of the country and the average Kenyan citizen consumes well over 103 kg/yr of maize, one of the highest levels in Africa (Pingali, 2001).

Western Kenya is among the country's major maize growing areas whose contribution to the national grain reserve is only second to the country's grain basket, the Rift Valley (see Table 1.1). Thus, these areas form a focal point for investment in order to improve the country's *per capita* maize requirement as well as to boost the national strategic grain reserve aimed at cushioning the country against deficits. Consequently, production challenges in these areas would have far-reaching adverse effects on national food situation.

One such challenge has been the high prevalence of the cereal stemborers (mainly *Chilo partellus* Swinhoe and *Busseola fusca* Füller) and parasitic *Striga* weeds (mainly *Striga hermonthica* (Del.) Benth. and *Striga asiatica* (L.) Kuntze), which cause 20% - 80% and sometimes up to 100% maize yield losses, respectively (Hassan *et al*., 1994; Kfir *et al*., 2002). The monetary losses are enormous and have been estimated to be close to USD 40.8 million annually (Kanampiu *et al*., 2002; Khan *et al*., 2008a). *Striga* infestation has been rated as the leading priority constraint to maize production particularly in the Lake Victoria Basin and western midlands where farmers experience food crop losses season after season and are therefore unable to sufficiently feed their families or make modest improvements in their lives.

Table 1.1: Estimation of national maize production during the long rains of 2008 and 2009

Province	Maize production in metric tonnes		% contribution to national reserve	
	2008	2009	2008	2009
Central	134,312	136,129	6	7
Coast	49,975	34,348	2	2
Eastern	114,365	24,072	5	1
Nyanza	252,361	254,402	11	14
Rift valley	1,085,765	939,715	46	52
Western	418,706	435,431	18	24
Total	**2,335,886**	**1,824,097**	**100**	**100**

Source: FOOD-SEC bulletins, (2008, 2009)

Farmers have previously attempted to minimise the adverse effects of these pests through conventional control strategies such as hand weeding, direct uprooting, use of nitrogen fertilizers and other chemical means. However, research findings have shown that these methods are insufficient, expensive, unaffordable and unfriendly to the environment (Berner *et al.*, 1995; Woomer *et al.*, 2004). In response to these challenges, the International Centre of Insect Physiology and Ecology (ICIPE) in collaboration with other research organizations developed a habitat management strategy for controlling the stemborers and *Striga* weeds in maize fields simultaneously (Khan *et al.*, 2001, 2004). This control method, termed as the 'push-pull' technology (PPT), is based on stimulo-deterrent strategy where companion crops release behaviour modifying stimuli that manipulate the distribution and abundance of pests (Miller and Cowles, 1990; Cook *et al.*, 2007). The PPT involves intercropping maize and desmodium (e.g. *Desmodium uncinatum* (Jacq)), with Napier grass (*Pennisetum purpureum* Schumach) planted as a border crop around this intercrop (Khan *et al.*, 2001, 2004; Midega *et al.*, 2010). The desmodium repels stemborers moths (hence push), while the surrounding Napier grass attracts them (hence pull) (Khan *et al.*, 2001). In addition, desmodium suppresses *Striga* weeds through a number of mechanisms, with allelopathy (root to root interference) being the most important (Tsanuo *et al.*, 2003).

With effective control of these biotic stresses a significant cost-benefit return of 2.2 was reported in the PPT relative to 0.8 for the maize monocrop (Khan *et al.*, 2001) while sustainable increases in maize grain yields and higher returns to labour were also reported (Khan *et al.*, 2008b). In addition, all the plants used (Napier grass and desmodium) have an added advantage of being useful fodder for livestock. This technology is currently being practiced by over 25,000 smallholder farmers in East Africa, and is being promoted and disseminated through various dissemination pathways to maximise output in cereal production while minimising negative environmental effects (Khan *et al.*, 2008a, 2008b; Amudavi *et al.*, 2008, 2009).

Despite the development of new important agricultural innovations such as PPT, the implementation of such new scientific research findings into practical solutions is faced with several challenges. One of these is enhancing access to information and uptake of new technologies through effective dissemination pathways that are crucial in optimising the adoption process especially for 'knowledge-based' innovations (Padel, 2001). It has also been established that information sources rather than subsidies are more effective in encouraging adoption through enhancing farmers' allocative ability and revising their perceptions on profitability of the new technology (Lohr and Salomonsson, 2000; Huffman, 2001; Feder *et al.*, 2003; Genius *et al.*, 2006). Thus, even though the PPT has been reported to have multiple benefits to maize farmers, the realization of maximum adoption would depend on how the information is delivered through effective communication channels. PPT is relatively knowledge intensive and its uptake will depend on how extensive and intensive farmers are trained and the effectiveness of dissemination pathways used. However, despite the heavy resource allocation in development and diffusion of new technologies, their success could be compromised due to low adoption rates (Moser and Barrett, 2003) - a fact that could be ascribed to lack of effective dissemination strategies as well as inappropriate extension approaches (Aberra and Beyene, 1997; Mulugeta, 1998). This necessitates concerted effort to develop a holistic and effective dissemination strategy that meets the needs of the target audience.

Efforts have been made to disseminate PPT via several pathways (Khan *et al.*, 2008a; Amudavi *et al.*, 2008, 2009). Some of these pathways include the use of radio, *Baraza* (public meetings), print materials (brochures, pamphlets and farmer leaflets), Field days (FD), Farmer Field Schools (FFS), Farmers teachers/trainers (FT) and Fellow farmers (FF) also referred to as farmer to farmer extension. Use of these multiple pathways to disseminate technology information is not only expensive to the institution and organization disseminating the technology, but also increases the information search costs by the target farmers. This is because, if ineffective pathways are used, then the farmers will spend more time searching for relevant information from as many sources as possible before making the final decision to adopt. This therefore implies an imperative need to evaluate the effectiveness and efficiency of the pathways being used in order to isolate the ones which are not only effective but also efficient.

There are stipulated differences in effectiveness and efficiency of dissemination pathways. Rogers (1997) and Mauceri *et al.* (2005) acknowledge that effectiveness of different pathways can be evaluated by assessing the differentials in farmer's attitude and trust towards dissemination pathways. This is because farmers are likely to be persuaded to adopt a technology if they receive information from pathways that they consider reliable and credible. It is easier for farmers to learn from each other when the messages conveyed are simple to understand, however more specialised information sources would be required when dealing with complex knowledge intensive messages (Feder *et al.*, 1985). This imputes a need to explore the apparent patterns of farmers' preferences of different pathways. On the other hand, based on the information presented in these dissemination pathways, there is likelihood of variations on the effects these pathways could have on technology adoption both in quantity and speed (Daberkow and McBride, 2001; Mauceri *et al.*, 2005). Some dissemination pathways are seen to be more credible and reliable in information delivery and therefore the need to verify these differences in order to exploit those pathways that have greatest impact on adoption.

Moreover, given that the amount of resources required for each pathway differs, the choice of a dissemination pathway has implications on cost effectiveness for both the research institution and field extension. The desire would be to match the available resources for dissemination to achieve maximum output in terms of adoption. Such knowledge would also be used to justify more resource allocation to promising dissemination pathways that are more effective. In doing so it is important to recognise that adoption is a multi-staged process that is influenced by many complex factors which are interactive in nature. Research funds to develop and disseminate new technologies are shrinking and therefore dissemination should carefully be packaged to optimise on available human and financial resources. There is need to synchronise efficiency and effectiveness of these pathways through critical analysis of the dissemination process. However, such type of knowledge is still scarce in literature especially in sub-Saharan Africa (SSA) mainly due to lack of consistent and reliable data (Lionberger and Gwin, 1982; Conley and Udry, 2003). The current study aims to contribute to planning and designing of an effective demand driven technology dissemination strategy by analysing the role of dissemination pathways on the linkage between research and the farmers using PPT as an example.

1.2. Statement of the research problem

Access to information is important in promoting uptake of a knowledge intensive technology such as the PPT. Also, to the extent that increased access to information promotes technology uptake, an understanding of the efficiency and effectiveness of dissemination pathways is equally important given that access to research funding is getting leaner and leaner. Several dissemination pathways including Farmer field schools (FFS), Field days (FD), Farmer teachers/Trainers (FT), Radio, Print, *Baraza* and Fellow farmers (FF) have been used to promote the PPT. It is not clear which of the available palette of the dissemination pathways or a combination is most effective and efficient in delivering the messages. These pathways are likely to have varied impacts on adoption because of the inherent characteristics unique to each dissemination pathway. Furthermore, the pathways may not be mutually exclusive, and more often are used in combinations and therefore it would be expected that their interactive nature would also have varied influence on the adoption process. Knowledge of such dynamics is required in order to account for heterogeneous information utilization as well as to exploit those pathways that are more promising in optimising the adoption of PPT. Such knowledge is scanty in literature particularly in developing countries. Most of the studies available in literature were conducted in developed countries whose application to developing countries is limited by the different circumstances. Other studies have been limited to examining the influence of a single or just a few of these pathways on adoption ignoring the interactive nature of the various pathways. This study aimed to fill this knowledge gap using PPT as an example, from a developing country perspective, while accounting for potential complementarities among pathways and the associated information dissemination costs.

1.3. Objectives of the study

The overall objective of the study was to evaluate the efficiency and effectiveness of PPT technology dissemination pathways in Western Kenya. The specific objectives were:

1. To determine PPT farmers' preferences for dissemination pathways and investigate factors influencing preference ranking.
2. To assess the effects of different dissemination pathways on the level and intensity of PPT adoption.
3. To establish the effects of different dissemination pathways on the speed of PPT adoption.
4. To evaluate the efficiency of PPT dissemination pathways.

1.4. Research questions

The present research seeks to provide answers to the following research questions:

1. Which dissemination pathways do PPT farmers prefer and what factors influence farmers' preference in ranking of the dissemination pathways?
2. To what extent do the dissemination pathways influence farmers' adoption decision and the intensity of use of PPT?
3. To what extent do PPT dissemination pathways influence the speed of PPT adoption decision?
4. Which dissemination pathway among the ones being used to up-scale PPT is more efficient in resource use?

1.5. Assumptions

This study was carried out under the following assumptions:

1. That each dissemination pathway provides information that could lead to adoption of PPT.
2. That all the farmers interviewed were aware of the existence of PPT.
3. That farmers' access to dissemination pathways is random.

1.6. Overview of the study sites

The study was carried out in Western and Nyanza provinces of Kenya in February and March 2009. In these two provinces, stemborers and *Striga* weeds cause huge damages on maize production consequently affecting a large number of smallholder farmers in the region. Nyanza province occupies a total area of 12,547 square kilometres and a population of about 5,442,700 persons with a density of about 456.4 persons per square kilometre, while Western province has a high population of about 4,334,300 persons and a density of 566.8 persons per square kilometre on a total area of 8,264 square kilometres (GoK, 2010). Agriculturally, Nyanza and Western provinces are characterized by mixed cropping systems with maize (*Zea mays*) and common beans (*Phaseolus vulgaris*) being the most important staple food crops. Productivity is generally very low and up to 95% of people remain food insecure in this region. *Striga* infestation is most severe in this region and is found in about 75,000 hectares of farmland and results in crop losses estimated at about US$ 10-38 million per year (Woomer *et al.*, 2004).

Four districts namely Homabay, Kisii, Busia and Bungoma, were purposively sampled based on the intensified promotion of PPT in controlling stemborers and *Striga* weeds. These districts' rural economies are mainly agriculturally based producing both cereal crops and livestock. However, the two pests have constituted a serious setback to sustainable cereal production, exposing the inhabitants of the region to serious food and nutrition insecurity. Administratively, Homabay and Kisii districts are located in Nyanza province, while Bungoma and Busia districts are in Western province. Homabay has an altitude of between 1220m and 1560m above sea level (asl), receives 500mm to 1000mm annual rainfall, has temperatures ranging between 17.1°C and 34.8°C, and has an area of 1155.5 square kilometres and an estimated human population of 293,676 persons (GoK, 1997a; GoK, 2010). Kisii district elevates between 1600m and 2000m asl, receives 1350mm to 2100mm of rainfall per annum, its temperature ranges from 10°C to 30°C, and covers an area of 645 square kilometres, with an estimated population of 488, 910 persons (GoK, 1997b; GoK, 2010). Bungoma district covers 2063 square kilometres with an estimated human population of 763, 656 persons, altitude rising from 1200m to 2000m asl, mean annual rainfall varies from 1250mm to 1800mm and temperatures range between 21°C to 25°C (GoK, 1997c; GoK, 2010). Busia district has an area of 1262 square kilometres and an estimated human population of 369,459 persons. The altitude ranges from 1130m to 1375m asl, mean annual rainfall is 1500mm per annum and temperatures range from 14°C to 30°C (GoK, 1997d; GoK, 2010). The map of the study area is shown in Figure 1.1

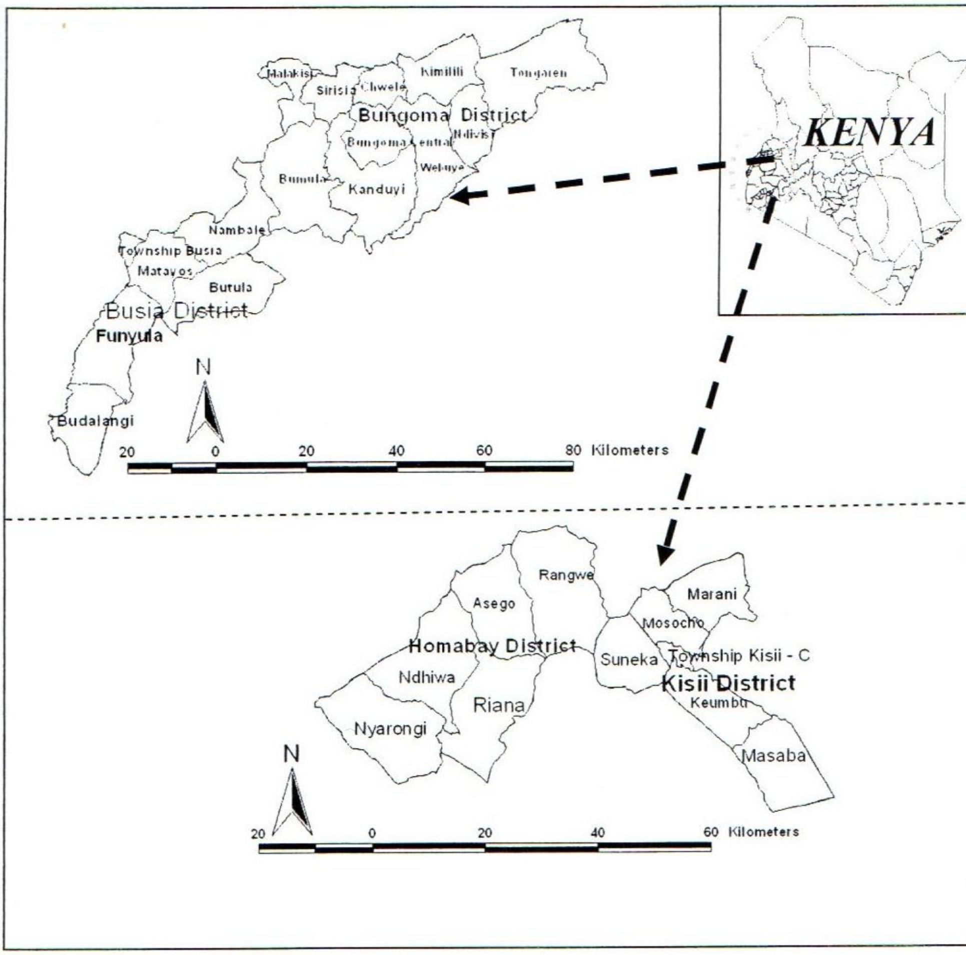

Figure 1.1: Map of the study sites

1.7. Justification of study

Since maize is an important staple crop in Kenya, its production needs to be improved in order to ensure sustainable supply and food security. This desire notwithstanding, sustainable maize production and the availability of maize to households in Kenya is threatened by stemborers and *Striga* weeds. This is particularly the case in Western and Nyanza provinces, one of the breadbasket provinces in the country. If not addressed, these two sources of threats can reduce the yields of cereals such as maize by as high as 100% (Khan *et al.*, 2002, 2008a). Farmers spend a lot of money trying to control these vices using various methods (e.g. chemical control, mechanical and cultural control methods). The environmental and health hazards resulting from the use of chemicals to control stemborers and *Striga* weeds could be substantial (Nielsen and Linda, 1987). Methods such as hand weeding and uprooting of *Striga* weeds have had serious socio-economic and opportunity cost implications due to their time consumption, especially the time of women who are largely involved in these activities. PPT has however been very well rated by smallholder farmers on its effectiveness to the target hosts. Besides, the technology has an added advantage of increasing the availability of livestock feeds (Napier grass and desmodium). The practice also leads to improvements in soil fertility, increased nitrogen fixation and soil erosion control. In view of these benefits, the need to embark on widespread dissemination of the PPT among farmers in Kenya cannot be overemphasized and calls for an efficient strategy given the limited resources available for the exercise. It is against this background that the current study is justified to enable development of a dissemination strategy that will be able to reach broad audience while taking care of their needs, and ensuring value for time and money.

1.8. Scope and limitations of the study

PPT has been promoted in Eastern Africa particularly in regions where *Striga* weeds and stemborers have been very pronounced. In Kenya, it has been promoted in 15 districts in Western and Nyanza provinces. Considering that surveys may be very expensive, the current study was limited to four purposively sampled districts from Western and Nyanza provinces of Kenya. It is hoped that the lessons learnt and insights gained can be used in similar regions.

1.9. Definition of terms

1. Dissemination pathways: These are routes through which information about a new innovation/technology (in this case PPT) follows from the institution to the target users (Garforth, 1998). Also referred to as information channels.
2. Scaling-up: Is the spread of more quality benefits of push-pull technology to more farmers over a wider geographical area more quickly and more equitably (adapted from IIRR, 2000).
3. Efficiency: Is the extent to which an activity achieves its goal whilst minimising resource usage (Harvey, 2004). It is the ratio of outputs to inputs, and the larger it is the better. In the context of this study, it is the ratio of dissemination inputs to dissemination outputs, from the point of view of the institution.
4. Effectiveness: Is a measure of how the activity being evaluated has achieved the goal for which it was set. In contrast to efficiency, effectiveness is determined without reference

to costs (Harvey, 2004). In the context of this study, effectiveness would mean the achievement of objectives and desired outcomes of dissemination (how pathways contribute to farmers' outcome).

1.10. Organization of the thesis

This thesis is organized in seven chapters. Chapter one gives the background of the research problem addressed in this study and a detailed description of study sites. Detailed review of literature is presented in chapter two. This describes various aspects of the PPT adoption process, the concept of adoption, farmers' preferences for information pathways, role of information sources and their definition, among other pertinent issue in the study. The theoretical and conceptual framework of the study is also presented in chapter two.

The results from this study are presented in four standalone chapters (chapters three, four, five and six). In chapter three, farmers' preferences for the various dissemination pathways are examined in order to proffer better targeting of resources in an optimal dissemination strategy. A weighted index was used to sequentially rank the different pathways and an ordered probit regression used to assess the factors influencing preference rankings. The results showed varying levels in magnitude and direction of significance implying a need to segment the target population prior to implementing the dissemination process. Sampling procedures of the entire study is described in this chapter.

Chapter four evaluates the effectiveness of dissemination pathways on the probability and intensity of adoption of PPT while controlling for selected socio-economic variables using a two limit tobit regression model. The marginal effects are decomposed using McDonald and Moffitt procedures. The results show that use of FD, FFS and FT chronologically, increased the probability of adoption of PPT technology as well as the intensity of adoption. Adoption intensity is relatively higher on small farms compared to the large farms while farms neighbouring major roads showed higher intensity of adoption than more remote ones. Furthermore, there are variations in the probability and intensity of adoption across districts, while individual pathways seemed to play a greater role than household socio-economic factors and farm characteristics.

In chapter five, it is shown how different dissemination pathways impact on the time taken by farmers to adopt a new innovation. This is achieved by using a parametric duration model (Weibull functional form), while controlling for selected socioeconomic and regional factors that may have effect on adoption. Positive duration dependence is demonstrated, with FD having the highest hazard to adoption, followed by FT. Other variables that accelerate adoption are education, household size and income level three. Gender, Tropical Livestock Units (TLU), group membership, and dummy variables representing the regions of study had a delaying effect.

Chapter six evaluates the efficiency of the three major pathways (FT, FFS and FD) using the Data Envelopment Analysis approach in which two output variables are considered namely: the number of farmers trained per given pathway and the proportion of adoption per pathway. This was aimed at bringing out the long term objective of the dissemination process, which is the eventual adoption of the technology by the target audience. Although hampered by data limitations, the results demonstrate that FDs are relatively cheap in training farmers but expensive in the long run. On the other hand, FTs are found to be relatively efficient in the long run. Chapter seven gives the general discussion, summary of main findings, implications for policy interventions and recommendations for further research.

CHAPTER TWO
LITERATURE REVIEW

2.1. Push-pull technology in perspective

Maize and other cereal crops have been recognized as important staple foods for most rural households in Kenya and in sub-Saharan Africa (SSA). In western Kenya, the crops are grown by smallholder farmers and now increasingly being challenged by two pests: the cereal stemborers and parasitic weed *Striga* which undermine sustainable production in the area. The cereal stemborers have two species: the *Busseola Fusca* which is indigenous and attacks mainly in the high altitude areas and the *Chilo partellus* which was introduced from Asia in 1930's and mainly attacks the low and mid altitude areas (Khan *et al.*, 2001; Khan *et al.*, 2003). The stemborer moths feeds on the leaves while the larvae cause the main damage by boring through the stalk thereby preventing full development of the crop. The control of the stemborers is largely affected by the cryptic and the nocturnal nature of the adult moths and the protection provided by the stem of the host plants for the immature stages (Ampofo *et al.*, 1986; Khan *et al.*, 2001).

The parasitic weed *Striga*, also known as the witchweed latches itself onto the roots of young maize plants, stunting its growth and causing severe under development. It produces purple flowers and creates millions of seeds that remain dormant in the soil for up to two decades until a sustainable host germinates. The weed has infested up to 40% of arable land in the savannah region, causing an estimated annual loss of USD 7 to 13 billion and affecting millions of people in this region (M'Boob, 1989; Lagoke *et al.*, 1991). Besides, its infestations have resulted in the abandonment of arable land by farmers - a problem that is exacerbated in areas where there is low soil fertility and rainfall. Under severe infestations, the two pests, stemborers and *Striga* weeds, cause 80% and 100% yield losses respectively.

There are recommended conventional control measures for these two vices but their level of acceptance by farmers have been mixed. To reduce *Striga* infestation for example, heavy applications of nitrogen fertilizer, crop rotation, use of chemicals to stimulate suicidal seed germination, hoeing, hand pulling, herbicide application and the use of resistant or tolerant crop varieties have been recommended (Berner *et al.*, 1995). Some of these methods such as hand weeding have serious socio-economic implications since women have to engage themselves in this activity which is not only time-consuming but also labour intensive. The commercial pesticides and herbicides, on the other hand, are unaffordable to most resource poor farmers in this region besides being detrimental to environment. As a result, the acceptance of most of these methods by farmers has been limited due to both biological and socio-economic reasons (Lagoke *et al.*, 1991).

Push-pull technology (PPT) has recently been promoted as a habitat management strategy in aid of controlling the two pests simultaneously. The terminology "push-pull" was first conceived by Pyke *et al.* (1987) in Australia as an Integrated Pest Management (IPM) strategy, and later formalized by Miller and Cowles (1990). It involves the use of behaviour modifying stimuli to manipulate the distribution and abundance of a pest and/or beneficial insects for management of the pest (Cook *et al.*, 2007). In this strategy, pests are repelled or deterred away from the main crop (push) by stimuli that masks host apparency. These pests are then simultaneously attracted (pull) to a trap crop where they are concentrated leaving the target plant protected (Cook *et al.*, ibid). So far, most of the push-pull strategy has targeted pest behaviour rather than manipulation of the beneficial organisms.

In Kenya, the push-pull strategy was introduced in the late 1990 as a strategy to control stemborers and *Striga* weeds in maize fields. The strategy involves intercropping maize with desmodium (e.g *desmodium uninatum* (Jacq)) and surrounding this intercrop with Napier grass (*Pennisetum purpureum* Schumach) or Sudan grass (*Sorghum vulgare* var. *sudanense*). Research has shown that desmodium produces chemical compounds some of which repel the stemborers (push component) while Napier grass produces other chemical substances during dusk that attracts the stemborer moths to lay eggs there (pull component) (Chamberlain *et al.,* 2006). Fortunately, the gummy substance produced by the same Napier grass traps the resulting stemborer larvae and only a few survive to adulthood, thus reducing their population (Khan *et al.*, 2001; Tsanuo *et al.*, 2003). In addition to repelling stemborer moths, desmodium was found to give an unexpected and dramatic reduction in the infestation of *Striga* weeds on maize.

Several studies have confirmed that the dramatic reduction of *Striga* weeds was through some allelopathic mechanism whereby some of the chemical compounds produced by the root exudates of desmodium stimulate germination of *Striga* and others inhibit the lateral growth and attachment of the *Striga* roots to maize roots (Midega and Khan, 2003; Tsanuo *et al.*, 2003; Midega *et al.*, 2006). In the event, the *Striga* dies and eventually the number of seeds in the soil declines. A study by Khan *et al.* (2003) demonstrated that there were increased benefits derived from availability of nitrogen and soil shading. Improved land productivity and increased gross returns have also been demonstrated by Khan *et al.* (2008b). This strategy has therefore been seen as a powerful tool whose potential is unfortunately still underexploited (Cook *et al.*, 2007).

The efficacy of PPT on the target hosts has been well rated by smallholder farmers and the strategy has been shown to be achievable and sustainable under the smallholder management conditions (Khan *et al.*, 2008a). Given that farming in Kenya is characterized by mixed crop-livestock systems, the additional benefits of PPT in provision of livestock feeds became one of the main entry points for adopting the technology by most farmers (Khan *et al.*, 2008a). In addition, there was strong evidence of controlled soil erosion and enhanced soil fertility through implementation of PPT (Midega and Khan, 2003; Khan *et al.*, 2006). For these potential benefits of PPT in improving food security to be realized, there is need for accelerated uptake by the farmers. However, proper establishment and management of the technology require appropriate training through effective dissemination pathways since PPT is relatively knowledge intensive (Khan *et al.*, 2008a). This relationship between potential adoption and effectiveness of dissemination pathways necessitates an overview of technology adoption as described in the following section.

2.2. Overview of technology adoption and diffusion

Adoption of agricultural practices is one of the subject areas that have been heavily researched globally. Adoption is defined as a mental process through which an individual passes from first acquiring knowledge of an innovation to the decision to adopt or reject (van den Ban and Hawkins, 1998). According to Feder *et al.* (1985) adoption refers to the decision to use a new technology, method or practice by a firm, farmer or consumer. Dasgupta (1989) indicates that, the decision to adopt an innovation is not normally a single instantaneous act but one that involves a number of mental stages before a farmer makes a final decision to adopt an innovation. In this process, an individual passes from first acquiring knowledge of an innovation, to forming an attitude towards the innovation, to a decision to adopt or reject the innovation, to implementation of the new idea, and to confirmation of the decision (Ray, 2001). Although adoption is seen as a process, Ray (ibid) emphasized that adoption does not necessarily follow the suggested stages from awareness to adoption; trial may not always be practiced by farmers to adopt new technology. Farmers may adopt the new technology without trial stage and in some cases farmers may be aware and have knowledge but because of other factors affecting the decision making process, adoption does not occur (Ray, ibid). Furthermore, Dasgupta (1989) showed that adoption is not a permanent behaviour and an individual may decide to discontinue the use of an innovation due to several personal, institutional or social reasons one of which could be the availability of an idea or practice that is better in satisfying his or her needs.

Adoption and diffusion are closely interrelated even though they are conceptually distinct. Farmers do not adopt a technology simultaneously but rather the diffusion of a technology takes a number of years and seldom reaches 100% of the potential adopters (Rogers, 1997). Roger and Shoemaker (1971) defined diffusion as a process by which new ideas are communicated to the members of a social system. Not all innovations diffuse at the same rate. The differences in the diffusion rates of innovations in a community can be largely explained by the differences in the characteristics of innovation, as perceived by potential adopters, such as relative advantage, compatibility, complexity, trial ability and observability (Dasgupta, 1989; Ray, 2001). The adoption or rejection of an innovation has therefore been treated as a consequence of diffusion of an innovation (Dasgupta, 1989; Ray, 2001).

Adequate understanding of technology adoption process is necessary for designing effective agricultural research and extension program (Feder *et al.*, 1985). The complexity of the adoption pattern has become of great interest to agricultural economists with a common objective of understanding the factors influencing it. This is because even with obvious advantages, some technologies take a lot of time from the time they are developed to the time they are applied by the intended audience. In developing countries like Kenya, adoption of agricultural technologies attracts considerable attention because it can provide the basis for increasing production and income. Farmers' decisions to adopt or reject agricultural technologies depend on their objectives and constraints as well as cost and benefit accruing to them (Tadesse and Kassa, 2004). It is important to realise that farmers are economically rational and they adopt new technologies that are in their interests and reject those that are not. When farmers resist a new technology, it is probably because it is not compatible with their objective, resources or environment, not because of their backwardness, irrationality or management mistakes (Franzel and van Hauten, 1992). Failure to understand the adoption process has led to various development initiatives of new innovation meant to increase yields being frustrated by low adoption rates (Feder *et al.*, 1985; Hayami and Ruttan, 1985).

In an effort to understand why new technologies are not adopted despite their obvious benefits, many researchers have embarked on adoption studies resulting to a huge body of empirical literature, which is even difficult to summarize. A large number of personal, situational and social characteristics of farmers have been found to be related to adoption behaviour. Considerable evidence has been accumulated showing that demographic variables, technology characteristics, information sources, knowledge, awareness, attitude and group influence affect the adoption process. These factors have been categorized differently by different researchers depending largely on the technology being investigated, the researchers' preference and the research question at hand. Lapar and Pandey (1999) acknowledge that factors influencing adoption operate in a complex and interactive way. In addition, innovations differ across socio-economic groups and over time (Feder *et al.*, 1985; Feder *et al.*, 2003). This calls for identification of technology attributes that are technological, site and temporal specific.

Three measures of technology adoption can be distinguished since all of them measure adoption uniquely. These include: the level of adoption which defines the proportion of farmers that adopt a given technology; the intensity of adoption which refers to the level of use of a given technology in any time period; and the rate of adoption which has the element of time and defines the relative speed with which farmers adopt an innovation (Doss, 2006; Langyintuo and Mungoma, 2008). Level of adoption has been modelled as a dependent categorical variable using maximum likelihood estimates (MLE), while accounting for the discrete nature of the dependent variable (Greene, 2003). While this is adequate in analyzing adoption decision that occurs over a discrete change of variable values, it doesn't handle the case of adoption choices that have a continuous range values (intensity). Thus many studies have modelled the intensity of adoption as a continuous variable using censored or truncated models. This is important because it is not only the choice to use a technology that is important, but also how much the farmer is using the technology.

More recently, the speed of adoption has become increasingly important where the element of time is used to take care of the dynamic nature of the adoption process (Hazel and Anderson, 1986). The importance of each category depends on the context of the study and distinguishing the three categories is important since they have important policy implications (Doss and Morris, 2001; Doss, 2006). Most of the past studies have measured adoption using any of the three measures stated. The current study departs from these studies in that it considered the three measures of adoption in assessing the effectiveness of dissemination pathways on the adoption process of PPT.

2.3. The role of agricultural information in technology adoption

One of the themes in the technology adoption literature is the role of information sources. Information and knowledge are a major ingredient in technology adoption and a critical resource in management. Information can be viewed as learning about a new idea, while knowledge is gained from access to information; and the two empower farmers to make rational decisions. Access to information has been identified as the cornerstone to successful farming in the 21st century (Weiss *et al.*, 2000). Many economists since the beginning of

Adam Smith have recognised that information availability is a crucial component of efficiency (Just *et al.*, 2002). In today's agricultural industry, survival depends on having an edge on information related to the market, efficient allocation of available resources and use of new or innovative farming practices. The final decision of an individual farmer to adopt a new technology primarily depends on his/her ability to acquire, process, and to decode the information related to the farming practices and the technological innovation itself (Stoneman and David, 1986; Rogers, 1997).

Information accumulation improves farmer's knowledge on farming practices which in turn reduces uncertainty and therefore induces new technology adoption by risk-averse operators. In some circumstances, access to information has been found to speed up the adoption and diffusion of new technologies more than even availing subsidies to the farmers (Lohr and Salomonsson, 2000; Genius *et al.*, 2006). This is because providing information to producers can change their perceptions by reducing uncertainty about the technology, which is very important in the adoption decision (Feather and Amacher, 1994). Therefore, inappropriate information sources may restrict farmers' innovativeness.

Farmers access information via different dissemination pathways and there is a strong relationship between these pathways and technology adoption (Rogers, 1997; Debarkow and McBride, 2001; Corrine, 2002). Pathways are considered effective if they are able to shift farmers' perception towards adopting the technology in order to yield the benefits. Given that the characteristics of these pathways differ, there is likelihood that this will have an effect on the manner in which farmers adopt the technology. Besides, the spread of information via different pathways is likely to influence the speed of adoption of a technology, which is crucial for the effectiveness of that technology (Hazel and Anderson, 1986; Corinne, 2002). Fast adoption of a technology maximises the returns to investments since the benefits of the technology are realised earlier (Hazel and Anderson, 1986).

Dissemination pathways have also been shown to play a key role in equipping farmers with skills to retain knowledge over time (Rola *et al.*, 2002; Feder *et al.*, 2003). Well-trained farmers are likely to implement and use a technology in the appropriate way and this in turn determines the longevity, usefulness and benefits of a technology. Therefore, there is need to assess how different pathways influence not only the adoption process, but also the speed of uptake and the continued use of a technology. This understanding is critical in order to develop an effective technology transfer strategy that promotes maximum adoption of the technology. The general lack of understanding of the role of different information dissemination pathways in inducing adoption has limited the designs in information outreach (Conley and Udry, 2003).

Unfortunately, amongst the previous studies, very few if any have investigated the role that an information source or pathway may have in influencing technology adoption (Corinne, 2002). In most cases, the studies analysed the relationship between adoption and access to information using extension contacts or a knowledge index as a proxy for access to information without clearly separating the effects based on each pathway. Although this approach may yield comparable results between farmers who have access and those who do not have access to information, how farmers receive information from different sources has a much more significant effect on adoption than just mere knowledge of the technology (Mauceri *et al.*, 2005). There is a difference between having close contacts with extension agents and being informed by them and/or being informed by another farmers who have already adopted the new technology. Not only are the information sources and the information processes different, but the information content may also differ. In addition, extension contact alone may not promote adoption if information dissemination pathway being used is ineffective or inappropriate (Agbamu, 1995).

Different dissemination pathways are likely to influence adoption at different stages of the individual decision making process (Rogers, 1997). There is a general impression that mass media creates awareness but for adoption to take place, technical assistance and detailed knowledge are required. For example, McBride and Darberkow (2003) acknowledged mass media as a more passive form of information relative to the active technical services such as field days and farmers field schools. In fact most non-adopters in the study cited mass media as their main source of information while farmers who use technical information sources are most likely to adopt the new technology. However, this is not always the case since in some instances mass media have been found to explain adoption more than the interpersonal methods (Longo, 1990). This leads to a question of evaluating the impact of different dissemination pathways on adoption in order to elicit the one or a combination that can lead to maximum adoption of a technology.

In other studies, the impact of dissemination pathways on adoption was found to vary depending on the technology and the pathways being used. For example, Wonziak (1993) observed that farmers were likely to be early adopters if they were in contact with input suppliers than with extension agents. This contradicts Adegbola and Gardebroek (2007) who observed that adoption and modification of technologies by maize farmers in Benin depended largely on whether they received information from extension agents or from other farmers.

Farmers who received information from extension agents were more likely to adopt and modify their technologies than those who received information from other farmers. Daberkow and McBride (2001) observed a positive and significant influence of information sources on adoption of precision farming in the United States. In their study, crop consultants and input dealers were found to have the greatest impact on adoption and this was attributed to them having greatest technical expertise about the technology. However, sources such as extension services had less impact due to lack of specialization.

In yet another study on the role of information sources in the decision to adopt genetically modified seeds, Corrine (2002) observed that the likelihood to adopt was positively related to farmers rating of information sources. Farmers who gave high rating to information sources related to genetically modified seeds were more likely to adopt than those who highly rated other information sources. In that case, seed dealers and agricultural publications were found to influence adoption while all the other sources were considered unimportant and unreliable.

These studies have shown that although information is critical, it is the quality of information offered by a certain pathway that matters but not necessarily the number of information sources. It is also evident that the impact of the information source on adoption may be related to the technology in question. Some technologies may diffuse naturally within the social system but for knowledge intensive technologies, intensive information sources may be required. This implies that there is probably a need for complementarities of information sources. Garforth and Usher (1987) posit that no single dissemination pathway can stand alone in delivering information about a technology. Instead, the transfer of information about technologies requires non-linear and complex interactions using various sources accessible to farmers which can then turn into achieving a multiplier effect. Given that there is a range of dissemination pathways used to deliver information, it becomes necessary to determine whether farmers who have access to a particular pathway have greater knowledge of the practice than the others. Therefore, rather than introduce a range of dissemination pathways, much of which might neither be effective nor relevant to the intended audience, there is need to assess which pathway is most important.

2.4. Farmers preferences for dissemination pathways

Often farmers strive to acquire information and knowledge from different dissemination pathways. Eugene *et al.* (1990) acknowledge that farmers gather information from different sources but when faced with choices, they select those that yield highest marginal returns. Farmers' perception on the credibility of information pathways has been shown to have a great influence on the pattern of technology adoption (Rogers, 1997). This implies that effective delivery of agricultural information must recognize the need of the farmers so that pathways that are considered credible by farmers can be utilised. Access to the right information, in the right format, from the right source may shift the balance between the success and failure of the farmer (Hossain, 1998; Opara, 2008). This also means that the success of information dissemination depends on how well pathways are oriented towards the needs of the user and should incorporate the types and levels of information needed, in the preferred forms and language. However the type of information sources that farmers prefer do not always match with the dissemination pathways employed by the disseminators and this has led to limited adoption of effective technologies (Leslie and Kelli, 2001).

Since agricultural research results constitute important knowledge base, it should then be made available through pathways whose attributes are acceptable to farmers. This requires an understanding of the pathways in question in order to bring out their relevance in stimulating adoption. However, there has been a general lack of emphasis in determining preferences of the target respondent leading to continuous use of multiple pathways without evidence of which among them is relevant to the users (Wallingford *et al.,* 1996). Variations in farmers' preferences for information pathways exist and evaluating how farmers view different pathways is increasingly important in order to maximise information use efficiency and optimize adoption of a technology.

Some studies have analysed the farmers' preferences for information sources and the factors that explain these preferences. For example, Ford and Babb (1989) found that private firms, cooperatives and other farmers were considered the most useful sources of information for farm input purchase decisions and this was mainly influenced by farm sizes and farming experience. Schnitkey *et al.* (1992) observed that salesmen, farm magazines, cooperative extension services and specialised farm magazines were considered to be the most useful sources of information for production decisions and that age, farm sizes, farm type and computer use tended to be more important in explaining preferences for specific information source. Ortmann *et al.* (1993) identified farm record consultants, university specialists and field days as the most useful information sources and their preferences were mainly explained by expenses on consultants and farm sales, computer use, off-farm investment and farmers' self-assessment of their production skills. Pompelli *et al.* (1997) evaluated farmers' attitude about soil conservation information from extension services in Tennesse and established that farmers consider soil conservation efficient if it was from the extension contacts but found no relationship between farmers and farm characteristics and use of information source.

Gloy *et al.* (2000) observed that commercial farmers in the United States preferred crop/livestock specific magazines as well as general magazines and this was strongly predicted by the type and number of commodities produced as well as internet use. Storer *et al.* (2001) observed that Australian farmers using the price risk tools preferred information from newspapers, brokers, seminars, faxes, farm management consultants and websites but the reasons for preferences varied across the respondents. Tucker and Napier (2002) distinguished between information sources and channels and observed that magazines and radio were the most preferred channels of information while farmer service agencies, agro-chemical dealers, and natural resource conservation were the most preferred sources soil and water conservation information by farmers in the three Mid-western watersheds of the United States.

Solano *et al.* (2003) in a study on the role of personal information sources on decision making process of Costa Rican dairy farmers observed that family members and technical advisors were the most preferred information sources while other farmers and commercial agents were the least preferred information sources. The correlation between age, education, dedication, land size, herd size and distance to population centres was found to significantly influence farmers' preferences towards information sources. Ngathou *et al.* (2005) on the other hand observed that computerized systems and marketing clubs were less preferred by limited resource farmers in Alabama, while printed materials were the most preferred. In this study, age exerted a downward pressure in preference, while land ownership and marketing plans had a positive significant relationship.

Cartmell *et al.* (2006) assessed the preferred information sources by limited scale land owners in Oklahoma and identified 19 sources of information from which farmers look for information. Direct mail was the most preferred source although extension contact was where farmers got information. This portrays a mismatch between the preferred pathway and the one used a fact that is likely to affect the adoption process. Roderick *et al.* (2008) evaluated preferences for risk management information sources in four states in the United States. The study established that information from experts and print materials were more preferred with age consistently influencing preference for the pathways negatively, while education and risk attitude were positive. Sharma *et al.* (2008) observed that Rapeseed-Mustard farmers in Rajasthan preferred neighbours, friends, progressive farmers and opinion leaders while agricultural supervisors had lost credibility among farmers and input dealers and commercial agents played an important role but with low credibility. Scientists and agricultural officers were perceived as much credible sources but were less accessible to farmers.

All these studies used revealed preference approach and the econometric models applied varied. The findings from these studies indicate that farmers' preferences for information sources are influenced by farm and farmers' characteristics, personal costs and benefits expectations. The findings of most of these studies are relevant in developed countries since some of these information sources assessed such as internet, are not accessible to smallholder farmers in the developing countries. In addition, the studies had numerous inconsistencies with respect to factors influencing farmers' preference for a particular source of information, which justifies a need to reassess these factors in a scenario in the developing countries like Kenya.

2.5. Efficiency of information dissemination

Efficiency, though an elusive concept, forms a great foundation of any planning approaches for development. It is defined differently by different disciplines (Jollands, 2006), but basically looks into how well inputs are converted into outputs. Whether public or private, it is a concern of the institution disseminating the technology to measure the efficiency with which the information is being disseminated to farmers given the scarcity of resources. In the face of stagnating and even declining funding, donors are putting pressure on efficient allocation available budget. Therefore, only those activities that promise most efficient use of research resources can be carried out. The efficiency of a diffusion process is of great practical importance in the design of a dissemination strategy as it affects the financial sustainability of publicly funded farmer information services (Feder *et al.,* 2003). It is assumed that, the larger the number of individuals who eventually adopt a technology, the greater the benefits to the programme. This may imply that a pathway that triggers adoption of a technology is more efficient because the benefits are realised earlier.

Allocating budgets across the various information sources used by farmers is an important decision to research institutions (Gloy *et al.,* 2000). Ampofo *et al.* (1986) established that while various dissemination pathways were used to scale out pest management technologies, each of these pathways had a different level of demand on local resources, researchers' time and costs. One pathway may have great influence on adoption decisions, but may be expensive. This implies that without assessment of efficiency of the different pathways, one is likely to make wrong conclusions of a dissemination strategy. Efficiency measure is based on the level of output produced for each unit of input and reflects the ability of a firm to obtain maximal outputs from a given set of inputs. This study focused on dissemination of information, whose aim was to create awareness to as many farmers as possible and eventual adoption of the technology. Therefore the output is treated as the number of farmers made aware and the proportion of farmers who ends up adopting the technology after hearing from the different sources.

2.6. Dissemination pathways for push-pull technology in Kenya

Several dissemination pathways can be classified depending on the nature of information delivery. Some of these pathways include the mass media, the print media and the interpersonal pathways such as field days, Farmer field schools, Farmer teachers/trainers, fellow farmers and the *Barazas*. Mass media are classified into electronic (radio, television) and print media (brochures, leaflets, booklets and magazine). Mass media has the advantage of reaching a large number of farmers quickly compared to other personal information pathways (Irfan *et al.,* 2006). These methods are particularly useful in creating awareness of a new idea and serve as an important and valuable tool for stimulating farmers' interest in the new idea. Once stimulated, farmers may seek additional information from neighbours, friends etc. (Behrens and Evans, 1984). However, they have the disadvantage of transmitting less detailed information and are classified as one way information source (from source to receiver) and permits limited or delayed feedback.

Print materials can be classified as audio-visual which help the trainer to improve on the effectiveness and clarity of ideas. They include posters which are normally displayed in common places, and brochures, leaflets and pamphlets which are usually distributed to the target groups. They have the added advantage of preserving the information and can therefore be used for a long time as a permanent reminder, but have the limitation for the illiterate (Abbas *et al.*, 2003). Although mass media plays a great role in provision of information in shortest possible time over large area of coverage, compared to other communication channels, its effect on behavioural change is weak as it is limited to awareness creation than skill development. But since awareness is pre-requisite for behavioural change, its role cannot be underestimated.

Farmer Field Schools (FFS) started as "schools without walls" where farmers took charge by organising experiments, leading discussions, making plans and accomplishing the tasks that were initially thought to be too complex. The FFS were first introduced in the rice fields in Indonesia in 1989 with specific focus on Integrated Pest Management (IPM). They stemmed from adult education principles and evolved to become a distinct approach that builds on the process of group learning and community action. These participatory extension methods have spread from Asia to Latin America and Africa. FFS recognizes the need to involve farmers in the technology development and transfer and its popularity and spread has been remarkable in the past decade (Asiabaka, 2002). The approach is among the key influences in rethinking dominant paradigms of agricultural extension and training. Farmers experiment and solve their problems independently, with the expectation that they will thus require fewer extension services and will be able to adapt the technologies to their own specific environmental and cultural needs. Participants are encouraged to share their knowledge with other farmers, and are sometimes trained to teach the courses themselves, thus reducing the need for external support.

Field days are day-long events common especially in rural agricultural extension. During these open days, interested farmers are invited to a particular field or plot and specific information about the technology are demonstrated and discussed. Field day session takes between 4 to 6 hours and ranges from a structure presentation or an informal event where participants walk through the field plot at their own pace to view the demonstrations (Lionberger and Gwin, 1991). The communication process in a field day varies depending on the technique being featured and the facilitators. However, farmers are able to interact with the facilitators as well as with other farmers and exchange ideas and experiences. In some cases, hands-on training and physical participation of the farmers is encouraged. Most farmers arrive at the field day venue on foot or bicycle, as such, no transport costs are incurred. A snack offered to participants as refreshment. The only limitation about the field days is the limited time and interaction between the facilitators and the farmers.

Farmer teachers/trainers refer to on-farm training of farmers by farmers. The method capitalizes on local social networks, based on belief that experienced and skilled farmers are the people best suited to train other farmers. The concept of farmer trainers is based on the hypothesis that there are always farmers who have above average skills, knowledge and talents in farm management (King'ori, 1999; Tanui, 1999). These farmers can motivate other farmers, help them to improve their skills, share their know-how and therefore are trained to train other farmers. The process starts with identification of farmer trainers based on their knowledge and understanding of the technology, and motivated by the need to take advantage of trainers' knowledge of socio-economic set-ups (Van Eckert, 2000). In addition, it allows the trainees to familiarize themselves with the technology since training takes place in the field where the farmers have the opportunity to see how things are done; they do them, make mistakes and receive advice. The training is totally hands-on, initially at the trainers' farm and later at the trainees' farm with monitoring and evaluation visits by the trainer to ensure that the training is going on well.

Fellow farmers are a common and important vehicle for diffusing new technology. This approach, otherwise referred to as farmer-to-farmer diffusion, represents a network of social capital whereby farmers interact and converse amongst themselves in many occasions in the farm. Often neighbouring farmers gather themselves in small groups chatting while in the farm, resting at home or even walking home together and it is common during such times for them to discuss their farming problems and possible solutions (Palis *et al.*, 2002). During these discussions, a trained farmer is more likely to share information with the other farmers.

Barazas are described as public gatherings of people usually in the village to listen to the chief, village elders, politicians or government officials (Kitetu, 2005). The concept has been widely used by the Kenyan government to mobilize communities, particularly when there is information to pass to the people. In order to get a gathering, the chief or the assistant chief often uses the religious leaders to announce to their congregations about the meeting. Some posters may also be pinned up for those who are literate to read. The meeting place may be in an open field outside the chief's office, a school, a church or a mosque. It is in such a place that development officers will try to pass their teachings. Both training and announcements take place here. If for example there is a new project or technology introduced in an area, government officers use this venue along with other venues such as churches and schools to make announcements.

Several authors have acknowledged the importance of *Baraza* in mobilizing farmers and passing information about a new technology. Kitetu, (ibid) and Njuguna *et al.* (2007) have pointed out *Baraza* as one of the key methods for passing information about new innovation to farmers. The main disadvantage of *Baraza* as a method of passing information is that it falls under the top-down approach because the experts come with information and programs to pass down to the rural community. The group being big leaves little room for interactive talk, questions or other topics outside the schedule set for the day by the expert (Kitetu, ibid).

2.7. Theoretical framework

2.7.1. Theory on preferences and adoption

In this study, we empirically investigate the effectiveness of dissemination pathways via farmers' preferences as well as the impact of information pathways on adoption. A farmer makes decision to adopt PPT as a stemborer and *Striga* weed control strategy among other available strategies. The study posits that the decision to adopt PPT is subject to the information constraints reaching a certain threshold, among other constraints. This information threshold is arrived through a process of information gathering which is in itself a product of an underlying utility maximization. A farmer voluntarily attends training sessions offered in different pathways, a decision derived from the need to maximize allocative ability. Once the information gathered reaches a certain threshold, a farmer may decide to adopt the technology or not. Information is gathered from different pathways and the choice of the pathway can also be viewed as a utility maximization problem where farmers are expected to prefer a pathway that is going to maximize their allocative skills. Since farmers are rational, they are expected to reveal their preferences in line with their objective function of welfare maximization.

Assuming that farmers are technology and information consumers, then the conventional consumer theory can be applied here which explains that a rational consumer chooses what to consume subject to certain constraint (Sadoulet and de Janvry, 1995). Based on this conventional consumer theory, farmers are hypothesized to adopt a technology or to prefer a pathway from a given set, which maximises their utility. This utility is derived from idiosyncratic preferences that a farmer places on the attributes of the technology or the pathway (Louviere, 1988). Therefore, this can be modelled under the random utility (RU) framework which provides the theoretical basis for integrating choice behaviour with economic evaluations (Rolfe *et al.*, 2000).

RU theoretical framework assumes heterogeneous actors and/or heterogeneous goods. Each actor is assumed to maximize utility which is assumed to consist of two components - a deterministic component that can be calculated based on model equations, and a stochastic component reflecting the uniqueness of individuals and situations that varies according to a distribution. Under this framework, it is hypothesized that the existence of a latent construct, called utility, that characterizes every individual and cannot be observed (Abraham and Hunt, 2007). In the RU model, the individual chooses the alternative that yields the greatest utility, so that the probability of choosing an alternative technology and/or pathway increases as the utility associated with it increases too. This latent utility can be decomposed into two components (an observable and an unobservable or random), such that the farmers' utility U_{ij}, associated with the j^{th} choice of a technology or pathway is modelled as a linear function of his/her characteristics and the choice attributes plus an error term as follows (Anderson *et al.*, 1992; Fernandez-Carnejo *et al.*, 1994):

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{2.1}$$

where V_{ij} is the deterministic part that captures the observable components of the utility function and which includes the characteristics of the farmer and that of the alternatives, ε_{ij} is the stochastic error term that models the unobservable component of the function including measurement and random errors. The error term represents the heterogeneity across the individual preferences once the observable variable has been taken into account and also implies that predictions cannot be made with certainty (Greene, 2003; Verbeek, 2004).

If U_1 represents the utility of the farmer when he/she prefers a pathway, or chooses to adopt a technology, and U_0, if he/she doesn't prefer, or doesn't adopt, then the farmer will prefer a pathway, or adopt the technology if $U_1>U_0$. With the assumption that the deterministic component of the utility function is linear in the explanatory variables, the utility function can be expressed as:

$$U_1 = \beta_1' X_i + \varepsilon_1 \tag{2.2}$$

$$U_0 = \beta_0' X_i + \varepsilon_0 \tag{2.3}$$

The presence of the random component permits the probabilistic statements about the decision makers' behaviour. Given the unobservable nature of the utility and with appropriate distribution assumptions of the error terms, a relevant model can be selected from the family of probabilistic models that exist. In this study, three probabilistic models were used as discussed in the section 2.9.

The application of the utility theory methods does not require decision makers to have an explicit idea of the probability surrounding their decisions or make explicit mathematical calculations around their decisions (Rapoport, 1966). Instead, the theory assumes that decisions are made based on subjective perception of probabilities by the decision maker. The theory further assumes that decision makers' preferences are complete, transitive and continuous (Myerson, 1979). It is usually the farmers' preferences for aspects of a technology or a pathway that motivate the choice decision. Where preference ordering of the defined technology or pathway satisfies completeness, reflexivity, transitivity and continuity axioms, some underlying utility functions can be specified.

Briefly, the axiom of completeness means that given any two choices x and y, one of the following is true; either x is preferred to y, y is preferred to x, or x is indifferent to y;

Reflexivity is where a bundle x is always indifferent to itself (i.e $x \sim x$), an axiom that appears to be obvious but very necessary for rational behaviour; Transitivity implies that if $x > y$ and $y > z$ then it must be true that $x > z$; while continuity states that if consumption bundles are close together, they will be assigned utility numbers that are close together but some preferences violate this assumption (Rubinstein, 2005). These axioms provide the rationale for representation of individual behaviour in a continuous utility function on an ordinal character and its augments. Theoretically, it is hypothesized that a rational individual will arrange and choose in order of preferences from among alternatives or available bundles of products and services. Such preferences decision requires the processing of information on a complex set of augments of the utility functions of individual decision makers.

2.7.2. Theory on efficiency

There is little evidence of any theory to guide efforts of measuring efficiency (Salerno, 2008). However, Farrell (1957) provided the impetus for developing the literature on empirical estimation of technical, allocative and economic efficiency. In view, the modern efficiency measurement begins with Farrell (1957), who drew from the work of Debreu (1951) and Koopmans (1951), to define a simple measure of firm efficiency which could account for multiple inputs. Farrell (1957) proposed that the efficiency of a firm consists of two components, technical efficiency which reflects the ability of a firm to obtain maximum output from a given set of inputs, and allocative efficiency which reflects the ability of a firm to use the given set of inputs in optimal proportions, given their respective prices. The two measurements combined provide economic efficiency.

Assuming two inputs X_1 and X_2 are used to produce a single output Y, the unit isoquant of an efficient pathway would be represented by SS^1 as shown in Figure 2.1 Any pathway using quantities of input defined by P has a technical inefficiency represented by the distance QP, which is the amount of inputs that can be reduced without reducing the outputs. This can also be expressed in a ratio form as QP/OP which represents the percentage by which the inputs could be reduced. The technical efficiency of such a pathway is thus given by:

$$TE = \frac{OQ}{OP} = 1 - \frac{QP}{OP} \qquad (2.4)$$

This takes the value of between 0 and 1, where 1 indicates a fully efficient pathway e.g. point Q. If the input price ratio AA^1 is known, then the allocative efficiency of the pathway using input P can be expressed as follows:

$$AE = \frac{OR}{OQ} \tag{2.5}$$

This measure of efficiency assumes that the production isoquant is known, but in practice, this is not the case and the efficient isoquant must be estimated from the sample data. Farrell suggested two measures, the non-parametric piecewise-linear convex isoquant, or parametric functions such as the Cobb-Douglas form fitted to the data. Due to data limitations, this study adopted the non-parametric piecewise-linear convex, using Data Envelopment Analysis.

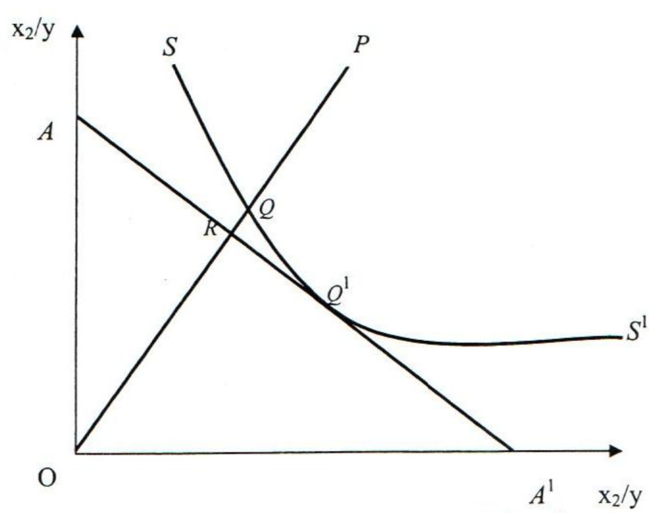

Figure 2.1: Technical and allocative efficiencies

2.8. Conceptual framework

The conceptual framework of the current study is represented in Figure 2.2. The study evaluates the relationship between the resource use in technology up-scaling and the expected outputs in terms of technology adoption. Every research institutions' desire is to have an impact on farmers' livelihood through innovations that increase production. Both private and public research institutions expend resources in development and up-scaling of improved innovations. The concern however is how to maximise output (which in this case can be measured in terms of awareness and adoption by farmers) given the available inputs. This input output relationship is referred to as 'efficiency'. Various dissemination pathways (e.g. Field days, Farmer field schools, farmer trainers, print, brochures etc.) are used to reach out to the farmers with the aim of triggering adoption. Each of these pathways demands varying levels of resources from the institution in question. Given that the intensity of information delivered via these pathways differs, it is expected that the impact of the pathways on adoption will also differ depending on the pathway used. This study uncovers the impact of these pathways on adoption of PPT in terms of level, intensity and speed in order to assess the most efficient and economic pathway which more resources can be channelled to maximise adoption. Farmers need to be properly trained since they often face uncertainty when making adoption decisions. In this case, the adoption can be measured in three levels – the decision to take up the technology or not, the intensity of adoption and the speed of adoption as represented the figure 2.2.

For a farmer to be able to make a decision to adopt the technology or not, he/she has to be made aware about the new innovation, so as to trigger interest. However, farmers' selection of information source as well as adoption decisions is influenced by many factors. Just *et al.* (2002) modelled this process in three stages. First stage, the farmer decides how much information is needed to establish and implement a new innovation. There is a level of uncertainty associated with unobserved information benefits. Once the farmer is satisfied he then decides to take up the technology using the information acquired in the first stage. Finally, the profits are realized in the third stage. The information provided via the different pathways helps reduce to uncertainty. Since farmers are assumed to be rational, their decision about the sources of information to use is based on the perception that the source of information used will be useful to them with respect to making management decisions. The study further evaluates the effectiveness of the pathways based on farmers' preferences and the target farmers' characteristics that influence the preference. This feedback to the research institution provides insights of the best way to target technology dissemination process.

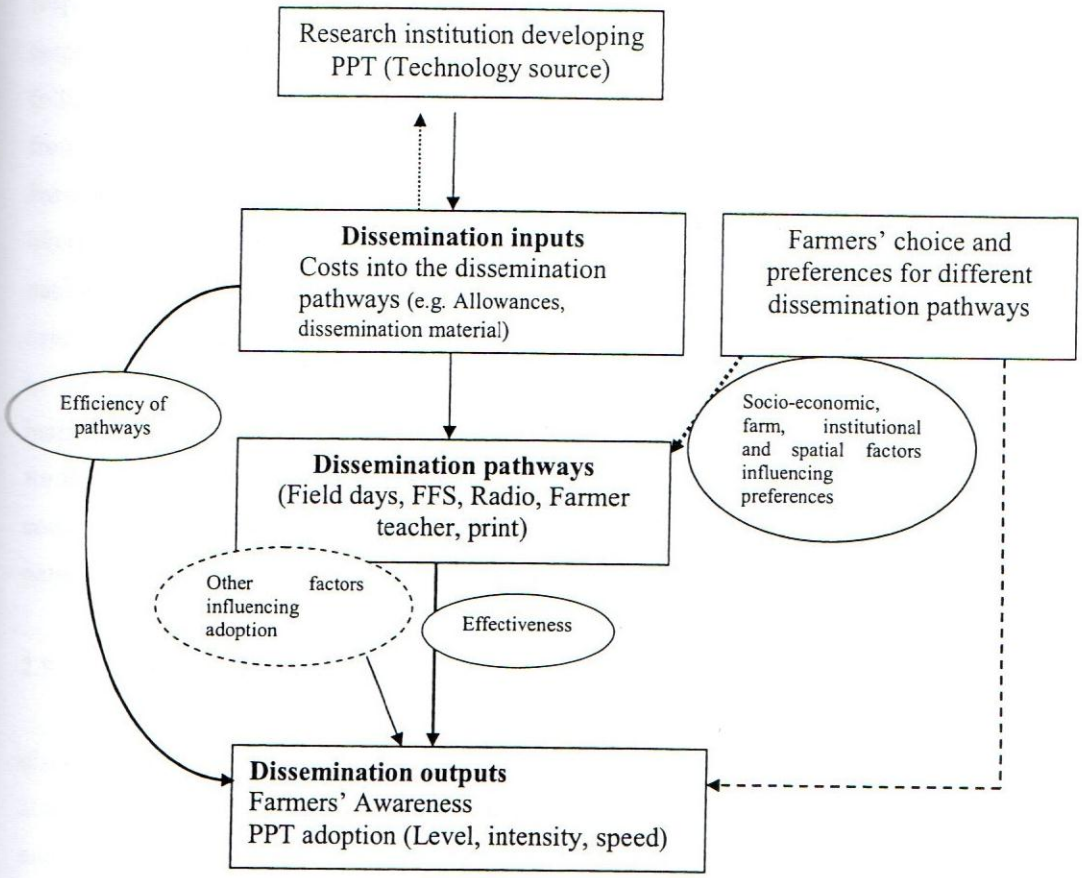

Figure 2.2: Conceptual framework for PPT dissemination

Source: Own conceptualization

2.9. Theoretical models

The following section gives a brief highlight on the theoretical models used in the analysis in this study. Details of the theoretical models are presented in relevant chapters accordingly.

2.9.1. Ordered probit model

Like many models for qualitative dependent variables, ordered probit has its origin in bio-statistics (Aitchison and Silvey, 1957), but was introduced into the social science by Mckelvey and Zavoina, (1975). This model belongs to the class of discrete choice probability model widely used in the analysis of attitudes, behaviours and choices and the likelihood of occurrences. The model is used when the dependent variable is discrete, nominal, ordered and non-continuous (Liao, 1994). Ordered probit recognizes the indexed nature of various response variables and underlying this indexing is a latent but continuous descriptor of response. The random error term associated with this continuous descriptor is assumed to follow a normal distribution. It was used in this study to explain the multiple choice variable from the likert type scale ranking of farmers' preference of different dissemination pathways. Farmers' preference ordering of the dissemination pathways was represented by a 3-point likert scale type (1= not preferred, 2 = somewhat 3 = most preferred) which is an ordinal nature of individual's utility function. There is clear order among the preference ranking categories, but the difference between the adjacent categories is not treated as the same. Due to the non-interval nature of the dependent variable ordinary linear regression (OLS) is inappropriate for this kind of analysis, while binomial and multinomial models fail to account for the ordinal nature of the dependent variable (Greene, 2003). Thus, ordered probit has been considered appropriate for analysing such categorical data in order to account for the ordinal nature of the dependent variable and will be used in this study.

2.9.2. The two-limit tobit model

The two limit tobit model was originally presented by Rosett and Nelson (1975) and discussed by Maddala (1993) and Long (1997). The model is an extension of the tobit model also referred to as the censored regression model which differs from the binary models (Logit and Probit) by allowing for censored or truncated data (Greene, 2003). The relevance of this model in this study is its ability to utilise all the observations from zero to the upper limit, thus preferred over the conventional ordinary linear regression procedure especially where a significant proportion of observations for the dependent variables are clustered at zero (in this case, the non-adoption of PPT) (Chandran, 2004). Since the dependent variable in objective two of this study is censored between 0 and 100% (proportion of land under PPT), the two limit Tobit was found appropriate. Besides, the model enables the simultaneous estimation of the factors influencing the likelihood of adoption as well as the extent of technology adoption.

2.9.3. The duration model

Duration model has an extensive history of use in biomedicine and in engineering. It was first used in social sciences by Lancaster in 1972 to study the factors influencing unemployment. In the recent times, it has been used in several agricultural technology adoption studies (e.g. Fuglie and Kascak, 2001; Burton *et al.*, 2003; Carletto *et al.*, 2007 and D'Emden *et al.*, 2006) among others. The model builds on the dichotomous choice methods and is widely used to statistically identify those factors which have significant effect on the length of time (duration) farmers wait before adopting a new technology as well as to provide projections for the future diffusion of these technologies under the current conditions (Feder *et al.*, 1984). The advantage and relevance of the duration model in the current study is its ability to incorporate the dynamic nature of the adoption process and to provide information on the diffusion process which the limited dependent variable models (e.g. Logit and Probit) fail to account for. These models implicitly presupposes that the probability of adoption is unaltered even with the passage of time (Fuglie and Kascak, 2001; Dadi *et al.,* 2004; Carletto *et al.,* 2007; Winters *et al.,* 2004).

2.9.4. Data Envelopment Analysis model

Data Envelopment Analysis (DEA) was first introduced by Charnes *et al.* (1978) extending the work of Farrell (1957). Details of desirable features of DEA are given by Lovell (1993) and Färe *et al.* (1994). The model is non-parametric and is used to identify empirical frontiers in evaluating relative efficiency, whereby a firm's efficiency is measured relative to all other firms in the industry subject to restrictions that all firms are on or below the efficiency frontier (Zhu and Norwell, 2003). In applying DEA, no *a priori* assumptions are made about the functional form of the underlying technology. Instead, an efficiency frontier known as envelopment surface from observed sample data is estimated and individual units deviation from the frontier is calculated. The method is mostly preferred for efficiency analysis in the non-profit sector where inputs are used to produce single or multiple outputs, and where it is difficult to obtain input and output price data; thus was used in this study to evaluate the efficiency of dissemination pathways.

The underlying concept of DEA is based on pareto optimality (Charnes *et al.*, 1978). In which case, a pathway would be considered relatively efficient if there is no other one which can produce at least the same level of outputs with less of one input and not more of another input. DEA calculates the comparative ratio of outputs to inputs for each unit with the score expressed as 0-1 or 1% to 100%. DEA has widely been used to evaluate the performance of public (non-profit making) service sectors such as hospitals, schools, universities and courts which operate outside the market and therefore income and profitability does not work satisfactorily. However, its use in investigating and analyzing efficiency of dissemination pathways is limited. Dissemination process bears similarities to service organizations such as schools and hospitals and the common problem is lack of ultimate criterion of effectiveness and often the difficulties in discovering the relationship between the inputs and the outputs, which makes the use of regression models very difficult. For such service organizations, the focus is not on obtaining profit and also the main source of finance does not come from sale of goods and services. Thanassoulis *et al.* (1987) acknowledge that the most difficult stage in use of DEA is in identifying the inputs and outputs to use and collecting data especially for the non-profit making sectors since most of the relationship between the inputs and outputs of such sectors are complex and chaotic.

2.10. General description of variables used in the various regression models

Table 2.1 presents all the variables used in the three econometric models and a brief explanation of these variables is given in this section. The choice of these explanatory variables was mainly based on the general working hypothesis and partly on empirical findings from literature. The explanation given may slightly differ depending on the model being used. Human capital was represented by age (*Age*) and education (*Noeduc, Prieduc, Seceduc, Pseceduc*), which reflects the social aspects of the farmer and their ability to obtain and evaluate information about an innovation. The influence of age on adoption has been mixed and is described as a composite of the effect of farming experience and planning horizon (Fernandez-carnejo *et al.*, 2001). In some technologies, older farmers are known not to be enthusiastic about a new technology, especially if the benefits are not expected in the near future. However, farmers with advanced age are associated with more experience through which they can use to discern economic benefits of the technology. For this reason, the effect of age was expected to be either positive or negative. Education is used as a proxy for farmers' ability to acquire and effectively use information (Genius *et al.*, 2006). An educated farmer is more likely to accept a new farm technology compared to a farmer with no formal education. It is also expected that effective pathways for information exchange would be different for educated and non-educated farmers. In this study, the variables representing education level were expected to have a positive effect on adoption. However, the effect is likely to be positive or negative for the dissemination pathway preferences.

Gender (*Gender*) is an important variable affecting adoption decision at the farm level since female and male-headed households differ in terms of access to assets, education and other critical services such as credit, technology and input supply. In the developing countries for example, male-headed households have been reported to have higher access to resources and information and therefore greater capacity to adopt technologies (Kaliba *et al.*, 2000). For this reason, the effect of gender was expected to be positive.

Table 2.1: Description of variables used in the econometric models

Variable	Description of the variable	Model[1] in which the variable is used
Gender	Gender of the main farmer (1= Male 0 = Female)	OP, TLT, DA
Age	Age of the farmer in years (Continuous)	OP, TLT, DA
Noeduc	If farmer had no formal education (1 = Yes, 0 = No, reference variable)	OP, TLT, DA
Prieduc	If the farmer had primary education (1 = Yes, 0 = No)	OP, TLT, DA
Seceduc	If the farmer had secondary education (1 = Yes, 0 = No)	OP, TLT, DA
Pseceduc	If the farmer had post-secondary education (1 = Yes, 0 = No)	OP, TLT, DA
Hhsize	Household size (continuous)	OP, TLT, DA
Tenure	Land owner ship (1 if Owned 0 if Otherwise)	OP, TLT, DA
Landsiz	Total land size in acres (Continuous)	OP, TLT, DA
Pptadopt	I the farmer has adopted PPT (1= Yes, 0 = No)	OP
Baraza	If the farmer has heard about PPT from a *Baraza*, (1 = Yes, 0 = No)	TLT, DA
Radio	If the farmer heard about PPT from the radio (1 = Yes, 0 = No, reference variable)	TLT, DA
FFS	If the farmer has attended FFS on PPT (1 = Yes, 0 = No)	TLT, DA
FT	If farmer has been trained by the farmer teachers, (1 = Yes, 0 = No)	TLT, DA
FD	If farmers have attended PPT field days (1 = Yes, 0 = No)	TLT, DA
Print	If farmer has read printed materials on PPT (1 = Yes, 0 = No)	TLT, DA
FF	If farmer has been trained by the fellow farmers (1 = Yes, 0 = No)	TLT, DA
*FT*FD*	If interaction exist between Farmer teacher and field days (1 = Yes, 0 = No)	TLT, DA
*FFS*FD*	If interaction between FFS and field days (1 = Yes, 0 = No)	TLT, DA
TLU	Total livestock unit (Continuous)	TLT, DA
Inc_lev1	Farm income level (1 if farm income is <20,000, 0 = No, reference variable)	OP, TLT, DA
Inc_lev2	Farm income level (1 if farm income is 20,000 to 40,000, 0 if otherwise)	OP, TLT, DA
Inc_lev3	Farm income level (1 if farm income is > 40,000, 0 if otherwise)	OP, TLT, DA
Grpmember	If the farmer is a member of organized group (1 = Yes, 0 = No)	OP, TLT, DA
Credit	If the farmer had access to credit (1 = Yes, 0 = No)	OP, TLT, DA
Distarmac	Distance of the farm to the nearest tarmac road (km)	OP, TLT, DA
Homabay	Dummy for Homabay district (reference variable)	OP, TLT, DA
Kisii	Dummy for Kisii district	OP, TLT, DA
Busia	Dummy for Busia district	OP, TLT, DA
Bungoma	Dummy for Bungoma district	OP, TLT, DA

Note: [1] OP = Ordered Probit, TLT = Two limit Tobit, DA = Duration Analysis

Household size (*Hhsize*) is linked to supply of farm labour and is expected to have a positive effect on adoption of PPT which is relatively labour-intensive during establishment stage. However, in some cases negative relationship has been reported between family size and adoption (e. g. Carletto *et al.*, 2007). Battershill and Gilg (1997) attribute this to limited freedom in farm decision making as the household size increases. Alternatively, it could be due to household members being engaged in off-farm activities and therefore has little time to offer labour to agricultural activities.

The effect of land size (*Landsiz*) is expected to be either positive or negative. Large farmers are assumed to be less risk averse and therefore able to adopt new technologies, or they could be under less pressure for alternative ways to improve their income via new technologies, while small farmers adopt labour intensive technologies as they use relatively more family labour which has low opportunity cost (Genius *et al.*, 2006). A lot of inconsistencies have been reported on the effect of land tenure (*Tenure*) on the adoption process. Fernandez-carnejo *et al.* (2001) attribute this to the differences in the nature of technologies, whereby tenants are less likely to adopt a technology requiring investment tied to land. In the case of PPT, land tenure was given a positive sign since it involves planting of some perennial crops such as desmodium and Napier grass, which could deter tenants from adopting the technology. Credit (*Credit*) is expected to have a negative effect on adoption of capital intensive technologies if farmers are constrained in accessing, but for PPT the effect may be different since the technology is less capital intensive.

The direction of group membership (*Grpmember*) may not be well defined since farmers are likely to form positive or negative attitude towards an innovation through group contacts. Distance from information sources is treated as a barrier to adoption. Even with advances in communication technology, potential adopters still face problems relating to distances from information sources when trying to access whether innovations are suitable in that area. In this study, distance to the tarmac road (*Distarmac*) was used as a proxy for the accessibility of input and output markets as well as information availability. It may also be an indication of the remoteness of a given area and the nature of risks that households face. Households residing in remote rural areas are far away from major services, such as extension and are less likely to receive information that will promote agricultural production. In addition, longer distances are associated with an increase in transaction costs (Abdulai and Huffman, 2005), which essentially translates to inability to access essential services. For this reason, this variable was expected to be negative.

The importance of livestock as an economic resource is represented by the number of Tropical Livestock Unit (*TLU*)[1]. In rural context, livestock holding is an important indicator of household's wealth and also an income source which enables farmers to invest on the adoption of improved agricultural technologies. It is hypothesized then that the more TLUs a farmer has, the larger the probability of adoption of PPT. Households' income position which was grouped in three levels (*Inc_lev1, Inc_lev2* and *Inc_lev3*) was expected to have a positive impact on adoption as shown by most adoption studies in literature. In the context of rural households, annual farm income is obtained from sale of crop and/or livestock, off-farm and non-farm income.

The adoption process of agricultural technologies depends primarily on access to information and on the willingness and ability of farmers to use information channels available to them. The role of information in adoption decision-making process is to reduce risks and uncertainties to enable farm households to make right decision on adoption of improved agricultural technologies. The dummy variables representing information access via the seven dissemination pathways (*Baraza, Radio, FFS, FT, FD, Print* and *FF*) were expected to have a positive effect on PPT adoption. These variables were used to capture the variations in information available to farmers in different areas and to capture the on-going exposure of farmers to PPT information. To capture the effects of interactions between the pathways in the analysis, multiplicative interactive variables were included in the model. For brevity, only two interaction variables were created (*FT*FD* and *FFS*FD*) since they had the highest frequency of occurrence. Dummy variables representing the four districts of study were also included to control for the regional effects on adoption of PPT as well as for factors outside the farmers' production decision context.

The above discussion is best suited for the adoption models (two limit Tobit and the Duration Model). This explanation is likely to differ for the ordered probit model which explains the preferences for the dissemination pathways. A variable of PPT adoption (*Pptadopt*) was used in the ordered probit model to distinguish the preferences of dissemination pathways among adopter and non-adopters. All the other variables used in the ordered probit model were expected to be either positive or negative depending on the pathway in question.

[1] Total livestock unit 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)

CHAPTER THREE

DETERMINING SMALLHOLDER FARMERS' PREFERENCES FOR PUSH-PULL TECHNOLOGY DISSEMINATION PATHWAYS

3.1. Introduction

Potential for uptake of knowledge-intensive technologies such as PPT can be limited especially among the smallholder farmers if appropriate dissemination pathways are not used to ensure its effective transfer. One way to assess the effectiveness of dissemination pathways is evaluating the farmers' preferences for the pathways. It has been shown that farmer' preferences for dissemination pathways do exist and farmers are likely to be persuaded to adopt a technology by information pathways that they perceive as credible and reliable (Rogers, 1997; Gloy *et al.*, 2000; Tucker and Napier, 2002; Roderick *et al.*, 2008). Therefore the choice of a dissemination pathway should not only be based on their effectiveness and capacity to reach larger number of farmers, but also according to their perceived credibility, relevance and preference among target audience. Unlike in developed countries where studies have analysed farmers' preferences for various information sources (e.g. Gloy *et al.*, 2000; Ngathou *et al.*, 2005; Roderick *et al.*, 2008), no study has been conducted in a developing country context such as Kenya where requisite circumstances and information sources for knowledge intensive technology and the socio-economic circumstances of intended beneficiaries differ significantly. This chapter aims at evaluating farmers' preferences for the different pathways used in the dissemination of the PPT technology in order to assist in development of a targeted dissemination strategy that would allow farmers to receive adequate information to enable them learn and make informed adoption decisions.

3.2. Methodology

3.2.1. Sampling procedures and data collection

Primary data were collected through a household survey from February to March 2009. A structured questionnaire was designed to collect data on general household and socio-economic characteristics such as age, education, gender, farm ownership, land size, total household income, group memberships, access to credit and distances to the tarmac and extension services and also farmers' preferences for given dissemination pathways. Since the data selection criterion was to increase validity in addition to obtaining a representative sample as required in studies that aim to make inferences to the study populations (Carmines and Zeller, 1988), purposive sampling was used to select the districts with predominant use of

PPT to control the stemborers and *Striga* weed. This is because purposive sampling ensures that certain important segments of the target population are represented and also allows selection of rich information that provides a great deal of insight into the issues of central importance to the research (Patton, 1990). A sample frame was prepared consisting of all the farmers who had received information on PPT through different pathways in the target districts. The sampling frame included both adopters and non-adopters who have at least heard about PPT. A sample of 516 farmers was drawn randomly using a computer package www.randomizer.org. The 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 1066 farmers in the study area who had the characteristics of interest, and assuming that the sample mean should be within a range of ± 3% of the population mean with 95% probability, the sample size was calculated as follows:

$$n = \frac{(1.96)^2 * (0.5) * (0.5) * 1000}{(0.03)^2(1000-1) + (1.96)^2 * (0.5) * (0.5)} = 516 \tag{3.2}$$

However, the analysis was done on 491 farmers since some of the questionnaires were discarded due to poor responses and a few respondents were not reached due to poor accessibility. Before the administration of the questionnaire, the respondents were informed about the objectives of the survey. The questionnaires were pre-tested in Vihiga and Migori districts before actual data collection and amendments were made to modify some of the questions to make them fit to the context. Four enumerators were recruited per district with the help of ICIPE field staffs in the respective districts. The enumerators were trained on the objective and contents and the interviews were conducted in the local language.

Relevant to this chapter, farmers were presented with a list of the seven pathways and asked to rank each one of them using a 3-point likert scale where 1 = not preferred, 2 = somewhat preferred, 3 = most preferred based on how they perceived their effectiveness in information delivery. For the purposes of ordered probit analysis, these ranking were re-coded as 0 = not preferred, 1 = somewhat preferred and 2 = most preferred. The seven dissemination pathways considered were *Barazas* (public gatherings), radio, farmer field schools (FFS), field days (FD), farmer teachers (FT), the fellow farmers (FF) and print materials (Brochure, leaflets and booklets).

3.2.2. Model specification and analysis

A weighted rank index was used to assess farmers' preference ranking for the seven PPT technology dissemination pathways by farmer category as shown in equation 3.3. The farmers were grouped into either adopters, non-adopters or both of these groups combined. The overall rank for each pathway was computed as; index = Sum of scores [3 for most preferred + 2 for somewhat preferred + 1 for not preferred] for each dissemination pathway divided by sum of scores [3 for most preferred + 2 for somewhat preferred + 1 for not preferred] for all preferences of all the dissemination pathways.

$$I_i = \begin{pmatrix} 3 \\ 2 \\ 1 \end{pmatrix} [\sum_{j-1}^{3} x_j]_j / \sum_{k-1}^{n} [\begin{pmatrix} 3 \\ 2 \\ 1 \end{pmatrix} \sum_{j-1}^{3} x_j]_k \qquad (3.3)$$

where I_i is the ranking index, x_j is the number of respondents ranking pathway i in the j^{th} rank, and k is the sum of ranks for n number of pathways.

An ordered probit model was used to assess the factors influencing preference for the seven dissemination pathways. This model has been adopted in the analysis of human attitudes, behaviours and choices and has lately been applied in estimating coefficients to predict factors influencing preference ranking based on maximum likelihood estimate (Verbeke and Ward, 2003; Lohr and Park, 2003; Ngathou *et al.*, 2005; Alexandra and Mario, 2006). In the formulation of the model, the observed responses were represented by a variable Y_i which denotes the preference rank given to each dissemination pathway by farmer i and takes on j different values which are naturally ordered, in this case 3 values (j = 0, 1, 2). However, these observed values are assumed to derive from some unobservable latent variable Y_i* such that:

$$Y_i^* = X_i\beta + \varepsilon_i \qquad (3.4)$$

where X_i represents the observable individual specific factors, β is a vector of parameters to be estimated and ε_i is the stochastic-disturbance term whose distribution is estimated to be normal (Greene 2003). The values for observed choice outcome Y_i are assumed to be related to the latent variable Y_i* as follows:

$$
\begin{aligned}
&Y = 0 \Rightarrow \text{not preferred if } Y^* < \mu_o \text{ where } \mu = 0 \\
&Y = 1 \Rightarrow \text{somewhat preferred if } 0 \leq Y^* < \mu_1 \qquad (3.5) \\
&Y = 2 \Rightarrow \text{most preferred if } \mu_1 \leq Y^* < \mu_2
\end{aligned}
$$

where μ_i is unknown threshold parameter for outcome i that separate the adjacent boundary values and is estimated together with the β's. The estimated μ follows the order $\mu_0 < \mu_1 < \mu_2$. The probability of each observed outcome falling in a given category is given as:

$$
\begin{aligned}
&\Pr(Y = 0) = \phi(-\beta' x) \\
&\Pr(Y = 1) = \phi(\mu_1 - \beta' x) - \phi(-\beta' x) \qquad (3.6) \\
&\Pr(Y = 2) = 1 - \phi(\mu_1 - \beta' x)
\end{aligned}
$$

where ϕ is the cumulative density function of μ_i. Using maximum likelihood estimates technique, the values for the parameters β can be estimated. However, interpretation of coefficients from an ordered probit is not straight forward. To elicit causal relationship between the explanatory variables and qualitative dependent choice outcome variable, computation of partial changes or marginal effects in the probabilities of an outcome for a given change in each dependent variable is conducted (Long, 1997). Marginal effects measure the expected change in predicted probability associated with changes in the explanatory variables. The marginal effect of an independent variable is the derivative (that is, the slope) of the prediction function, which, by default, is the probability of success following probit. The marginal effect measurement is required to interpret the effect of the regressors on the dependent variable (Greene, 2003). Following Greene (2003), these marginal effects are estimated by taking the first derivative of the log likelihood functions as:

$$\frac{\partial \Pr(Y=0)}{\partial x} = -\phi(-\beta' x)\beta$$

$$\frac{\partial \Pr(Y=1)}{\partial x} = [\phi(-\beta' x) - \phi(\mu_1 - \beta' x)]\beta \qquad (3.7)$$

$$\frac{\partial \Pr(Y=2)}{\partial x} = [\phi(\mu_1 - \beta' x)]\beta$$

For this study the estimated marginal effects show the change in the likelihood that a respondent would "somewhat prefer" or "most prefer" (as opposed to "not prefer") as a result of the unit change in that particular variable. In other way, the marginal effects show the probabilities that a farmer would rank a dissemination pathway in any of the two preference categories, given a set of farmer characteristics and farm attributes. The signs in the parameter estimates and their statistical inferences indicate the direction of the relationship (Verbeek, 2004).

An ordered probit regression was fitted for each of the seven dissemination pathways to obtain estimates of the coefficients and marginal effects. The following empirical model was specified and used to estimate the relation between preference ranks and other attributes (farmer, institutional and spatial).

$$\begin{aligned} Prefrank = {} & \beta_0 + \beta_1 Gender + \beta_2 Age + \beta_3 Prieduc + \beta_4 Seceduc + \beta_5 Pseceduc + \beta_6 Tenure + \\ & \beta_7 Landsiz + \beta_8 Pptadopt + \beta_9 Inc\_lev2 + \beta_{10} Inc\_lev3 + \beta_{11} Grpmember + \\ & \beta_{12} Distarmac + \beta_{13} Kisii + \beta_{14} Busia + \beta_{15} Bungoma + \varepsilon_i \end{aligned} \qquad (3.8)$$

Prefrank is the dependent variable and was measured as the observed ordered response for a particular pathway which takes on any of the three possible outcomes (0, 1 and 2). The statistical significance of individual parameters was interpreted using the *p*-value which is the alternative way to assess individual significance estimates in maximum likelihood estimates. The *p*-value is the lowest significance level at which a null hypothesis can be rejected (Greene, 2003). The description and measurement of the explanatory variables is given in Table 2.1 in chapter 2.

Before running the regression model, all the hypothesized explanatory variables were checked for the existence of multicollinearity problem. Variance inflation factor (VIF) was used to test multicollinearity problem following Maddala (1993) where VIF is defined as:

$$VIF(X_i) = \frac{1}{1 - R_i^2} \tag{3.9}$$

R_i^2 is the squared multiple correlation coefficient between X_i and the other explanatory variables. Large values of VIF indicate the existence of multicollinearity. As a rule of thumb, if the VIF of a variable exceeds 10 (which happens if R_i^2 exceeds 0.95), that variable is said to be highly collinear (Gujarati, 1995). All the variables in the model had a VIF less than 10 (See appendix 5).

3.3. Results and Discussion

3.3.1. Sample summary statistics

Table 3.1 presents the descriptive statistics of the key variables describing farmers' and farm characteristics in the four districts where the study was conducted and the overall responses. Chi-square (χ^2) or F-tests were used where appropriate for statistical significance or otherwise, for the differences between the responses (overall sample and study districts). For most of the variables, the differences were statistically significant between the districts. Although the majority (84%) of the respondents had taken up the technology, a few (16%) had not adopted PPT. A majority of the non-adopters (73%, n = 89) stated lack of planting materials and insufficient information as the main reasons for non-adoption. This may be an indication that some of the dissemination pathways used to train the respondents may not have been effective. Alternatively, it implies that there is need to understand the clients' information needs and preferences prior to using particular dissemination pathways. Other reasons for non-adoption were; farmers still in the process of starting to use the technology (13%), farmers on rented land (7%), PPT considered labour intensive (5%) and lack of interest (2%) (See appendix 3).

There were slightly more female respondents than males, a scenario which is common in many developing countries, whereby women are more involved in farming activities while their male counterparts often go for off-farm activities. Further, the results show a middle aged farming community (mean age = 44 years) with an education level that reflects relatively high literacy levels. This is quite relevant in technology up scaling since the two (age and education) reflect farmers' ability to obtain and evaluate information about an innovation and therefore an indication of the mode of technology dissemination to be used.

Table 3.1: Descriptive statistics and frequencies for selected farmers' and farm characteristics per study district and for the overall sample

Demographic variable[1]	Sample N = 491	Study districts Homabay N = 122	Kisii N = 121	Busia N = 120	Bungoma N = 128	*F*-statistic	χ2
Gender of the farmer (%)							
Female	57	62	59	60	47		7.32**
Male	43	38	41	40	53		
PPT adoption (%)							
Adopted	84	80	80	93	83		10.52***
Not adopted	16	20	20	7	17		
Education level of the farmer (%)							
No formal education	6	8	10	7	1		34.62***
Primary education	52	57	59	51	40		
Secondary education	36	27	26	33	54		
Post-secondary education	7	7	6	9	5		
Household income category (%)							
Level 1 (< Ksh 20,000)	31	48	31	27	20		42.18***
Level 2 (Ksh 20,000 to Ksh 40,000)	35	38	37	29	36		
Level 3 (> Ksh 40,000)	33	13	32	44	44		
Others							
Ownership of land (%)	97	96	98	94	100		8.99**
Group membership (%)	87	89	79	96	82		17.27***
Age of the farmer (years)	44 (11.5)	43.7 (10.9)	41.5 (10.2)	46.0 (12.4)	45.4(11.8)	3.88***	
Household size (persons)	7 (3.2)	6.5 (2.9)	6.5 (2.4)	7.4 (3.1)	8.0 (4.0)	7.32***	
Total land size (acres)	3.9 (3.7)	3.5 (3.7)	3.2 (2.3)	4.2 (2.8)	4.7 (5.2)	4.03***	
Tropical Livestock Units (TLU)	2.6 (2)	3.3 (2.4)	1.7 (1.2)	2.5 (1.9)	3.0 (2.3)	16.31***	
Distance to tarmac (Km)	4.9 (5.4)	2.3 (3.1)	4.7 (4.8)	5.2 (4.9)	7.5 (6.9)	21.1***	
Number of pathways used	3.7 (1.6)	3.2 (1.4)	3.5 (1.9)	4.1 (1.4)	4.1 (1.4)	8.56***	

[1] Socioeconomic characteristics of the farmer and farm characteristics; Figures in the parenthesis are the standard errors associated with the means for the continuous variables. Significance levels given as: *** *P< 0.01*, ***P < 0.05* and * *P < 0.10*

The average household size was seven members. On average, land sizes were 3.9 acres, an indication that farmers in this region are smallholders. The average Tropical Livestock Units (TLUs) was estimated to be 2.6 units. On average the respondents had received information about PPT from four pathways out of the seven that were assessed. This reflects the information seeking behaviour whereby farmers tend to seek for information from different sources before making a technology adoption decision. Such a scenario is likely to happen if the pathways used do not provide sufficient information, such that farmers have to look for extra information from other sources. This would suggest that using tested and effective pathways is likely to minimize farmer information search costs. Land was mainly owned by the majority (97.1%) of the farmers but without title deeds. About 86.5% of the farmers belonged to organized groups mainly women and men social welfare groups, production and marketing groups, all of which represent the social capital among the respondents. The household income was fairly distributed along the three levels (31.4% in income level 1, 35% in income level 2 and 33.4% in level 3).

3.3.2. Weighted scores based dissemination pathway preferences

Table 3.2 shows farmers' preferences for the various dissemination pathways by farmer category and based on weighted rank index. The result shows that FDs were the most preferred dissemination pathway, with the highest index of 0.171 for adopters, 0.167 for non-adopters, and 0.170 for the overall sample. Farmer teachers and FFS were ranked second and third respectively. The ranking for all the pathways was similar both in position and the score index (Table 3.1). The overall farmers' preferences for the FD compared to other pathways is probably due to their ability to catalyze interactive learning among participants and the tendency to elicit interest farmers compared to other forms of dissemination (Doss, 2003). In addition, FDs have been a predominant extension technique used by various agents and non-governmental organisations to disseminate information. During these open days, farmers are able to interact with the facilitators as well as with other farmers and exchange ideas and experiences (Madukwe, 2006). In some cases, hands-on training and physical participation of the farmers is encouraged. These results corroborate the findings of Amudavi *et al.* (2008) who found that the farmers' propensity to seek new agricultural knowledge motivated farmers to attend the FDs and overall, it was favourably rated in terms of its effectiveness in information dissemination. However, Amudavi *et al.* (2009) acknowledge that in this era of tight budgets for public extension and the challenges faced in extension delivery to cover large geographical areas, well trained FTs can be alternative effective pathways of knowledge dissemination to other farmers. The results from the current study complement this observation since FT ranked second in preference.

Table 3.2: Farmers' perception for the various pathways based on a weighted rank index

Pathway[2]	Farmer category														
	Adopters[1]					Non adopters[1]					Combined[1]				
	1	2	3	N	Rank[3]	1	2	3	n	Rank[3]	1	2	3	n	Rank[3]
FD	12	106	295	413	0.171	2	21	52	75	0.167	14	127	347	488	0.170
FT	32	89	291	412	0.167	6	17	53	76	0.167	38	106	344	488	0.167
FFS	45	86	281	412	0.163	7	23	46	76	0.160	52	109	327	488	0.163
FF	35	192	186	413	0.151	4	31	39	74	0.153	39	223	225	487	0.151
Print	112	198	102	412	0.125	18	36	22	76	0.131	130	234	124	488	0.126
Radio	87	256	70	413	0.125	16	45	14	75	0.124	103	301	84	488	0.125
Baraza	213	163	33	409	0.098	37	33	5	75	0.099	250	196	38	484	0.098

Notes: n = Number of farmers ranking the pathway; [1]1 = not preferred; 2 = somewhat preferred; 3 = Most preferred; [2]FD = Field days, FT = Farmer Teachers, FFS = Farmer Field Schools, FF = Fellow farmers
[3]Ranking index = Sum of [3 for most preferred + 2 for somewhat preferred + 1 for not preferred] divided by [3 for most preferred + 2 for somewhat preferred + 1 for not preferred] for all preferences of all the dissemination pathways.

3.3.3. Determinants of preference ordering and marginal effects

Table 3.3 presents ordered probit coefficients, for the various factors influencing farmers' preferences for the seven PPT dissemination pathways. All the models were significant at 1% ($p < 0.01$). The estimated thresholds or cut-off points (μ) satisfy the condition $\mu_0 < \mu_1 < \mu_2$ implying that the categories are ordered (Knight *et al.*, 2005). The first cut-off point ($Y = 0$ for "not preferred") was used as reference for comparison purposes. The cut-off points show the likelihood or probability of ranking a particular pathway high or low. For example, the boundary between not preferred and somewhat preferred for FD preference falls at z = -2.5. The coefficients presented in Table 3.3 show varied levels of significance both in magnitude and direction for some explanatory variables.

Table 3.3: Ordered probit coefficients and standard errors for factors influencing pathway preferences

Variables	Pathways													
	FD		FT		FFS		FF		Print		Radio		*Baraza*	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Gender	0.052	0.126	-0.173	0.127	-0.062	0.125	-0.230**	0.114	0.208**	0.110	0.147	0.113	0.213**	0.118
Age	-0.001	0.006	0.006	0.006	0.001	0.006	-0.002	0.005	-0.014***	0.005	-0.001	0.005	0.000	0.006
Prieduc	-0.617**	0.290	0.073	0.261	-0.151	0.262	0.118	0.237	0.153	0.229	0.522**	0.233	-0.032	0.243
Seceduc	-0.332	0.307	0.137	0.280	-0.055	0.280	-0.058	0.252	0.464**	0.244	0.419*	0.249	-0.294	0.260
Pseceduc	-0.247	0.382	0.144	0.361	-0.228	0.352	-0.138	0.316	0.758***	0.311	0.675**	0.315	-0.554*	0.334
Tenure	-0.215	0.373	-0.105	0.391	-0.130	0.390	-0.175	0.356	0.047	0.320	-0.315	0.327	0.074	0.346
Landsiz	0.020	0.020	-0.035**	0.017	-0.020	0.019	0.001	0.017	0.009	0.017	-0.008	0.017	-0.019	0.018
Pptadopt	0.076	0.170	-0.005	0.167	-0.030	0.165	-0.314**	0.158	-0.013	0.147	0.118	0.153	-0.048	0.160
Inclev2	0.119	0.138	0.102	0.139	-0.172	0.142	0.029	0.122	-0.119	0.127	-0.017	0.124	0.105	0.132
Inclev3	0.144	0.198	0.225	0.193	-0.131	0.202	-0.127	0.171	-0.130	0.178	-0.227	0.175	0.574	0.179
Grpmember	0.129	0.191	-0.211	0.191	0.319**	0.176	0.253**	0.169	0.099	0.167	-0.412**	0.171	-0.117	0.177
Distarmac	0.017	0.012	-0.024**	0.011	0.050***	0.014	-0.005	0.010	-0.003	0.010	0.046***	0.010	0.053***	0.011
Busia	-0.390**	0.174	0.510***	0.189	0.066	0.183	0.685***	0.166	-0.650	0.155	0.302**	0.158	0.821***	0.173
Bungoma	-0.230	0.190	-0.395**	0.180	-0.052	0.192	-0.182	0.166	0.499	0.165	-0.181	0.168	0.356**	0.183
Kisii	0.261	0.187	0.018	0.183	-1.281***	0.179	0.219	0.163	-0.046	0.156	0.645***	0.164	0.521***	0.179
μ_1	-2.503	0.584	-1.609	0.583	-1.436	0.574	-1.984	0.528	-0.928	0.492	-0.582	0.498	1.419	0.527
μ_2	-1.093	0.572	-0.663	0.579	-0.458	0.570	-0.366	0.521	0.511	0.490	1.334	0.501	3.034	0.540
Statistics														
-Log L	323.45		355.36		350.90		414.55		463.68		415.01		383.16	
Observations	484		484		484		483		484		484		481	
LR chi2(15)	26.35		44.75		114.27		57.47		94.39		68.34		103.97	
Prob > chi2	0.004		0.000		0.000		0.000		0.000		0.000		0.000	
Pseudo R^2	0.039		0.059		0.140		0.065		0.092		0.076		0.120	
AIC	1.411		1.543		1.524		1.791		1.990		1.789		1.668	
BIC	-2233		-2170		-2179		-2044		-1953		-2050		-2093	

Note: Coef = Coefficients, SE = Standard errors; AIC = Akaike Information Criteria, BIC = Bayesian Information Criteria
Significance levels given as: *** $P < 0.01$, ** $P < 0.05$ and * $P < 0.10$

Gender of the farmer (*Gender*) was significant with respect to preference for FF, print media and *Baraza*; farmer's age (*Age*) with respect to print alone; primary education (*Prieduc*) with respect to FD and radio; secondary education (*Seceduc*) with respect to print and radio; post secondary education (*Pseceduc*) with respect to print, radio and *Baraza*; land size (*Landsiz*) with respect to FT; PPT adoption (*Pptadopt*) with respect to FF; group membership (*Grpmember*) with respect to FFS and FF; and distance to the tarmac road (*Distarmac*) was significant with respect to preference for FT, FFS and radio. The significance of dummies representing the regional effects varied across all the pathways.

Since it was difficult to directly interpret the ordered probit coefficients, Marginal effects (ME) were calculated and are reported in Table 3.4 and Table 3.5. The marginal effects are partial derivatives which represent the probabilities of farmers ranking the pathways as "somewhat preferred" and "most preferred" as opposed to "not preferred". They measure the change in one of the regressors while holding the other regressors constant. The predicted marginal effects assist in understanding the relationship between the dependent and independent variables. The signs of the parameter estimates and their significance indicate the direction of the relationship.

The results show that gender was significant with respect to farmers' preference for FF, print and *Baraza* pathways. For print material, the marginal effect was positive (ME = 0.064) implying that male farmers preferred information received from print materials compared to their female counterparts. This scenario would be expected especially in a developing country like Kenya, where men are likely to be found reading printed materials such as newspaper articles and magazines. On the other hand, female farmers tend to engage in many farming activities which eventually render them unable to engage in reading activities. This implies that any effort to use printed materials for technology dissemination should target the male respondents as opposed to female respondents. The marginal effects for gender was however negative for FF and *Baraza,* implying that male farmers put less emphasis on FF (ME = 0.061 for somewhat preferred and ME = -0.091 for most preferred) and *Baraza* (ME = 0.063 for somewhat preferred and ME = 0.022 most preferred).

Table 3.4: Marginal effects and standard errors for "somewhat preferred" preference rank.

Variable	Pathways													
	FD		FT		FFS		FF		Print		Radio		*Baraza*	
	ME	SE	ME	SE	ME	SE	ME	SE	ME	SE	ME	SE	ME	SE
Gender	-0.015	0.036	0.037	0.027	0.014	0.027	0.061**	0.030	0.001	0.005	0.005	0.005	0.063**	0.034
Age	0.000	0.002	-0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.002
Prieduc	0.170**	0.077	-0.016	0.055	0.033	0.057	-0.032	0.063	0.001	0.004	0.021	0.016	-0.009	0.072
Seceduc	0.094	0.087	-0.029	0.059	0.012	0.061	0.016	0.067	-0.010	0.016	0.003	0.012	-0.089	0.079
Pseceduc	0.071	0.111	-0.031	0.076	0.049	0.073	0.035	0.075	-0.094	0.074	-0.066	0.071	-0.172*	0.102
Tenure	0.058	0.096	0.022	0.082	0.028	0.085	0.050	0.107	0.001	0.009	0.011	0.035	0.022	0.106
Landsiz	-0.006	0.006	0.007**	0.004	0.004	0.004	0.000	0.004	0.000	0.000	0.000	0.001	-0.006	0.005
Pptadopt	-0.022	0.049	0.001	0.035	0.006	0.036	0.091**	0.049	0.000	0.001	0.007	0.012	-0.014	0.047
Inc_lev2	-0.033	0.039	-0.022	0.030	0.037	0.031	0.000	0.001	0.032	0.034	-0.001	0.005	0.030	0.038
Inc_lev3	-0.040	0.054	-0.047	0.040	0.028	0.043	-0.003	0.008	0.034	0.044	-0.016	0.019	0.140	0.036
Grpmember	-0.037	0.055	0.044	0.040	-0.068**	0.036	-0.062*	0.037	0.002	0.007	0.014	0.021	-0.034	0.050
Distarmac	-0.005	0.003	0.005**	0.002	-0.011***	0.003	0.001	0.003	0.000	0.000	0.002	0.001	0.016***	0.003
Busia	0.111**	0.050	-0.105***	0.037	-0.014	0.040	-0.199***	0.050	-0.050**	0.026	0.000	0.010	0.196	0.034
Bungoma	0.066	0.055	0.082**	0.037	0.011	0.042	0.047	0.041	-0.021	0.019	-0.010	0.014	0.099	0.048
Kisii	-0.072	0.050	-0.004	0.039	0.206***	0.027	-0.061	0.047	-0.001	0.003	-0.026	0.024	0.139	0.042

Significance levels given as: *** $P < 0.01$, ** $P < 0.05$ and * $P < 0.10$

Table 3.5: Marginal effects and standard errors for "most preferred" preference rank

Variable	Pathways													
	FD		FT		FFS		FF		Print		Radio		*Baraza*	
	ME	SE	ME	SE	ME	SE	ME	SE	ME	SE	ME	SE	ME	SE
Gender	0.018	0.042	-0.059	0.043	-0.022	0.044	-0.091**	0.045	0.064**	0.034	0.035	0.027	0.022*	0.013
Age	0.000	0.002	0.002	0.002	0.000	0.002	-0.001	0.002	-0.004***	0.002	0.000	0.001	0.000	0.001
Prieduc	-0.205**	0.093	0.025	0.088	-0.053	0.091	0.047	0.094	0.046	0.069	0.121**	0.054	-0.003	0.025
Seceduc	-0.115	0.108	0.046	0.092	-0.019	0.099	-0.023	0.100	0.147**	0.080	0.104	0.065	-0.028	0.023
Pseceduc	-0.088	0.142	0.047	0.113	-0.084	0.134	-0.054	0.123	0.272**	0.122	0.203*	0.113	-0.038**	0.015
Tenure	-0.068	0.110	-0.035	0.124	-0.044	0.128	-0.070	0.142	0.014	0.094	-0.085	0.099	0.007	0.031
Landsiz	0.007	0.007	-0.012**	0.006	-0.007	0.006	0.000	0.007	0.003	0.005	-0.002	0.004	-0.002	0.002
Pptadopt	0.026	0.059	-0.002	0.056	-0.010	0.057	-0.125**	0.062	-0.004	0.045	0.026	0.033	-0.005	0.017
Inc_lev2	0.040	0.047	0.034	0.047	-0.060	0.049	0.009	0.037	-0.047	0.050	-0.004	0.029	0.011	0.014
Inc_lev3	0.047	0.063	0.073	0.059	-0.047	0.073	-0.037	0.049	-0.051	0.070	-0.049	0.035	0.083	0.034
Grpmember	0.045	0.068	-0.068	0.058	0.117**	0.067	0.099	0.064	0.029	0.048	-0.111**	0.052	-0.013	0.021
Distarmac	0.006	0.004	-0.008**	0.004	0.018***	0.005	-0.002	0.004	-0.001	0.003	0.011***	0.003	0.005**	0.001
Busia	-0.138**	0.064	0.158***	0.052	0.023	0.063	0.267***	0.061	-0.172***	0.035	0.076*	0.043	0.118	0.035
Bungoma	-0.080	0.068	-0.139**	0.066	-0.018	0.068	-0.072	0.065	0.163***	0.058	-0.040	0.036	0.042	0.025
Kisii	0.084	0.058	0.006	0.061	-0.471***	0.061	0.087	0.065	-0.014	0.047	0.175***	0.050	0.066	0.029

Significance levels given as: *** $P < 0.01$, ** $P < 0.05$ and * $P < 0.10$

Farmer's age had a negative influence on his/her preference for print materials (ME = -0.004 for most preferred rank), while it had no significant influence on the other dissemination pathways. This can possibly be attributed to low literacy levels among older farmers, which would make them prefer other sources of information other than print. On the other hand, older farmers are considered to have enough expertise through their own farming experience compared to the young ones and therefore more likely to adopt new farming methods without consulting external information sources. These findings are contrary to previous studies which found age to strongly influence farmers' attitudes towards preferences for various information sources (Ford and Babb, 1989; Schtinkey *et al.,* 1992). However, the result agrees well with findings by Roderick *et al.* (2008) who reported a decreasing preference for information source with advance in age. Similarly, Ngathou *et al.* (2005) observed that older farmers placed less emphasis on any external information compared to young farmers, while Gloy *et al.* (2000) reported a significant preference for technical specialists as an information source by young farmers compared to the old ones. Other adoption studies have found age to be irrelevant in the preference ranking for farmer information sources (Pompelli *et al.,* 1997). These results indicate that use of printed materials as a dissemination strategy would bear fruits if the young farmers are targeted.

Level of education was significant for FD, print, radio and *Baraza*, but was insignificant in all the other pathways. The results indicate that more educated farmers preferred print materials and radio compared to FD and *Baraza*. The probability of farmer with primary education ranking for FD as somewhat preferred was higher (ME = 0.17) than for ranking it as most preferred (ME = -0.205). However, farmers with secondary and post-secondary education preferred print materials and radio to *Baraza*. This would be so partly because print materials contain more technical information that would require at least a farmer to have some formal education in order to be able to discern the contents (Gloy *et al.,* 2000; Ngathou *et al.,* 2005). It has also been argued that some farmers with high levels of education tend to rely more on outside sources of information other than on their own farming experience (Ngathou *et al.,* 2005). This is because, such farmers tend to be involved in more formal employment and utilize hired labour for their farming activities. Such farmers would therefore tend to rely more on print as an information source which they can read at their own convenient time. Furthermore, educated farmers are more flexible in acquisition of information sources and would often consult depending on the prevailing circumstances to meet their information needs. In such cases they would be more associated with more sophisticated sources such as print than would be their less educated counterparts. These results are consistent with what has been reported in literature (e.g. Pompelli *et al.*, 1997).

Land size was significant but with an inverse relationship to FT, but insignificant in all other pathways. The negative marginal effects (-0.012) for the most preferred rank indicates that personal information sources such as farmer teachers are less popular with large scale farmers. This suggest that intervention strategies targeting the use of FT as a dissemination pathway should actually aim at the farmers with small pieces of land. In our study, the use of farmer teacher approach was an initiative of ICIPE with an aim of taking advantage of them (FTs) being part of the social network and therefore able to closely relate with the fellow farmer (Amudavi *et al.*, 2009). This finding corroborate that of Gloy *et al.* (2000) who reported decreasing preference for personal information sources with increase in farm size. However, Ford and Babb (1989) and Schnitkey *et al.* (1992) reported a positive association between farm size and personal information sources arguing that farmers with large farms had the capacity to mobilize resources to benefit from information provided by private extension providers and therefore more likely to prefer personal information. This kind of arrangement is seldom applied in the developing countries due to infrastructural and other economic factors that are prohibitive to use of private extension agents and subsequently personal information (Muyanga and Jayne, 2006).

The technology use variable (*Pptadopt*) had a significant negative influence on FF but was not significant for the other pathways (Table 3.5) implying that adopters put less emphasis on fellow farmers as a dissemination pathway as compared to the non-adopters. This would be expected because PPT is a relatively complex technology and farmers consult other farmers only for simple messages but as the message becomes complex, they will most likely seek information on its implementation from more technical sources. Similar observations were made by Gloy *et al.* (2000) in a study on sources of information for commercial farms.

Membership of group (*Grpmember*) had a significant positive influence on both FFS and FF pathways. Farmers who were members of organized farming groups ranked FFS more favourably compared to those who were not in any organised group (ME = 0.117 for most preferred and ME -0.068 for somewhat preferred, Table 3.4 and Table 3.5). This is probably because farmers who belong to organized groups are likely to benefit from the established social capital that is likely to enhance information and knowledge sharing. It follows, therefore, that such farmers would prefer to receive information from such pathways which engage interaction with colleagues. Furthermore, FFS are organised farmer groups where farmers come together to learn about new technologies in groups. Moreover, while in a group, farmers are more likely to learn from each other, which would explain the positive preference for FF as a dissemination pathway. The results suggest a need to encourage formation of farmers groups so that an intervention targeting the use of FFS as a dissemination pathway can be effective. Similar results are also observed in the FF pathway whereby "somewhat preferred" rank decreased by 6.2% for farmers who belonged to organised groups as opposed to those who were not in such groups (Table 3.4).

Distance to tarmac road (*Distarmac*) is often related to accessibility to information and other services. The coefficient for this variable was significant in FT, FFS, radio and *Baraza* pathways but not significant for the rest (see Table 3.4 and Table 3.5). This implies that poor proximity to the main tarmac resulted in farmers preferring FFS and radio as compared to FT and *Baraza*. This is possible because, if an FFS is formed within a village, regardless of how far it is from a tarmac road, farmers are more likely to learn about the technology without necessarily travelling for long distances to acquire information. This also applies to use of radio where the farmer can receive information at his/her convenience regardless of proximity to good road network. Use of FFS could be considered in technology dissemination in areas where there is poor road network as was in some cases in our study area. This is so because once a facilitator has been trained farmers can conveniently learn about new technologies within their own village while at the same time accruing benefits from the wealth of social capital. The less emphasis for FT in farms which are far from the tarmac road can possibly be as a result of poor accessibility to these FTs.

Regional dummies representing study districts indicate variations in preferences for the seven pathways across the four districts. For example, farmers in Busia preferred FT (ME = 0.158) and FF (ME = 0.267) while Bungoma farmers put more emphasis on print material (ME = 0.163) all compared to Homabay which was the reference district. This variation reflects the heterogeneous nature of the farmers in the four districts as well other differences in the physical structure of the four districts.

3.4. Conclusion

The role of information pathways in dissemination and up-scaling of promising intervention technologies and strategies has been of interest in the recent past. This study examined farmers' preferences for some of these dissemination pathways and how various factors influenced farmers' choices for the information sources. In general, this study has demonstrated that factors affecting farmers' preferences for different dissemination pathways are varied among the different pathways and that the significance of farm and farmer characteristics in explaining preferences depends on the information source.

Although the majority of the farmers would prefer the FD as the pathway through which they would effectively receive information about a new agricultural technology, most of the other pathways evaluated had niches within different farmers with selected characteristics. The results show that factors which positively favour preference for a particular information source in a given region might not necessary translate to similar preference by farmers in other regions. Important characteristics of local populations may be masked by generalizing from regional data. The variability that can exist in land characteristics, farmers' perceptions, and socioeconomic conditions within regions implies that broad-based use of dissemination approaches for delivering agricultural information may not be appropriate. This would be particularly critical in order to avoid cases of dis-adoption (or non-retention) of promising intervention strategies on the basis of applying a dissemination pathway that could be unpopular among farmers in certain regions. Therefore, it is important to understand the socio-economic and other demographic factors within a given region prior to using a particular information transfer mechanism. This implies that a 'one-size fits all' approach is clearly not appropriate in technology dissemination. The results suggest that dissemination pathways would be more effective if the target population is segmented and right pathways utilised for the various farmer segments. This is likely to increase the farmers' probability to take up the new technology (in this case the PPT). Further evaluation of the impact of these dissemination pathways on adoption, as well as their cost effectiveness gives more insight in terms of technical efficiencies.

CHAPTER FOUR
THE EFFECTS OF DISSEMINATION PATHWAYS ON THE PROBABILITY AND INTENSITY OF PUSH-PULL TECHNOLOGY ADOPTION

4.1. Introduction

Effective dissemination of research results is of critical importance in maximising adoption of an improved technology and therefore achieving food security. Given the socio-economic diversity of smallholder farmers in sub-Saharan Africa, the challenge is to determine the most effective and economically feasible pathway(s) where resources could be concentrated in order to reach many farmers to maximise adoption and achieve economies of scale. The effectiveness of a dissemination pathway depends not only on the number of farmers that receive information but also on how successful that pathway influences farmers to adopt a given technology. This chapter evaluates the impact of various dissemination pathways on probability and intensity of adoption of PPT in western Kenya while controlling for other socioeconomic and farm factors that may influence technology adoption.

Significant variations of dissemination pathways' impacts on adoption levels have been reported. For example, information from crop consultants was reported to have the largest impact on adoption of precision farming than did mass media sources in the United States (Daberkow and McBride, 2001) while farmer field schools had the greatest impact on adoption of integrated pest management (IPM) than did field days and media in Ecuador and Bangladesh respectively (Mauceri *et al.*, 2005; Ricker-Gilbert *et al.,* 2008). Moreover, access to active information sources such as mass media, agricultural shows, seminars and demonstrations raised the probability of full adoption of organic farming compared to access to passive information sources such as periodic contacts with extension agents in Greece (Genius *et al.*, 2006). These studies, although carried out in the developed countries where conditions and circumstances are different from those in the developing world, clearly show that technology adoption could be influenced, among other factors by the dissemination pathways.

There is still paucity of information on how the various dissemination pathways influence technology adoption. In Kenya for example, Khan *et al.* (2008a) observed that exposure to a variety of extension methods significantly influenced likelihood of PPT adoption in western Kenya. This study however did not assess the magnitudes these extension methods had on adoption. In other cases, studies failed to separate the impacts based on each pathway but chose to use number of extension contacts or knowledge index as a proxy for access to information (For example Dadi *et al.*, 2004; Njuguna *et al.*, 2009). Extension contact alone may not promote adoption if information dissemination pathway being used is ineffective or inappropriate. Furthermore, knowledge may be an important variable, but how farmers receive information from different sources has a more significant effect on adoption than just mere knowledge acquisition (Mauceri *et al.*, 2005). This in essence implies that combining the impact of different dissemination pathways on adoption may sometimes be misleading since the actual impact and magnitude of each pathway might not be discernable. Moreover, there is expected interaction between these sources of information which need to be addressed when quantifying adoption, a fact that most of the previous studies ignored. The results from the study would thus inform on the development of an effective strategy that would effectively enhance the dissemination process.

4.2. Methodology

4.2.1. Sampling procedures and data collection

Details of the study sites have been discussed in section 1.6 of chapter one while sampling procedures are similar to those already presented in section 3.2 of chapter three. Relevant to this chapter, additional information was collected on PPT adoption and non-adoption; and for adopters only, the current land size under the technology was also recorded in order to measure the intensity of PPT use. To evaluate the impact of the seven dissemination pathways, farmers were required to indicate whether they had heard about PPT from any one of these dissemination pathways. The answers to this question were recorded as one (1) if the farmer had heard from any pathway and zero (0) if otherwise. These responses formed the binary variables representing the dissemination pathways that were included in the model. In this case radio was used as the reference pathways. Data on other socio economic, institutional, and farm attributes were also collected and were included in these models in order to account for their potential influence on the adoption process. These included: farmers' age, gender, household size, level of education, land tenure, land size, number of livestock units, annual household income, group membership, credit access and distance to the tarmac road.

4.2.2. Model specification and analysis

To assess the impacts of dissemination pathways on the probability and the intensity of adoption, a two limit tobit model was fitted. Theoretical aspect of this model has been described in section 2.10 of chapter two. Briefly the model is preferable to binary adoption models since it does not only measure the probability of adoption, but also the intensity of adoption (Feder and Umali, 1993). In addition, the dependent variable under consideration was the proportion of land under PPT and lies between 0% and 100%. This model has been applied in previous studies (For example, Fernandez-carnejo *et al.*, 2001; Chukwuji and Ogosi, 2006; Schroeder *et al.*, 2007; Hong *et al.*, 2009) to assess factors that influence the probability and intensity of technology adoption. The stochastic model underlying Tobit is expressed as follows:

$$Y_i^* = \beta_i X_i + \varepsilon_i \tag{4.1}$$

where Y_i^* is the latent, unobserved variable representing percentage land under PPT, X_i is a vector of the explanatory variables influencing the probability and intensity of adoption, β_i are the coefficient estimates and ε_i is the random error term, ε~N(0, σ^2). In reality, we observe Y_i which is censored between 0 and 100 and is described thus:

$$Y_i = \begin{bmatrix} L_{1i} & & Y_i^* \le L_{1i} \\ Y_i^* & \text{if} & L_{1i} < Y_i^* < L_{2i} \\ L_{2i} & & Y_i^* \ge L_{2i} \end{bmatrix} \quad i = 1, 2 \ldots\ldots n \tag{4.2}$$

where L_{1i} and L_{2i} represent the lower and the upper limits of the dependent variable respectively. Estimation of this model using the maximum likelihood estimates yields coefficient which explain the probability and intensity of adoption. These coefficients however, cannot be interpreted directly as magnitudes of the marginal effects of the changes in the explanatory variables on the expected value of the dependent variable, as would in an ordinary regression. In addition, each marginal effect in a tobit equation includes both the influence of the explanatory variable on the probability of adoption as well as the intensity of adoption. As such, McDonald and Moffitt (1980) formula was used to decompose the relevant effects of changes in the explanatory variables on the dependent variable, expressed as follows (Fernandez-carnejo *et al.*, 2001; Chukwuji and Ogosi, 2006):

$$E(Y) = F(z)E(Y^*) = X\beta F(z) + \sigma f(z) \tag{4.3}$$

$$E(Y^*) = X\beta + \sigma f(z) / F(z) \tag{4.4}$$

E(Y) is the expected intensity of PPT adoption or the level of adoption expected by new adopters of the technology, *E(Y*)* is the expected value of the level of adoption by those who are already using the technology, *F(z)* is the normal cumulative distribution function which predicts the probability of adoption of a technology given the mean value of the explanatory variable and also the percentage chance of the technology being used by new adopters, *f(z)*, is the normal density function and σ is the standard deviation of the error term. The marginal effect for the independent variable on *E(Y)* is further obtained by getting its derivative of equation 4.4 as applied in other studies (for example, Chukwuji and Ogosi, 2006; Schroeder *et al.*, 2007; Hong *et al.*, 2009):

$$\frac{\partial E(Y)}{\partial X_i} = F(z)\frac{\partial E(Y^*)}{\partial X_i} + E(Y^*)\frac{\partial F(z)}{\partial X_i} \quad (4.5)$$

where $\partial E(Y^*)/\partial X_i$ is the change in the expected value above the censoring limit (intensity of adopters) and $\partial F(z)/\partial X_i$ is the possibility of change being above the limit (probability of adoption). The following empirical model was estimated:

$$PPTINTEN = \beta_0 + \beta_1 Gender + \beta_2 Age + \beta_3 Prieduc + \beta_4 Seceduc + \beta_5 Pseceduc + \beta_6 Hhsize + \beta_7 Tenure + \beta_8 Radio + \beta_9 FFS + \beta_{10} FD + \beta_{11} FT + \beta_{12} Print + \beta_{13} FF + \beta_{14} FT^*FD + \beta_{15} FS^*FD + \beta_{16} Landsiz + \beta_{17} TLU + \beta_{18} Inc\_lev2 + \beta_{19} Inc\_lev3 + \beta_{20} Credit + \beta_{21} Orgmember + \beta_{22} Distarmac + \beta_{23} Kisii + \beta_{24} Busia + \beta_{25} Bungoma + \varepsilon \quad (4.6)$$

The description and the expected sign of these variables are presented in Table 2.1 in chapter two. The multicolinearity of the variables used in the model was tested using VIF as shown in equation 3.8 (chapter 3). From this test, a variable on the number of pathways used by each respondent was dropped since it had a VIF greater than 10 which signifies the existence of multicolinearity (Maddala, 1993). All the other variables in the model had a VIF less than 10 which satisfy the rule of the thumb (see appendix 6).

4.3. Results and Discussion

4.3.1. Information pathways used by push-pull farmers

The results on the descriptive analysis of the key variables describing farmers' and farm characteristics are presented in Table 3.1 of chapter three. In this chapter the description of the different pathways through which farmers received information about PPT is given in Table 4.1. The results indicate that in the overall sample, the majority (76%) of the respondents had received information from FDs. This refers to any farmer who had at least attended the FD either as a first source of information, or as a subsequent source to gather more information. The study however did not correct information on the number of times a farmer had attended FDs' trainings. The high percentage of farmers receiving information from FD reflects the appropriateness of this pathway to spread the information fast and to a large group of farmers compared to other pathways. FFs were second in spreading the information, indicating that there is a lot of informal diffusion taking place amongst the farmers. *Baraza* was the least in spreading the information (28% overall). Using χ^2 tests, the results indicate that the differences were statistically significant across the different pathways in the four study regions.

Table 4.1: Percentage of farmers who received information from various pathways

Dissemination pathways	Respondents districts					
	Sample N = 491	Homabay N = 122	Kisii N = 121	Busia N = 120	Bungoma N = 128	$\chi 2$
FD	76	68	80	73	81	7.7^{**}
FF	59	63	55	68	51	9.0^{**}
FFS	57	54	32	64	77	53.21^{**}
Radio	57	39	53	83	55	59.95^{**}
Print	51	48	52	40	63	13.9^{**}
FT	44	42	48	52	36	7.22^{*}
Baraza	28	9	33	26	45	40.6^{***}

Significance levels given as: *** $P< 0.01$, $^{**}P < 0.05$ and * $P < 0.10$

4.3.2. Effects of dissemination pathways on level and intensity of PPT adoption

Table 4.2 presents the coefficients, marginal effects (MEs) and the corresponding standard errors (SE) for the factors influencing probability and intensity of PPT adoption. The model was significant at $P < 0.01$ with 25 degrees of freedom, meaning the model was fit in explaining the variation in the dependent variable. This implies that, given the null hypothesis, the estimated means are significantly different from zero. The results provide insights into factors influencing the probability and intensity of adoption of PPT. Although the coefficients for the variables cannot be interpreted directly, the positive and negative signs indicate whether the variables had positive or negative influence on adoption. The results indicate that the coefficients of variables representing dissemination pathways were all positive, but only FFS, FT and FD were significant. *Baraza*, print and FF were not statistically significant. Other variables that significantly influenced adoption were land size, distance to tarmac roads and regional dummies although their magnitude and direction varied. All the other factors included in the model were not significant. The computed MEs were decomposed into three[2] variables following McDonald and Moffitt (1980) procedures.

The positive relationship observed for FD, FFS and FT supports the expectations of the study. The MEs indicate that the FDs had the highest impact on both the probability of adoption and intensity of adoption followed by FFS and FT in that order when compared to radio. Participation in FDs is likely to enhance intensity of PPT adoption by 3.8% for the whole sample and 2.7% by adopters. Additionally, the probability of PPT adoption is likely to increase by 26.8% if farmers are trained during FDs. This is perhaps because FDs stimulate the interest of as many farmers as possible and there is a strong likelihood that the majority of these will adopt the technology. The result corroborate those of Amudavi *et al.* (2008) who observed that over 80% of farmers who attended FDs were able to start and subsequently manage PPT without further on-farm demonstrations. Although these observations show a high rate of adoption by farmers trained through FD, it remains indiscernible if these farmers are able to retain the knowledge as well as the technology for longer periods given that FDs are single day activities which can be considered less intensive. The implications for this would be the desire to complement the use of FD with other more intensive pathways which can be used to reinforce the messages. This is more so for FFS whose effect is explained hereafter.

[2] The three variables are: "Unconditional expected value" which indicates the marginal change induced by the independent variable on the dependent variable for all the participants in the sample (adopters and non-adopters); "conditional on being censored" which is the marginal change induced by the independent variable on the dependent variable, given that the dependent variable is positive (adopters); and "Probability uncensored" which represents the marginal effect on the probability of adoption of the technology by new adopters

Table 4.2: Two limit tobit maximum likelihood estimates and marginal effects results

Variables	Coefficients		Marginal effects[1]					
			Unconditional expected value		Conditional on being censored		Probability uncensored	
	Coefficient	SE	ME	SE	ME	SE	ME	SE
Gender	-0.939	0.880	-0.643	0.600	-0.452	0.422	-0.039	0.037
Age	-0.027	0.041	-0.019	0.028	-0.013	0.020	-0.001	0.002
Prieduc	0.312	1.769	0.214	1.215	0.151	0.854	0.013	0.073
Seceduc	2.145	1.886	1.501	1.343	1.058	0.951	0.087	0.075
Pseceduc	0.704	2.347	0.492	1.671	0.347	1.179	0.029	0.093
Hhsize	-0.103	0.135	-0.070	0.093	-0.050	0.065	-0.004	0.006
Tenure	0.326	2.546	0.222	1.717	0.156	1.205	0.014	0.107
Baraza	0.471	0.958	0.326	0.667	0.229	0.469	0.019	0.039
FFS	5.325***	2.159	3.560***	1.395	2.516***	0.998	0.222***	0.089
FT	4.499**	2.034	3.130**	1.426	2.214**	1.020	0.181**	0.080
FD	6.142***	1.700	3.786***	0.921	2.682***	0.670	0.268***	0.075
Print	0.343	0.894	0.236	0.614	0.166	0.431	0.014	0.037
FF	1.857	1.326	1.263	0.892	0.888	0.628	0.077	0.056
*FT*FD*	-1.624	2.102	-1.101	1.406	-0.774	0.988	-0.068	0.089
*FS*FD*	-3.164	2.046	-2.158	1.382	-1.520	0.978	-0.131	0.084
Landsiz	-0.542***	0.129	-0.372***	0.089	-0.262***	0.063	-0.022***	0.005
TLU	0.096	0.232	0.066	0.160	0.047	0.112	0.004	0.010
Inc_lev2	-1.520	1.046	-1.030	0.699	-0.723	0.491	-0.064	0.044
Inc_lev3	-0.722	1.185	-0.493	0.803	-0.346	0.564	-0.030	0.050
Grpmember	-1.036	1.315	-0.728	0.945	-0.513	0.668	-0.042	0.052
Credit	-0.452	0.912	-0.310	0.624	-0.218	0.438	-0.019	0.038
Distarmac	-0.182**	0.085	-0.125**	0.059	-0.088**	0.041	-0.008**	0.004
Kisii	3.258***	1.387	2.344**	1.040	1.661**	0.746	0.127***	0.051
Busia	5.509***	1.282	4.073***	1.008	2.917***	0.743	0.205***	0.042
Bungoma	2.564*	1.381	1.824*	1.015	1.289*	0.723	0.102**	0.053
Log likelihood	1516.420							
LRchi^2(25)	100.13							
Prob > chi^2	0.000							
Pseudo R^2	0.032							

Note: N = 487, [1]See footnote 2 for description of the three components of marginal effects, SE = Standard errors, ME = Marginal effects
Significance levels given as: *** $P < 0.01$, ** $P < 0.05$ and * $P < 0.10$

FFS are more intensive pathways whose implementation process is slow and lengthy and this is likely to limit farmers' participation. This perhaps explains the lesser effect of FFS on adoption compared to the FDs. However, the fact that FFS ranked second in this study demonstrates the strength of FFS in influencing adoption. This is so despite the doubts raised regarding the expected diffusion effects of knowledge from trained farmers to non-participants, which are essential for achieving large-scale impact of FFS (Rola *et al.*, 2002; Feder *et al.*, 2004). The results show that the expected intensity adoption by the sample was 3.6%, 2.5% for adopters, and 22.2% increase in probability if farmers were trained through the FFS (Table 4.2). Given that the typical strategy is normally to introduce one FFS per village, the proportion of trained farmers in a given area would therefore be small. Thus, FFS can be considered as an alternative pathway for spreading the information which can be used to reinforce the messages from FD. The importance of FFS has been emphasized in several other studies. For example Njuguna *et al.* (2009) acknowledged that farmers' participation in FFS offered a good avenue for interactive learning and knowledge accumulation. Similarly FFS has been strongly recommended by over 50% of the respondents as an alternative dissemination pathway to FD probably to emphasize the messages (Amudavi *et al.*, 2008). In related studies, Mauceri *et al.* (2005) and Ricker-Gilbert *et al.* (2008) observed that FFS-participation had the strongest impact on adoption of Integrated Pest Management (IPM) than FD and other media sources.

Further results show that farmer training through FT would lead to 3.1% increase in expected intensity of PPT adoption of the overall sample, 2.2% increase in acreage under PPT for adopters and 18.1% increase in the probability of adoption ranking third in the current analysis (Table 4.2). This is probably due to the importance of FT as a farmer led extension method which has lately been considered useful in technology adoption. However, Amudavi *et al.* (2009) acknowledge that the use of farmer led extension methods such as FT have not reached the optimal levels yet and this has been attributed to limited facilitation and lack of extension training to carry out the dissemination process. Nevertheless, the use of FT is critical pathway given that it utilises farmers (especially the innovators) in the community who are likely to positively influence other farmers to take up a new innovation. Like FFS, the use of FT as an alternative pathway to FD can help in strengthening the messages.

Contrary to the expectations of this study, the multiplicative interaction variables included in the model were not significant. The plausible explanation for this would be that these dissemination pathways are not mutually reinforcing (or are not complimentary) in their adoption intensity impacts. This observation suggests that use of multiple pathways does not necessarily lead to higher impact on adoption, but would otherwise imply a waste of resources. Compared to the impact of an individual pathway on adoption, the marginal effects for the interaction variable indicate that, a single pathway had much more impact on adoption than the conglomerate of different pathways. The findings are fairly consistent with those of Mauceri *et al.* (2005) who observed that the combined effects of the information sources had no significant influence on adoption of IPM; instead how farmers received knowledge through the different information sources had the most significant effect on adoption.

4.3.3. Effects of other selected variables on the level and intensity of PPT adoption

None of the farmers' characteristics was found to have significant influence on the intensity of PPT adoption. This observation is attributable to inclusion of more variables representing information sources which tend to overshadow the impact of some farmer characteristics. This implies that while farmer characteristics may significantly influence adoption, from a wider perspective, access to information, especially through specific means, has much more significant impact on adoption than any household factor. Similar observations have been made elsewhere. For example, in a study on adoption of IPM in Ecuador, Mauceri *et al.* (2005) established that education and health factors affected the degree of adoption but when the variables representing the source of information were added, education and health effects became insignificant. Furthermore, a study on factors determining the intensity of use of an adopted hybrid maize variety in Zambia concluded that age and education were only significant at the first stage of farmers' decision to adopt, but after adoption these variables were of no influence on maize acreage under a given variety (Langyintuo and Mungoma, 2008). This finding is relevant in guiding extension practitioners on how to improve technology promotion.

An inverse relationship was observed between farm size and the probability and intensity of adoption of PPT (ME of -0.372 for the overall sample, -0.262 for adopters and -0.022 on probability of adoption, Table 4.2). This implies that the expected intensity of new adopters as well as the current adopters was less with the increase in land size. This is fairly consistent with the study expectations where farmers with large pieces of land are said to be under less pressure for alternative ways to improve their income via new technologies, while small farmers adopt labour intensive technologies as they use relatively more family labour, possibly due to its low opportunity cost. This observation is in fact desirable, especially for Nyanza and Western provinces which comprise mainly smallholder farmers (Mean land sizes = 3.9 acres as can be seen from Table 3.1 in chapter 3). In addition, this group of farmers is more vulnerable to the *Striga* and stemborers attack resulting in major economic losses, thus are more likely to respond to intensified adoption of PPT. The recommended conventional methods for *Striga* and stemborers such as crop rotation and use of chemicals have not effectively controlled the two vices despite some of them being prohibitive and economically unviable to these resource poor farmers (Khan *et al.*, 2001). Compared to these conventional control methods, PPT is relatively affordable and therefore, with the majority of smallholder farmers opting to adopt the technology as depicted by the regression results, a positive trend is emerging to addressing these major cereal production constraints. In other separate studies Fernandez-carnejo *et al.* (2001) observed a positive relationship between farm size and precision farming, while McBride and Derbakow (2003) observed that increasing farm size increased the probability of adoption of precision farming but at a decreasing rate over time. This implies that the relationship between farm size and adoption is technology specific and probably depends on the characteristics of each technology.

As expected, an inverse relationship was observed for distance to a major access road (tarmac road) and adoption measures. The marginal effects indicate that a unit increase in distance to the tarmac road reduced the proportion of land under PPT by 0.126% for the overall sample and 0.088% for the adopters. It equally decreased the probability of PPT adoption by 0.8%. This can partly be associated with increased transaction costs which are a disincentive to technology adoption. Alternatively, the inverse relationship between distance to the access road and technology adoption can be attributed to poor accessibility to information as well as to the inputs and output market which acts as a barrier to adoption. Inaccessibility to information can greatly affect the intensity of adoption, given that it has already been shown that information sources play a bigger role in influencing adoption. The findings corroborate those in chapter three, whereby farmers living in remote areas were found to have preference for FFS and radio pathways, yet these pathways have less impact on the intensity of adoption. Similar observations were made by Ricker-Gilbert *et al.* (2008) on adoption of IPM in Bangladesh, Chukwuji and Ogosi (2006) on the intensity of fertilizer use by cassava farmers in Nigeria and Langyintuo and Mungoma (2008) on intensity of use of hybrid maize variety in Zambia.

The probability of adopting PPT and the use intensity varied across districts. Busia had the highest impact both on probability of adoption as well as the intensity compared to Homabay which was the reference district (ME = 4.12 for expected intensity, ME = 2.94 for adopters and ME = 0.207 for the probability, Table 4.2), followed by Kisii and Bungoma districts. This is probably due to the heterogeneous nature of resource base across these regions and other location factors such as soil fertility, pest infestation, climate and availability of information sources which are known to influence the profitability of a technology and hence its adoption. For example, climatic conditions in Homabay are rather diverse with the majority of farmers getting their income from small scale sugarcane production, and others on fishing activities, given the proximity of the district to Lake Victoria. In addition, the district is one of the poorest in Nyanza province, and among the most poorest in the country (GoK, 1997a). This probably explains the low adoption rates by the farmers in the region.

4.4. Conclusion

This chapter assessed the impact of dissemination pathways on the intensity of PPT uptake. The study controlled for the effects of the socioeconomic, institutional, farm and regional factors in order to isolate the effect of dissemination pathways. The results have shown that farmers utilized several dissemination pathways some of which had a relatively higher impact than others on the adoption. Further, it has been shown that dissemination pathways had a major impact on the adoption of PPT more than did socio-economic factors of farmer, farm and community characteristics. While farmers utilized several pathways to get information on PPT, some pathways had relatively more influence on the probability and intensity of adoption than others. For example, FD had the highest impact on adoption suggesting that in an effort to develop an effective dissemination strategy, FD should be considered a potential pathway that could aid in enabling farmers intensify adoption. Perhaps, further analysis on the cost of these dissemination pathways and comparison with the impact on adoption would give an indication on the cost effectiveness of the pathways.

The results also suggest that smallholder farmers need to be targeted when it comes to trainings, since they are likely to more intensely adopt PPT, and also because they are not favoured economically, to use other conventional control methods. The inverse relationship observed between the distance to the tarmac road, and adoption of PPT implies a need for concerted effort to make available information to those farmers in the remote areas in order to enable them to easily adopt the technology. Furthermore, this implies a need to open up rural access roads in order to facilitate farmers' access to major resources, in particular the information which can allow them to make decisions to adopt the technology.

CHAPTER FIVE

DETERMINING THE EFFECTS OF DISSEMINATION PATHWAYS ON THE SPEED OF PUSH-PULL TECHNOLOGY ADOPTION

5.1. Introduction

The potential benefits of PPT like any other promising technology can be realized by farmers if there is timely adoption. This is because increase in production in the early years is likely to have a significant impact on the rate of return on capital investment than in later years (Hazel and Anderson, 1986). For some technologies, timely technology adoption can determine the overall survival of farms since widespread diffusion and adoption is likely not only to lower output prices but also put upward pressure on input prices (Fuglie and Kascak, 2001; Carletto *et al.*, 2007). In that case, only those farmers who adopt the technology early are likely to enjoy the full benefits.

Several studies have evaluated the factors influencing timely adoption of introduced new/improved technologies (Fuglie and Kascak, 2001; Burton *et al.*, 2003; Dadi *et al.*, 2004; Abdulai and Huffman, 2005; D'Emden *et al.*, 2006; Carletto *et al.*, 2007). For 'knowledge-based' innovations such as PPT, access to information through effective pathways has been reported to be critical in speeding up the adoption process. It has also been established that information sources rather than subsidies are considered more effective in encouraging fast adoption of a technology. They do so by enhancing farmers' allocative ability and revising their perceptions on profitability (Lohr and Salomonsson, 2000; Genius *et al.,* 2006). This means that spreading information widely alone may not be as effective without the associated incentives embedded in a particular pathway in speeding up the technology adoption.

Often, institutions and organizations use diverse dissemination pathways to promote information about a new innovation to targeted farmers. The multiple use of different pathways may not only be expensive but also sometimes could be ineffective. Besides, the spread of information may be affected by different pathways and this may likely influence the speed of adoption which is crucial for the effectiveness of that technology (Hazel and Anderson, 1986; Corinne, 2002). Understanding how different pathways affect the speed of uptake is therefore important in order to design and select appropriate dissemination strategy for scaling up.

In this study, various dissemination pathways have been used in scaling of the technology in control of stemborers and the *Striga* weeds in maize growing areas (Khan *et al.*, 2008a; Amudavi *et al.*, 2008, 2009). However, it is not clear from these studies which pathway among those being used has the greatest effect on the speed of uptake of the PPT. Besides, there is paucity of literature in general and on PPT in particular on how different dissemination pathways influence the speed of technology uptake. There is a strong need therefore for evaluation of the effectiveness of the different pathways in order to identify the most promising information sources that would enhance faster technology adoption. This chapter therefore evaluated the effects of various dissemination pathways on the speed of dissemination and adoption of PPT in western Kenya. The information generated can be used to draw insights on the relevant pathways to use in order to speed up technology uptake.

5.2. Methodology

5.2.1. Sampling procedures and data collection

Part of the questionnaire was designed to collect additional information on the length of time farmers took from the date they first learnt about PPT to the date they first adopted the technology. This variable was measured as proposed by Burton *et al.* (2003) as the date at which the innovation was first made available or the date at which the respondent started farming, whichever is the latest, till the time the farmer adopted the technology. Since PPT is a relatively new technology, first introduced in western Kenya in 1997, the entry date was chosen as the year the farmer first learnt about the technology (see Figure 5.1).

5.2.2. Model specification and analysis

To model the influence of dissemination pathways on the duration to PPT adoption, a Weibull parametric duration model was fitted. This model builds on the dichotomous choice models by adding the dynamic element of adoption. It has its history in biomedical and statistical engineering and labour economics (Lancaster, 1972) but has recently become more popular in the agricultural economics in explaining the time it takes a farmer to adopt a certain innovation (e.g. Fuglie and Kascak, 2001; Burton *et al.*, 2003; Dadi *et al.*, 2004; Abdulai and Huffman, 2005; D'Emden *et al.*, 2006; Carletto *et al.*, 2007). The duration to adoption was defined as the time the farmer learnt about the technology (PPT) to the time adoption took place. In the sample analyzed, different farmers had different time origins as well as the time of event (adoption). The length of the duration is represented by a random variable denoted by T which is assumed to be a continuous and a large population of farmers have their origin of the duration at $T = 0$. Assuming that the population is homogeneous then every farmer's duration is a realization of a random variable from the same probability distribution.

Data on PPT adoption history were recorded as a binary sequence where 0 denotes non-adoption and 1 denotes the adoption as used by Beck *et al*., (1998). Thus, if a farmer is observed for 6 years and technology adoption occurs in the last year, then the binary sequence would be 5 zeroes followed by a one. For those farmers who had not adopted PPT at the time of data collection, their duration was right censored indicating that for these farmers, the process is on-going (That is, their observation duration end at the time of survey since it is not known how long they would take till adoption takes place). To put the model into context, the probability that a farmer adopts PPT (if he/she had not adopted before), at time t, is defined by a conditional distribution function $F(t)$ as:

$$F(t) = \Pr(T \leq t) \tag{5.1}$$

T is a non-negative continuous random variable representing the duration of stay in the non-adoption state. The variable t is the actual time a farmer takes from being a non-adopter to being an adopter. However, not all farmers had adopted PPT at the time of survey. In that case, the probability of not adopting at time t is defined as a survival function ($S(t)$) as:

$$S(t) = 1 - F(t) = \Pr\ (\mathrm{T} \geq \mathrm{t}) \tag{5.2}$$

The relationship between explanatory variables to timing of PPT adoption can be explored using several categories of models, but what is important and common to all the models is the specification of a hazard rate $h(t)$ (Madlener and Schmid, 2003). Hazard rate is defined as the instantaneous rate of adoption obtained by taking the average over a short time interval Δt and is formally given as:

$$h(t) = \underset{\Delta t \to 0}{Lim} \frac{\Pr(t \leq T \leq t + \Delta | T \geq t)}{\Delta t} \tag{5.3}$$

where $h(t)$, the hazard rate is the probability that farmer i adopts PPT at time $t + \Delta$, conditional on him/her having not adopted at time t and Δ is short interval of time. Following Madlener and Schmid (2003) and to account for the influence of the different dissemination pathways and other covariates the hazard function was redefined as follows:

$$h(t) = h_0(t)g(x,\beta) \quad (5.4)$$

where $h(t)$ is as already defined, $h_0(t)$ is the baseline hazard (the hazard rate that is solely a function of time and is independent of the covariates, x), β is a vector of parameters to be estimated and $g(\cdot)$ is a non-negative function which acts multiplicatively on the baseline hazard. This specification of the baseline hazard is known as proportional hazard (Burton *et al.*, 2003; Dadi *et al.*, 2004; Abdulai and Huffman, 2005) and is commonly expressed as follows:

$$g(x,\beta) = \exp(\beta' x) \quad (5.5)$$

Equation 5.4 can be estimated using various parametric[3] functional forms. The difference among the functional forms are usually pronounced along the tails of distribution, but if adoption is still at an early stage (as in the case of PPT), the tail may not fully be observed and therefore the Exponential and Weibull distribution are considered more appropriate (Fuglie and Kascak, 2001). However, since the empirical adoption path depicts adoption rate that is not uniform over time, the assumption of a constant hazard rate corresponding to an exponential distribution function would be unreasonable in this case (Heckman and Singer, 1984; Abdulai and Huffman, 2005; D'Emden *et al.*, 2006). Weibull distribution which assumes a baseline hazard that is monotonically increasing or decreasing is more suitable for modelling adoption data and was therefore used in this study. The decision to use the Weibull function was also reached by first estimating the distribution of adoption durations using non-parametric survivor function which gives insights on the baseline hazard besides being useful for descriptive purposes. In this case, the Kaplan Meier (Kaplan and Meier, 1958) functional form was used.

All the explanatory variables used in this model are described in Table 2.1 in chapter 2. Most of the covariates were assumed to be time invariant (do not change over time). However age was included in the model as a time-varying covariate to take care of changing conditions. The study also sought to establish if the interaction between the pathways had a significant impact on the speed of adoption. Thus multiplicative interactive variables were

[3] Standard parametric models include the Exponential, Weibull, log-normal, log-logistic, or gamma models the models are more efficient in the use of information provided by the data since it does not ignore what happens to the covariates in the periods when adoption does not occur. Further, parametric models specify explicitly the distribution of the hazard, and also account for duration dependence i.e. the extent to which risk of occurrence increases or decreases as a function of time

created and fitted in the regression model. For brevity, only two interaction variables were created (Farmer teacher vs field days, FFS vs farmer teacher) which were mainly common at the field. Two models were estimated, first without the interaction and second with the interaction effects. A multicollinearity test was done using VIF and all the variables fitted in the model had a VIF less than 10 (see Appendix 7) which signify inexistence of multicollinearity (Maddala, 1993).

5. 3. Results and Discussion

5.3.1. Awareness, adoption and diffusion of PPT over the years

Figure 5.1 gives a graphical presentation of different dates from when farmers first received information about PPT. The first recorded date of hearing in the sample was 1997. The awareness was rather poor in the initial stages, but rose gradually from 1999 to peak in 2007.

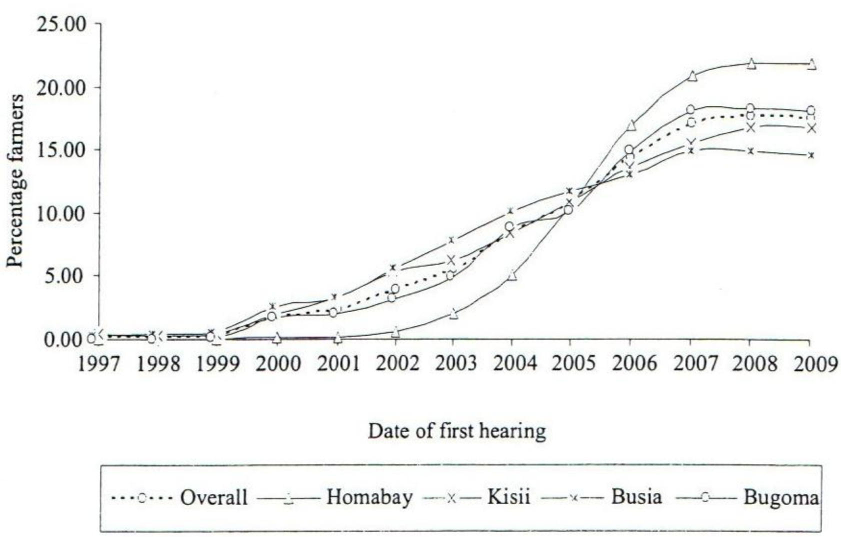

Figure 5.1: Distribution of farmers dates of first hearing about PPT

This trend can be attributed to the sources of information that were used to deliver the information. For example, in Table 5.1 it is shown that at least 27.2% of the farmers received information about PPT for the very first time, from their fellow farmers. From these results, it is evident that most of these farmers got information from secondary sources through information sharing since these fellow farmers must have received the information from another initial source. Other sources of awareness are presented in the table. The primary sources were perhaps the radio which ranked second with 21.5% of respondents citing it as the initial source, FT (cited by 14.9% of the respondents), FD and FFS which were cited by 11.9% and 11.2% of the respondents respectively. These results are very relevant in designing an effective dissemination strategy. Some pathways do not allow quick spread of information or information sharing and should therefore be avoided as an initial source. For example, although the radio ranked second as an initial source of information, this pathway offers simplified messages which may not allow farmers to effectively establish a knowledge intensive technology. Furthermore, use of radio to create awareness would only be effective if all the target recipients own a radio. This perhaps explains the adoption lag between the year 1997, when PPT was first introduced (Figure 5.1) to the year 2000 when the technology was first adopted by the sampled farmers (Figure 5.2). This phase can be linked to information gathering stage where farmers seek information from different sources before adoption. A longer wait would imply that the initial sources of information were not effective and can be avoided if proper pathways are used.

Table 5.1: Percent of farmers identifying first sources of information about PPT in four districts

	Overall	Homabay	Kisii	Busia	Bungoma
Fellow farmers	27.2	46.7	28.9	29.2	5.5
Radio	21.5	0.8	6.6	47.5	30.5
Farmer teachers	14.9	28.3	15.7	7.5	8.6
Field days	11.9	7.5	2.5	4.2	32.0
Farmer Field School	11.2	7.5	20.7	1.7	14.8
ICIPE Extension staff	7.8	4.2	20.7	5.0	1.6
Baraza	3.1	1.7	2.5	3.3	4.7
Non-Governmental Organizations	1.0	2.5	0.0	0.0	1.6
Government Extension staff	0.6	0.8	0.8	0.0	0.8
Women groups	0.4	0.0	0.0	1.7	0.0
Posters	0.4	0.0	1.7	0.0	0.0

The adoption of PPT over time among the selected farmers in the four districts is shown in Figure 5.2. The earliest recorded adoption from the sampled farmers occurred in the year 2000. In all the study districts, adoption was generally low in the first four years but rose steadily from 2004, to peak at 2007. Bungoma district had the highest number of adopters, while Kisii had the lowest. The low trend of adoption in Kisii was attributed to lack of planting materials which was reportedly mentioned by the respondents during the survey.

There was a sharp drop in the adoption trend in the year 2008 in all the districts a scenario which could be attributed to inflation and instability as a result of the post-election violence which affected most sectors including the agricultural sector. The resultant increase in input prices could have contributed to the decline in adoption levels. However, the figure shows that adoption picked up again in 2009 and is still on-going in all the districts.

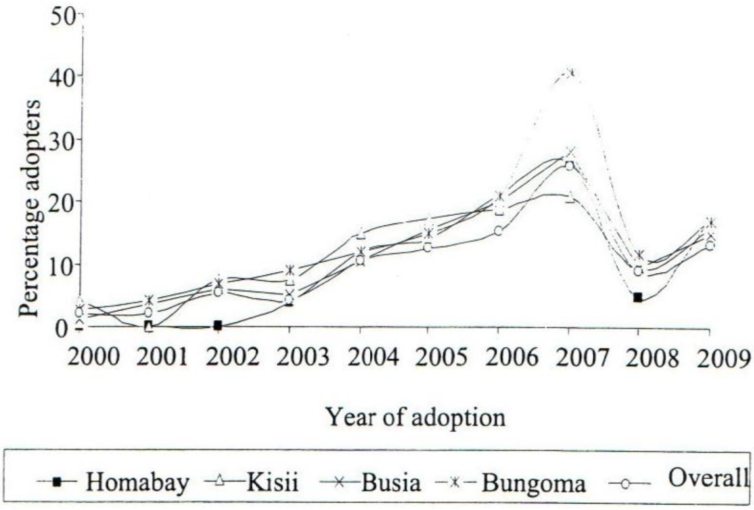

Figure 5.2: Distribution of adoption dates among the overall sampled farmers per district

Summaries of time taken to adoption of PPT are also presented in Table 5.2. Overall, the minimum recorded time to adoption from the time the farmer learnt about PPT was 0.2 years, and a maximum of 10.3 years, with a mean of 2.3 years (n = 490). This observation varied across the four districts and the variation was statistically significant with $F = 9.03$ and $p < 0.01$.

Table 5.2: Duration to adoption of push-pull since introduction in the study districts

			Duration	
	N	Descriptive statistics	Time to adoption from first hearing (Years)	Time to adoption from inception of PPT (Years)
Total	490	Min.	0.2	1.0
		Max.	10.3	12.0
		Mean	2.3	8.4
		Std Dev.	1.8	2.6
Homa bay	120	Min.	1.0	1.0
		Max.	7.0	12.0
		Mean	1.6	8.6
		Std Dev.	1.1	2.6
Kisii	121	Min.	1.0	1.0
		Max.	9.8	12.0
		Mean	2.4	8.2
		Std Dev.	1.9	2.7
Busia	120	Min.	1.0	1.0
		Max.	10.3	12.0
		Mean	2.7	7.9
		Std Dev.	2.2	2.7
Bungoma	129	Min.	0.2	1.0
		Max.	10.2	12.0
		Mean	2.4	9.2
		Std Dev.	1.8	2.4
F-stat			9.03^{***}	6.428^{***}

Significance levels given as: *** *P< 0.01,* ***P < 0.05* and * *P < 0.10*

Figure 5.3 presents the survivor function for the adoption; that is the percentage of farmers who had not adopted at the time of survey. In the graphs, all cases enter at $t = 0$ a point at which the value of the function is 1, since all farms initially are assumed to having not adopted. The value of the function falls sharply in the first four years implying that during these initial years, many farmers were able to take up the technology. This is possible given the exponential nature of adoption in the initial stages of the technology dissemination. Many farmers tend to rush to adopt the technology, others probably just trying and later abandoning it. Between the 5th and 8th year, the survivor function was almost level, depicting a slow adoption phase. The function however levelled between 8th and 9th year, probably confirming the previous observation in Figure 5.2 where adoption fell sharply in 2008, meaning there was little or no new adopters during that phase. However, the function seems to continue to fall implying that the adoption of PPT is still on-going.

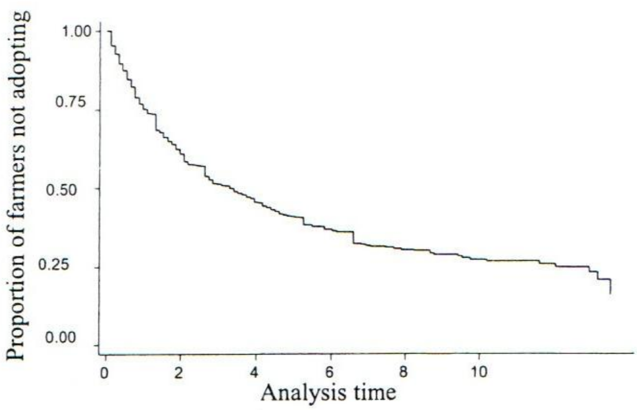

Figure 5.3: Kaplan Meier survivor function

5.3.2. Coefficients and marginal effects results from weibull parametric function

The results for the weilbul hazard function and marginal effects (ME) are presented in Table 5.3. Marginal effects were estimated to measure the difference in time of adoption (in years) between the variable and the reference variable. A negative value of marginal effects (or hazard ratio greater than one) implies that the variable reduces the time until adoption or the variable hastens the adoption process; whereas a positive marginal effect (or hazard ratio less than one) means that the variable is associated with a longer adoption lag or delayed adoption process. The models were significant at $p<0.01$. The significance level of the hazard ratio is with respect to the null hypothesis of these variables having no impact on speed, i.e., the hazard ratio equals one. In a weibull distribution function, p is the shape parameter, capturing the monotonic time dependency of the phenomenon at hand. In this study, p was greater than one (1.306) indicating positive time dependence or that the probability of adoption of PPT increases with the number of years. The parameter "ln_p" measures the rate of change in the adoption process. The results show a positive "ln_p" (0.267) implying that the rate of change over time was positive.

azard ratio, standard errors and marginal effects from the adoption model

Model 1				Model 2			
Hazard ratio	SE	Marginal effects	SE	Hazard ratio	SE	Marginal effects	SE
0.724***	0.040	0.770***	0.133	0.737***	0.041	0.728***	0.135
1.000	0.003	-0.001	0.006	1.000	0.003	-0.001	0.006
1.672***	0.188	-1.222***	0.272	1.662***	0.188	-1.209***	0.273
1.427***	0.173	-0.807***	0.266	1.428***	0.174	-0.809***	0.269
1.262*	0.182	-0.510*	0.293	1.237	0.180	-0.468	0.299
1.015**	0.008	-0.035**	0.018	1.014**	0.008	-0.033**	0.018
1.034	0.051	-0.080	0.115	1.029	0.050	-0.068	0.115
0.998	0.010	0.004	0.023	0.999	0.010	0.002	0.023
0.937	0.058	0.154	0.149	0.941	0.058	0.144	0.149
1.033	0.061	-0.076	0.141	1.293**	0.172	-0.615**	0.324
1.725***	0.097	-1.289***	0.137	1.741***	0.232	-1.312***	0.323
2.685***	0.204	-2.945***	0.296	3.019***	0.366	-3.402***	0.498
0.958	0.053	0.102	0.131	0.975	0.055	0.060	0.133
0.926	0.054	0.180	0.135	0.931	0.055	0.167	0.138
-	-	-	-	0.998	0.146	0.004	0.344
-	-	-	-	0.762**	0.110	0.647**	0.348
0.973***	0.010	0.066***	0.025	0.972***	0.010	0.066***	0.025
1.021	0.067	-0.049	0.154	1.024	0.068	-0.056	0.156
1.197**	0.091	-0.415***	0.172	1.211***	0.093	-0.441***	0.172
0.789***	0.067	0.522***	0.174	0.780***	0.066	0.548***	0.174
1.064	0.062	-0.145	0.135	1.073	0.062	-0.166	0.136
1.003	0.006	-0.006	0.013	1.003	0.006	-0.007	0.013
0.338***	0.031	3.210***	0.341	0.334***	0.031	3.259***	0.347
0.380***	0.030	2.727***	0.274	0.374***	0.030	2.780***	0.278
*0.402****	*0.038*	*2.602****	*0.331*	*0.396****	*0.037*	*2.654****	*0.335*
0.267				0.267			
1.306				1.306			
0.766				0.766			
2764				2764			
610.82				614.380			
-3130.49				-3102.393			
0.000				0.000			

LR chi^2 has 25 df; Significance levels given as: *** $P< 0.01$, ** $P < 0.05$ and * $P < 0.10$

Variables representing education (*prieduc, seceduc* and *pstseceduc*), household size, pathways (*FT, FD*) and the variable for income level three (> Ksh. 40,000) were significant with hazard ratio greater than one implying that these variables accelerated the conditional probability of adoption given their reference variable. On the other hand, gender, TLU, group membership and the three dummy variables representing the districts of study (*Kisii, Busia* and *Bungoma*) were also significant but with hazard ratio less than one implying longer time taken to adopt. All the other variables included in the model were not significant.

5.3.3. Effects of dissemination pathways on the speed of PPT uptake

For all the seven dissemination pathways considered, only two pathways (FD and FT) were found to significantly and positively influence the speed of PPT uptake as shown in model 1 (Table 5.3). All the other pathways did not significantly influence the speed of uptake. The marginal effects indicate that farmers who attended FDs were likely to adopt PPT earlier (ME = -2.95), followed by those who were trained by FT (ME = -1.29), relative to radio which was the reference variable. The impact of FD can be attributed to the usually high attendance of farmers to these open day demonstrations, thus the likelihood of fast widespread of information about a new innovation. It has also been shown that farmers who attended FDs are able to fully establish and manage a PPT plot without further field demonstrations (Amudavi *et al.*, 2008). This implies that intensified use of FD as a dissemination pathway is likely to lead to fast spread of information about a new innovation and subsequently prompt adoption, other factors held constant. This would however require that a thorough cost benefit analysis is done to ensure that the pathway being used is not only effective in the fast spread of information, but also cost effective. Further analysis on cost effectiveness of these pathways will therefore provide some of these insights.

The adoption lag observed for FT can be attributed to the slow process of recruitment and training of farmers through FTs. This is fairly consistent with findings by Amudavi *et al.* (2009) who observed that in a span of three years, one FT was only able to directly train and influence 17 farmers to adopt the technology, and indirectly 34 farmers through their follower farmers. To ensure widespread flow of information, an institution or organization promoting technology uptake would require that more FTs are recruited and appropriately trained in order to achieve a multiplier effect. Moreover, the use of FT has the advantage of being interactive in nature and consequently facilitating sharing and exchange of information and experiences that reduce uncertainty about new innovations, besides contributing to the social capital of rural farming community. Therefore, the use of FT may not be appropriate for use where fast adoption is required, but for long term knowledge accumulation and technology retention, this pathway can be used to reinforce the messages.

The non-significance of FFS in this model can also be attributed to the slow process of establishment and implementation which may lead to slow adoption process. In PPT for example, one complete FFS cycle took two planting seasons, amounting to one year. In addition, the membership of FFS is limited probably due to other factors such as opportunity costs which could limit the farmers from attending the sessions. In this study for example, the survey established that the average membership of FFS is 28 members. For this reason, FFS may also not be relevant dissemination pathway for quick spread of information. However, like FT, FFS can be used as a long term dissemination pathway for reinforcing the messages and to encourage information sharing.

Although the direct effect of FFS on adoption was not significant, its interaction with FD in model 2 was shown to have a significant marginal effect of 0.647 (Table 5.3). The implication for this observation would mean that the effect of FD on adoption subject to the presence of FFS results in a delay in adoption. This would be expected because where both pathways have to be used in training farmers, then more time would be required to achieve adoption. Similarly if farmers have to wait until they have gathered enough information from several sources, it is expected that they would require more time for information gathering prior to making adoption decision. This process is not only expensive to the farmer but also to the institutions and organizations supporting the dissemination process. It further implies that use of ineffective dissemination pathways increases the information search costs. This scenario can be avoided if the institution has the knowledge of the effective pathway which offers quick information that can lead to prompt adoption. This observation further suggests that use of multiple pathways does not necessarily lead to faster adoption, but instead the researcher should concentrate on the single most effective pathway that is speeding up the adoption process. However, it would be interesting to find out the overall effect of using multiple pathways in terms of knowledge accumulation which is likely to influence continued use of a technology. Perhaps further research could ascertain this scenario.

The above findings show that the speed of adoption of a technology is likely to depend on the pathway of information being used. Varied results have been reported elsewhere. For example, Burton *et al.* (2003) observed that information from buyers and agricultural advisory service had a lower impact of adoption of horticultural crops than information from other farmers. Abdulai and Huffman (2005) observed contacts with agricultural extension had more impact on adoption of cross-bred cows in Tanzania, while

D'Emden *et al.* (2006) observed that farmers who attended extension events such as field days were more likely to adopt soil conservation tillage in Australia. This kind of information is relevant in formulating a dissemination strategy that enhances prompt adoption of a technology.

5.3.4. Effects of other variables on the speed of PPT uptake

The positive effect of education supports the human capital theory which states that innovative ability is closely related to education level, farming experience and information accumulation (Rahm and Huffman, 1984). The results indicate that compared to farmers who had no formal education, farmers who had attained primary education were likely to adopt faster (ME = -1.222) followed by those with secondary education (ME = -0.807) and those with post-secondary education (ME = -0.510). This is possibly because education is expected to allow farmers to obtain better information to comprehend and make better decision. However, it is also possible that such an observation could be related to technology characteristics. Some technologies are relatively simple thus do not require a high level of education to discern their use. However, as more complex technologies are introduced education may become more important. These findings corroborate those of Fuglie and Kascak (2001) who established that farmers with high school and college education adopted new technology more rapidly than farmers without a high school diploma. Elsewhere, the impact of education on the speed of adoption was mixed. Burton *et al.* (2003) observed a marginal but insignificant impact of higher education on the hazard to adoption while Dadi *et al.* (2004) and Carletto *et al.* (2007) found insignificant impact of education on technology adoption. The findings imply that for knowledge intensive technologies such as PPT, concerted efforts are needed to avail proper training to farmers who have no formal education.

The negative marginal effects for income level three variable (ME = -0.415) imply that farmers in higher income brackets are able to take up the technology earlier compared to those in the lower income bracket. This would be more so for capital intensive technologies where a farmer is expected to invest heavily before taking up the technology. In such cases, household income increases the possibility of adopting the innovation by mitigating the shortage of capital input, while households with less or no income are likely to be highly risks averse. The hazard ratio for gender was less than one (0.724) and corresponding marginal effects indicate that being a male farmer delayed the conditional probability of adoption of a technology by 0.77 years (Table 5.3). This scenario is common in developing countries like Kenya where women spend more time in farming than their male counterpart. In that case, they (women) are the ones directly affected by production constraints such as stemborers and *Striga* weeds. On the same note, the recommended cultural control measures of *Striga* such as hand weeding and uprooting were found to have serious socio-economic implications against the women who have to spend long hours in the farm uprooting the weed (Berner *et al.*, 1995; Woomer *et al.*, 2004). This probably explains why women are more likely to take up a new innovation faster since they are the ones receiving the direct benefits of the technology. This finding is consistent with that by Burton *et al.* (2003) who observed gender to be a strong predictor of adoption and that being female more than doubled the conditional probability of adoption of organic horticulture in the United Kingdom.

A positive marginal effect was obtained for the variable of group membership (ME = 0.522) which implies that, farmers who belonged to organized groups were likely to take longer time to adopt the technology than those who were not group members. This observation is attributed to exposure of individuals to a wide range of ideas which may either cause farmers to form a favourable or unfavourable attitude toward an innovation. This reflects the importance of non-economic factors in adoption, and the possible attitudinal effects which can also be corrected by proper provision of information. Though marginal, TLU took an unexpected sign (ME = 0.066) implying that farmer with more TLUs were likely to adopt PPT slightly later than those with less TLUs. These results were a bit surprising given that the *desmodium* and Napier used in PPT fields are useful livestock feeds. Finally, the hazard ratio for Kisii, Busia and Bungoma were statistically significant ($p<0.001$), but less than one implying that farmers in Kisii took 3.2 years, in Busia 2.73 years and Bungoma 2.6 years longer to adopt PPT compared to Homabay which was the reference district. This variation represents the effects of regional differences in terms of features such as infrastructure and other physical factors which could as well affect accessibility to information and hence the delay in adoption.

5.4. Conclusion

Timely adoption of PPT by smallholders is a means towards increased food security through improved maize production. This chapter has demonstrated the importance of evaluating the effects of dissemination pathways on technology adoption, in order to inform on those that promote faster technology dissemination and adoption. The findings indicate that the use of FD is probably the quickest way to spread technology information since it is likely to speed up the adoption rate. FTs are also quite relevant although slower than FDs.

Policy insights derived in the context of this study suggest that measures to promote speedy adoption of a technology fall primarily under provision of information. Specifically, the findings indicate that use of FD allows rapid spread of information and that farmers are subsequently able to promptly adopt the technology. This may imply then that in development of a dissemination strategy, FD must be considered if speedy adoption and diffusion of a technology is to be achieved. However, since FDs are only a single day activity, chances are that the knowledge generated is unlikely to lead to long term retention of a technology and therefore other intensive pathways such as FT and FFS should be integrated to reinforce the messages. It is however difficult to make such a conclusion without further analysis of the effects of these pathways on other technologies retention, something future research can ascertain. In addition, further analysis of cost effectiveness of these pathways would yield more policy insights.

CHAPTER SIX

TECHNICAL EFFICIENCIES FOR DIFFERENT PUSH PULL TECHNOLOGY DISSEMINATION PATHWAYS

6.1. Introduction

This chapter focuses on the efficiency with which information about PPT is passed on to farmers. The modern efficiency concept is context dependent and is signified by the ratio of output to inputs and has been a subject of research in a wide range of production activities (for example, Stein, 2001; Cheong and Leckenby, 2006). Its analysis has been linked to the relative difficulty encountered in the performance of production units. In the realm of dissemination of a technology, efficiency can be viewed as a ratio of inputs viewed in terms of the expenditures on each dissemination pathway, to the output viewed as the number of recipients who end up using the technology. Although seen as a challenging task to achieve, nonetheless measuring the efficiency of dissemination pathways is important in order to set targets for resource allocation decisions in light of the dwindling donor support (Reichmann, 2004). Though PPT is now at the stage of expansion in Kenya and beyond, the question of which pathway to put incremental resources for optimal dissemination has not been addressed.

Unfortunately, efforts to evaluate the efficiency of technology dissemination pathways have been very minimal. There are no clear methodological procedures that could be used to comprehensively demystify efficiency of dissemination pathways. Some researchers have used different approaches to compare the efficiency of various dissemination pathways. For example Mauceri *et al.* (2005) used marginal analysis from the ordered probit results and compared this with the cost of each pathway in order to determine the effectiveness of different information pathways for IPM in Ecuador. The study concluded that, Farmer Field Schools (FFS) were relatively more expensive than field days and pamphlets, but they (FFS) had an added advantage of increased sharing of information, retention of knowledge and complete adoption of IPM. Similar observations were made by Ricker-Gilbert *et al.* (2008) in Bangladesh using a cost-benefit analysis. Although these two studies gave insights into the cost effectiveness of dissemination pathways, the methodological approach used were limiting. For example, in the use of cost-benefit, it is improper to compare the costs of disseminations (some of which were incurred by the organization disseminating the technology), and the benefits of the technology (which were accrued by the farmers).

There is need to use an approach that compares the costs incurred by the organization and the intended benefits of the dissemination process from the organization point of view. Such an approach would give the organization in question guidelines as to which pathway is relatively efficient given their objective function. It is even more challenging when one has to rely on secondary data collected by field staff and accounting officers which in most cases is characterised by inconsistencies and irreconcilable inaccuracies. However an attempt made to discern this issue is better than no attempt at all. In this study the DEA was used to assess the technical efficiency of dissemination pathways used in promoting PPT. Use of DEA in this context is relatively new and literature reports in this regard were not identified. The chapter alludes to which dissemination pathway is more efficient in resource use, however due to the nature and limitations in the data available only three dissemination pathways (i.e. FFS, FD and FT) were considered.

6.2. Methodology

6.2.1. Data sources

Secondary data were extracted from available budgetary and expenditure reports filed by PPT project at ICIPE office in Mbita Point. This information was also corroborated with the findings reported in chapter three, four and five of this thesis. The analysis was based on a data set consisting of FT, FFS and FD over a period of two years (2006 to 2008). The main input variables were specified as the operating costs per pathway which included allowances, training materials, transport costs, and other miscellaneous costs. The decision to use costs of the pathways as the input variable was made on the ground that those costs represents the real resources used by the management to upscale the technology. Two outputs considered were the number of farmers reached per pathway and the proportion of farmers trained per pathway that adopted PPT. Using the two outputs, the study estimated two DEA models separately for each output.

6.2.2. Model specification and analysis

There is a shortage of literature on methods for analysing the efficiency of dissemination pathways. Garforth and Usher (1997) acknowledge that given the nature of dissemination inputs and outputs, it is difficult to apply conventional social science research methods to the analysis. In this study, the inputs of dissemination were quantified in terms of the cost (in Kenya shillings) incurred on each dissemination pathway, while the outputs were identified as the number of farmers reached and the proportion of adopters. Since this kind of output falls in the category of those outputs which lack real market price, this study adopts the non-parametric DEA that requires no *a priori* assumption of production function. This gives it an advantage over the econometric approach, and it gives a straight forward approach to calculating the gap between the efficiency of one pathway and that of a best practice. In addition, DEA results are not affected by sample size as long as the number of inputs is not too high in comparison to the sample size (Tanja and Heikki, 1998; Chambers, 1998; Thiam *et al.*, 2001).

In this study, pathways are viewed as production units often referred to as Decision Making Units (DMU) in DEA. The efficiency of the pathways could be evaluated based on different measures, namely technical, allocative and economic efficiency as proposed by Farell (1957). However, given the nature of outputs, this study concentrated on technical efficiency which is defined as the ability to produce maximum outputs from a given bundle of inputs (increasing output without incurring additional costs). Since the objective function of the organization is to maximise outreach and adoption of PPT, the study adopted the output-oriented DEA and further assumed Variable Returns to Scale (VRS) as opposed to Constant Returns to Scale (CRS). VRS permits the calculation of technical efficiency devoid of scale efficiency effects while CRS assumes that the firms are operating at the optimal scale which is not always the case (Coelli, 1996; Baris and Nilgun, 2007).

In formulating the DEA model, the study assumed n-dissemination pathways are being evaluated based on m-inputs and s-outputs. If Y_{rj} is a known level of the r^{th} output of pathway j (r =1,2.....s; j = 1, 2,.......n) and X_{ij} is a known level of i^{th} input to pathway j, (i = 1, 2, ...m), a hypothetical composite pathway was defined using weighted inputs and outputs of the pathway being evaluated. The efficiency of a pathway j was estimated by solving the following DEA model (Charnes *et al.*, 1978):

$$Max_{uv}\, h_0 = \sum_{r=1}^{s} U_r Y_{rj0} \tag{6.1}$$

S.t.:

$$\sum_{i=1}^{m} V_r X_{ij0} = 1 \tag{6.2}$$

$$\sum_{r=1}^{s} U_r Y_{rj} - \sum_{i=1}^{m} V_i X_{ij} \leq 0 \quad j = 1, 2....n \tag{6.3}$$

$$U_{r,} V_i \geq k \quad r = 1, 2...s, \quad i = 1,2.......m \tag{6.4}$$

where k is a small positive constant, U_r is the weight given to output r and V_i is the weight given to input I.

Constraint 1 indicates that the weighted sum of inputs for the particular pathway equals 1 and constraint 2 implies that all the pathways are on or below the frontier; that is the efficiency of all pathways have an upper bound of 1. Weights U_r and V_i are treated as unknown and are obtained in the solution to the Linear Programming problem.

6.3. Results and Discussion

6.3.1. Pathways distribution, variable description and cost analysis

Table 6.1 summarizes the distribution of use of different dissemination pathways in various districts of Western and Nyanza province. In total there were 112 FTs distributed across the various districts where PPT was disseminated. The FTs were first recruited and trained in the year 2002 and their selection was based on their success and experience in implementing PPT on their farms, integrity, and ability to teach other farmers (Pittchar, 2009, personal communication). The number of FDs varied across districts and the study period. There were a total of 40 FDs conducted in 2006, 44 in 2007 and 26 in 2008. These were basically organized by ICIPE field staff in collaboration with the government extension agents and were mainly conducted every beginning of the rainy season. It is worth mentioning here that the records indicated here are only those whose complete data could be obtained. Data on some other FDs were left out due to inconsistencies; therefore this does not reflect the complete number of FDs that were conducted in those years. At the time of this study, FFS were more recent technique for disseminating PPT which started being used in 2007. However, in some districts such as Bungoma, Bondo and Butere, a few FFS existed before introduction of PPT and were being used to disseminate other technologies. These existing FFS were then used to disseminate PPT in 2006. In 2007, there were 93 FFS which increased to 99 in 2008.

Table 6.1: Distribution of FD, FFS and FT in various districts

District	Number of FT			Number of FFS			Number of FD		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Bungoma	7	7	7	3	15	15	1	7	1
Vihiga	9	9	9	-	6	4	2	1	1
Siaya	5	5	5	-	5	5	1	3	2
Trans nzoia	47	47	47	-	-	-	10	10	5
Homabay	9	9	9	2	14	15	1	1	1
Busia	5	5	5	-	8	9	5	2	2
Kisii	7	7	7	-	8	9	1	2	2
Suba	10	10	10	-	9	7	1	3	1
Rachuonyo	8	8	8	-	5	5	4	3	2
Migori	5	5	5	-	3	5	4	3	2
Bondo	-	-	-	2	3	4	1	2	1
Teso	-	-	-	-	4	4	1	2	1
Nyando	-	-	-	-	3	5	5	3	2
Kuria	-	-	-	-	5	7	2	1	2
Butere	-	-	-	1	5	5	1	1	1
Total	112	112	112	8	93	99	40	44	26

Source: Compiled from PPT project record

Table 6.2 and Table 6.3 present the summary statistics of the variables used in the DEA model. There were considerable variations in the values of inputs and outputs variables depending on the pathway being evaluated. The diversity of these pathways is mainly from the nature of implementation. Some pathways such as FT are highly personalized and therefore the coverage of farmers may be limited. The costs incurred in the three pathways from 2006 to 2008 are presented in Table 6.2. The range of operating cost across pathways is large reflecting the differences in the scale and type. These costs included training materials, transport, farmer refreshments (during FDs) and allowances for the facilitators. FTs were also given a bicycle whose cost was discounted for a period of 5 years.

The relatively high cost of FTs in the initial years compared to FD and FFS was due to the initial capital cost of training them which was a once-off input cost (sunk cost). However, their cost declined in the subsequent years and was expected to be zero at some point since they are no longer being paid for the services. The FTs were initially given a motivation allowance of Ksh750 per month for the first two years with the expectation that they would continue training the farmers within the society in the subsequent years. The costs of FD were relatively uniform in the three years (Ksh. 7611, Ksh. 7549 and Ksh. 7529, in 2006, 2007 and 2008 respectively). For the FFS, there was a slight decline from Ksh. 7015 in 2007 to Ksh. 5884 in 2008. The decline was attributed to the fact that most of the FFS were continuing from the previous year, hence the initial costs of establishment was not incurred in 2009. This observation is very relevant in dissemination strategy formulation. The fact that the cost of FD is uniform over time may imply that cumulatively, this pathway may eventually be expensive compared to FFS and FT whose costs are declining over time.

Table 6.2: Major costs per pathway per year

Cost variable	Average costs per pathway per year (Ksh)[2]								
	FD			FFS			FT		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Transport cost	586	834	962	0	1625	1355	1081.25	0	0
Accommodation	0	0	0	0	0	0	2100	0	0
Per-diems	0	0	0	0	0	0	2700	0	0
Training material	398	400	400	0	404	432	100	0	0
Staff allowances	1625	1639	1717	0	1835	2003	0	0	0
FT allowances	0	0	0	0	0	0	9000	9000	0
Bicycle (Discounted)	0	0	0	0	0	0	900	900	900
Farmer refreshment	5002	4676	4450	0	2327	1257	0	0	0
Materials for establishment	0	0	0	0	823	837	0	0	0
Total cost[1]	7611	7549	7529	0	7015	5884	15881	9900	900

Note: [1]Tocal costs = costs incurred per pathway per year; [2]1USD = Ksh 75 at the time of data collection
Source: Authors' calculation

In Table 6.3, the average number of farmers trained and those who adopted PPT following these training is given. The results indicate a wide variation also on the outputs per given pathway. For example, the results show that on average, one FT was able to train 6 farmers per year out of which 5 of them had adopted the technology, which translates to 85% adoption. The FTs were given a target to train at least 10 farmers per year (5 farmers per cropping season). The average attendance of FDs was 105 farmers and of which 43 of them adopted (39.3% adoption), while the FFS had trained an average of 27 farmers out of which 11 adopted (41.4% adoption) (Table 6.3). These results further indicate that it would cost 1 USD to train 1 farmer if FDs were used, 2 USD for FFS and 22 USD if FTs were used. However, the proportion of adoption given the target audience is higher for FT than FFS and FD. This would imply that even though it is relatively cheaper to train farmers using FDs compared to FT and FFS, effectively FT achieved the overall objective of promoting maximum adoption based on the target requirement. In addition, the argument for the use of FT and FFS is that the knowledge obtained would spill over to other farmers through information sharing and therefore improve the cost effectiveness.

Table 6.3: Summary statistics of inputs and outputs used in DEA

Pathway	N	Year	Average number of farmers trained	Average number of adopters	Percentage of adopters	Average total cost (Ksh)[1]	Average cost per farmer trained (Ksh)
FT	112	2006	6(2)	5	87	15881(539)	2826 (658.8)
	112	2007	6(2.8)	5	78	9900(0)	1963(0)
	112	2008	7(3.6)	5	73	900(0)	199 (0)
	112	**Mean[2]**	**6(1)**	**5**	**79.3**	**8894(7541)**	**1663(1339)**
FD	40	2006	111(51)	50	45	7611(2426)	67.6(16.9)
	44	2007	104(63.4)	40	36	7549(2856)	78.9(25)
	26	2008	99(42)	30	37	7429(1963)	81.2(17.4)
	36.7	**Mean**	**105(6)**	**42.7**	**39.3**	**7570(36)**	**76(7)**
FFS	-	2006	-	-	-	-	-
	93	2007	25.4(6.1)	10	41	7015 (3724)	222.9(166)
	99	2008	27.9(6.4)	12	42	5884 (3307)	82(145)
	96	**Mean**	**27(2)**	**11**	**41.5**	**6450(800)**	**152(100)**

Note: [1] 1 USD = Ksh 75 at the time of data collection;
[2] Overall mean for the three years, and figures in parenthesis are standard deviations
Source: Authors' calculations

6.3.2. Technical efficiency scores for the different pathways

Based on the two outputs (number of farmers trained per pathway, and the proportion of adopters), two DEA models were estimated under the VRS assumptions. The assessment yielded the relative efficiency of each unit per pathway. Tables 6.4 and 6.5 present the distribution of the scores with an efficiency spectrum of 0 to 1. In the first scenario; most of the FDs in the year 2006 had an efficiency score of 1, while only a few FT and FFS had the score of 1 implying that FDs were relatively more efficient than FFS and FT when the number of farmers reached per given budget is considered as the output. However, when the proportion of adoption is used, then more FTs were recorded to have a maximum efficiency of 1 compared to FFS and FD, hence more efficient.

Often the most efficient unit within each set being assessed is useful in setting performance targets of the less efficient units. Thanassoulis *et al.* (1987) acknowledge that further analysis should however be done to ascertain why such units are more efficient.

Table 6.4: Distribution of technical efficiency scores based on number of farmers trained as the output

Efficiency score range	Number of FD			Number of FT			Number of FFS		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
1.00	24	6	8	3	1	2	-	3	7
0.9-0.99	9	17	6	0	0	2	-	1	3
0.8-0.899	4	11	3	0	0	7	-	7	5
0.7-0.799	1	2	6	11	2	4	-	12	19
0.6-0.699	2	2	2	7	1	18	-	31	33
0.5-0.599	0	2	1	18	9	17	-	22	23
0.4-0.499	0	4	0	15	18	5	-	12	6
0.3-0.399	0	0	0	47	34	30	-	3	2
0.2-0.299	0	0	0	11	37	19	-	2	1
0.1-0.199	0	0	0	0	6	8	-	0	0
0.0-0.099	0	0	0	0	4	0	-	0	0

Table 6.5: Distribution of technical efficiency scores based on percentage of adopters as the output

Efficiency score range	Number of FD			Number of FT			Number of FFS		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
1.00	2	3	4	11	1	1	-	3	3
0.9-0.99	0	3	1	7	38	12	-	2	2
0.8-0.899	5	5	5	46	19	24	-	5	4
0.7-0.799	4	1	3	16	22	16	-	9	11
0.6-0.699	10	7	2	13	22	16	-	6	10
0.5-0.599	7	6	1	10	8	24	-	10	19
0.4-0.499	3	5	4	5	1	9	-	17	24
0.3-0.399	5	3	1	2	1	8	-	18	13
0.2-0.299	3	3	3	0	0	2	-	15	10
0.1-0.199	1	2	2	2	0	0	-	8	3
0.0-0.099	0	6	0	0	0	0	-	0	0

The mean technical efficiency (TE) for the two scenarios is presented in Figure 6.1 and Figure 6.2. In the first scenario where number of farmers trained was used as an output, FD had the highest TE of almost 90%. This was followed by FFS whose TE was slightly above 60% and FT 40% (Figure 6.1). In the second scenario, where percentage of adoption was used as the output, FT led with an efficiency score of about 70%, followed by FD (58%) and finally FFS (52%). Both scenarios indicate that on average, the pathways are operating below the efficient scale, thus adjusting the scale of operation would probably improve the overall efficiency. This means that there is still a scope for increasing the number of farmers trained for each pathway using the current levels of resources. In the short-run, the use of FD appears to be more efficient than FFS and FT but in the long-run one can conclude that FTs are relatively efficient since the proportion of adoption, which is the ultimate goal of dissemination, is higher in FT than the rest of the pathways.

However, it is worth mentioning that in this analysis only direct costs were included. Other indirect costs that affect the efficiency of a pathway were not included in this analysis due to lack of appropriate data. Such costs include the opportunity costs of facilitators used in organization and implementation of the training programs (e.g. in FD, FFS) which could be used for other productive activities. Failure to include these costs overstates the efficiency of a dissemination pathway. For example, even though the technical efficiencies for FD was relatively high compared to other pathways, the opportunity cost of trainers in FD is likely to be more since the staff from the organizations convening the FDs were involved in the preparation and training. In the case of FFS and FT, the organizations are mainly involved in the initial training but the subsequent stages are operated by the farmers themselves. Inclusion of the opportunity costs of these trainers in the analysis is therefore likely to lower the efficiency of the pathway. Since data used in this chapter was basically secondary data from project records, it was not possible to include such costs. Perhaps further research could be done to bridge this gap.

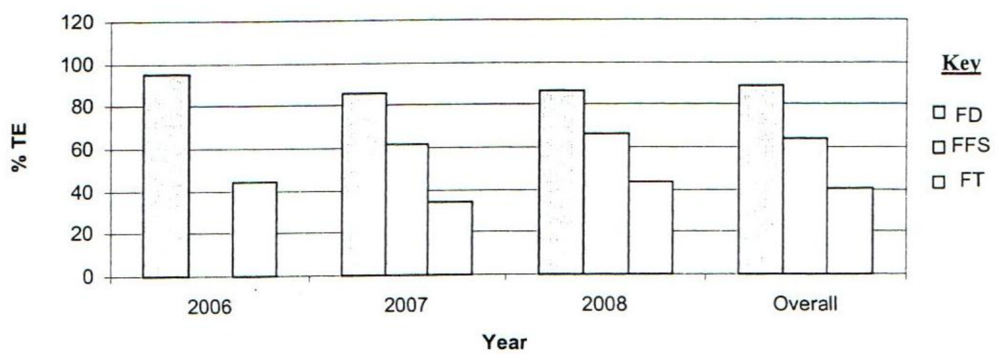

Figure 6.1: Technical efficiency scores based on number of farmers trained

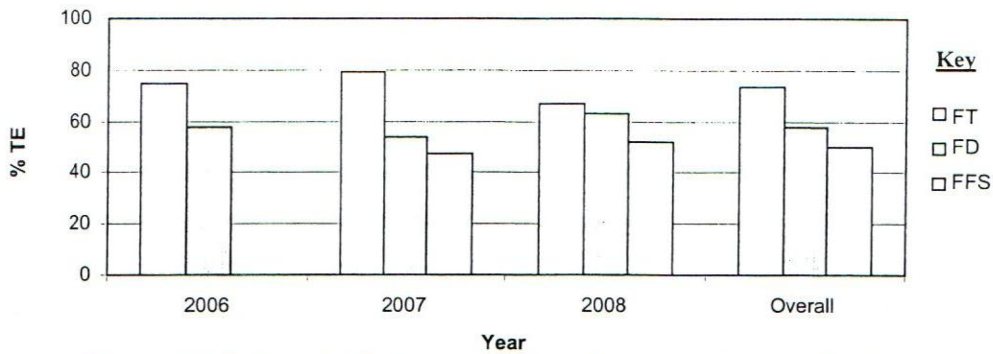

Figure 6.2: Technical efficiency scores based on percentage of adoption

Besides lack of data on indirect costs, the analysis only covered the number of farmers reached per given budget. However, a lot of diffusion naturally occurs within the social system whereby farmers who were reached directly by a particular pathway could share information with other farmers who were not trained. This was not accounted for in the analysis and this could underrate the efficiency of a pathway. When farmers spread information to other farmers, the benefit of a pathway extends beyond those farmers who were trained. During the survey, it was established that 80% of the respondents shared information with an average of 7 farmers, of which 3 farmers adopted. However, it was very difficult to associate this spread of information to a particular pathway bearing in mind that multiple pathways were simultaneously used in the same region. Accounting for such diffusion is rather difficult and would require a complete enumeration of all the stages and the individuals involved in the dissemination process. Garforth and Usher (1997) acknowledge that a single random sampling survey cannot possibly answer this type of complex question. Instead, snowball sampling is required where the researcher begins by identifying a single farmer and uses these responses to identify other farmers who have been reached.

Another relevant factor that influences this analysis is that some farmers often attend several FDs and were also trained through the FFS. These factors make it difficult to do an exact cost analysis due to an overlap of the information received. In addition, implementation of some pathways required capital (fixed costs) whose benefits could only be realized in future once adoption reaches maximum. For example, the costs of training FTs were relatively higher in the initial years but declined significantly in the subsequent years.

However, it is important to recognize that the long-term objective was to take imminent advantage of FTs as part of the society (innovators) who were more likely to influence others farmers in adoption. Equally important in evaluating efficiency is the cost that farmers bear in order to participate in the trainings. This is important since it can determine the willingness of farmers to participate in these trainings or not. Although no fee is directly charged to farmers to participate in the training, some farmers pay cost of transport to the training sites. In addition, the opportunity cost of farmers' time spent in the training sessions can be approximated. Finally, Thanassoulis *et al.* (1987) cautions that the optimal weights used in computing a units' efficiency may incorporate some weights so low as to exclude from consideration the corresponding input and outputs of which the input may be inefficient.

Despite the limitations, these results offer an initial classification of pathways in terms of relative efficiencies. This chapter emphasizes on efficiency of the pathways, under the context of technology dissemination, but interpretation of efficiency alone may not be complete without the effectiveness. Any evaluation of a pathway based on efficiency criteria would be termed improper without including the effectiveness. Drucker (1967) defined efficiency as 'doing things right', and effectiveness as 'doing the right things' and that although efficiency is a well valued concept, without proper attention on effectiveness, efficiency can be meaningless. Therefore, the results in this chapter should not be interpreted as standalone *per se*, but in comparison with the results from chapter three, four and five which has given a detailed analysis of the effectiveness of these pathways in influencing adoption. The observed efficiency scores can be improved by increasing the output (number of farmers reached), holding the cost variable constant. However, one should bear in mind that an increase in efficiency can lower the effectiveness if the goal of the organization is not achieved (adoption). For example, if more farmers are trained using the given budget, the efficiency score will improve, but if only a few farmers adopt, then the effectiveness of the pathway reduces.

The result from this chapter corroborates the findings from the previous chapters. FDs are relatively cheap in the dissemination of push-pull technology and the most preferred pathway by the majority of the farmers. This in essence results in high adoption levels as shown by finding reported in chapter four whereby the expected adoption level if FD is used was 26.8%. This is higher compared to expected adoption level of 22.2% if FFS was used and 18.1% if FT was used. Assuming there is no overlap in terms of which farmers are receiving information, then we can conclude that FD are more efficient compared to the other two. This finding is very relevant because, there are situations whereby the most preferred pathway by farmers may end up, being the most expensive in terms of needed resources. FT appears relatively very expensive compared to the other pathways. However if we take into account the diffusion between farmers, then the cost differential could be reduced significantly. Previously, a study by Amudavi *et al*. (2009) indicated that besides directly influencing 6 farmers per year, FTs were able to influence a total of 34 farmers in a span of three years through their follower farmers.

6.4. Conclusion

This study evaluated the technical efficiency of different dissemination pathways used in up-scaling PPT. Two scenarios were presented, in the first case, the number of farmers reached per budget was used as the DEA output and in the second case, the proportion of adoption given the number of farmers trained per pathway was used as an output. This study found that FDs were relatively a cheaper means of dissemination compared to FFS and FT when the number of farmers trained is used as an output. However, the proportion of adoption of the technology given the number of farmers trained was less for FD than FFS and FT. The study concludes that although the use of FDs appears relatively cheaper at the initial stages, in the long run, this pathway could be expensive since the cost was uniform over the years. On the other hand, the costs of FT and FFS was declining over the years since most of the initial costs incurred were non-recurrent, implying that in the long run, FT and FFS could be relatively cheaper. This would be more so if informal diffusion among the farmers being trained is encouraged.

Another advantage of FT over both FFS and FD is that there is less institution involvement in subsequent years since no monitoring and evaluation of the FT was done. The policy insights derived from these findings is that there is need to use a combination of the dissemination pathways in order to take advantage of the complementary strengths. FDs could probably be used at the initial stages to promote the technology, while FFS and FT could be used in the subsequent years to reinforce the messages. Perhaps institutions should aim at recruiting more FTs so that they can achieve a multiplier effect.

Despite the stated limitations presented in the analysis of data in this chapter, the results provide some insights into the relative efficiency of the different pathways, which could guide further process of up-scaling and out-scaling of PPT. In addition, the study has demonstrated the possibility of using DEA in evaluating the efficiency of extension methods and further shows the importance of combining both the qualitative and quantitative analysis in understanding the efficiency and effectiveness of the dissemination pathways.

CHAPTER SEVEN

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

7.1. Aims of the study

Food security continues to be a challenge in most developing countries. Despite the efforts being made to encourage food self-sufficiency among the rural households, many challenges continue to limit the fight against food insecurity. Among these challenges are the effects of *Striga* weed and stemborer pests on the productivity of cereal crops such as maize and sorghum which are important food security crops. The adoption of conventional control methods of these pests has been limited due to various socio-economic factors. The novel habitat management approach, called 'push-pull' technology (PPT) developed by ICIPE and its partners has been rated highly by farmers as effective. To date, PPT has been adopted by over 30,000 smallholder farmers in Western Kenya, where maize yields alone have increased from about 1 ton/ha to 3.5 tons/ha, with minimal external inputs. For this technology to make a difference in improving food security there is need for accelerated spread and uptake which would require vigorous diffusion of information so that farmers can be able to recognize the full advantages of the technology. Such flow of the information must be properly planned and managed through appropriate pathways in order to facilitate the adoption by potential farmers.

Although dissemination of this technology has been facilitated through many pathways, the socio-economic diversity in Africa limits the understanding of the most effective and economical strategy where incremental resources could be placed. This gave the impetus of the current study; to evaluate the efficiency and effectiveness of different dissemination pathways in order to inform on which pathway(s) to focus on in scaling up PPT and other knowledge-intensive technologies in Kenya and beyond. This study was based on the hypothesis that producers decide which information pathway or a combination to use from a suite of available sources, and then they decide on how much information is needed to manage a technology, subject to available constraints, decide to adopt and finally receive benefits (Just *et al.*, 2002; Velandia *et al.*, 2009). Although several studies have evaluated the effectiveness of pathways (e.g Irfan *et al.,* 2006; Bunyatta *et al.,* 2006; Amudavi *et al.,* 2008; Amudavi *et al.,* 2009) very few have compared the effectiveness of the pathway being evaluated with other pathways. This study used a holistic approach in evaluating the effectiveness and efficiency of different pathways.

7.2. Role of information in agricultural productivity and food security

In order to ensure sustainable food security, agricultural productivity must be encouraged. It has been acknowledged that the least expensive input for rural development is knowledge which together with information forms the basic ingredients of food security. One of the fundamental ways of improving agricultural productivity is through introduction and use of improved technologies and many research budgets have been justified based on the relationship between knowledge generation and the impact on food production and poverty reduction, while improved dissemination and adoption is the key to maximising value for money. In view, adoption of improved technologies is vital to agricultural growth and development. However, introduction of a new technology creates an information gap between its perceived and true characteristics. In most cases, this divergence results in poor or slow adoption due to uncertainty and/or the risk of making a costly wrong decision (Llewellyn, 2007). This means that farmers must be availed with information that has quality characteristics such that it is easy for them to analyse and integrate into existing farm specific knowledge and reduce information seeking and learning costs. The current study in general has demonstrated that information plays a key role in adoption process. For instance chapter four and chapter five of this thesis show that information received from different pathways significantly influenced not only the decision and intensity of adoption, but also the speed of uptake of PPT. In fact, the results in chapter four show that those information pathways were much more important than other socio-economic and farm characteristics in influencing adoption. This implies that the potential of PPT to improve food security through increased maize production would only be realised if farmers get information *inter alia.*

In general, there has been a concern on lack of impact of research on food security as a consequence of poor information dissemination which has been attributed to use of ineffective pathways and also based on the argument that many institutions have marginalised the interests of the farmers (Saywell and Cotton, 1999). The challenge therefore is not only to disseminate the research findings but to enable farmers demand the knowledge via effective pathways. To come up with an appropriate dissemination strategy, there is need for concerted effort of the researchers and the extension agents in understanding their clients (farmers).

Often the nature of the technology may dictate the preference towards information sources since some pathways are perceived to be more accurate and reliable. Compatibility between information pathways to use and farmers' preferences is therefore very critical. This study has indeed demonstrated that farmers' decision to adopt can be influenced by the perception they have on the pathways being used. For example, the results in chapter 3 indicate that FD was among the most preferred pathway followed by FT and FFS based on a weighted rank index. Although these preferences were unique based on the characteristics of the target population, it was interesting to find that FD had the greatest impact on the three adoption measures as shown in chapter 4 and chapter 5. This suggest that dissemination pathways could be more effective if the target population is segmented and right pathways utilised for the various farmer segments. This is likely to increase the farmers' probability to take up the new technology (in this case the PPT) and therefore improve food security through improved maize production. In other words, preference for dissemination pathways precedes the decision to adopt.

7.3. Economic relevance of information pathways on adoption

Different pathways are likely to have different economic values and this implies a need to use pathways that are less costly but offer quality information that enable farmers to make adoption decisions. There are differences in terms of intensity of the message being delivered through various pathways. Some pathways such as FFS have been classified as more intense, while others such as FD as less intense (Ricker-Gilbert *et al.,* 2008). The intensity of the pathways may reflect the cost implications in implementing such pathways (i.e intense pathways are in most cases likely to be more expensive). There is also a general impression that for a knowledge intensive technology such as PPT, intense diffusion mechanisms such as FFS would probably have higher impact on adoption since farmers receive intense learning. However, results in chapter four reveal that this assumption might not be valid. In this chapter, FD had the greatest impact on PPT adoption (both probability and intensity), though it is considered relatively less intense than FFS. This implies that it is very important to understand the roles played by each pathway before embarking on the dissemination process.

Besides being intense, there could be other characteristics of these pathways that limit farmers from accessing information from them, and hence the low impact on adoption. The results in chapter three and chapter four supports the views of Rogers (1997) that farmers' perception on the pathway may determine if they will access the information from these pathway or not and if they will decide to adopt or not. There are certain characteristics embedded on these pathways that make them more credible and attractive to farmers than others, something future research can ascertain. For example, FD has the advantage of being a one day activity which lasts only 3 to 4 hours, while FFS takes longer period, a whole cropping cycle or sometimes up to one year with weekly sessions which would mean a high opportunity cost of attendance than FD. Other reasons could be issues related to depth of content, timeliness in delivery of information and so forth. The current study has generated knowledge of the factors associated with preference for pathways but its value may be limited unless linked to specific information as to why search strategies are used by farmers (e.g. Why would farmers look for information in certain pathways and not others?). Answering this question would help the institution to utilise pathways that are relevant and therefore reduce the risk of non-adoption. Pound, (1985) notes that knowing where farmers look for information is only half of the battle for extension communication, but knowing where farmers find information is the other half. Since the information presented by different pathways takes different forms, recognizing these differences in farmers' involvement in information search is important because they may have economic implications (Diekmann *et al.*, 2009).

Failure to understand the farmers' preferences for dissemination pathways may be expensive especially if wrong pathways are used. The understanding of the factors influencing farmers' preferences given in this study offers insights particularly to ICIPE and other extension agencies in designing tailor made dissemination strategy for their clientele. For example, the preference for FD was highest among the less educated people, while FT was mainly preferred among farmers with small land sizes and FFS for farmers in organised groups (chapter three). Using these results, information providers can better anticipate which types of farmers are suited for which pathways or a combination. The results then suggest that prior to using any pathway to deliver information, it is important to at least identify the dominant characteristics of the target population. This will help in placing the right targets by using the information pathway that is suitable for that particular population. In reality, this has not been the case as most extension agencies continue to use multiple dissemination pathways to pass technology information to farmers across the diverse population. Apart from being expensive, this kind of approach is likely to result to low or delayed adoption of that particular technology especially if the pathways being used are not the one preferred by the farmers.

Time is very important in adoption and it has an economic value. Farmers should be availed with information that allows them to reach a state where they can cease investing in the evaluation stage and arrive at a decision to adopt or not adopt more rapidly. This will require that farmers are exposed to information sources that do not require much translation to the local conditions (Marsh *et al.,* 2000). This perhaps explains why FD had the highest impact on the speed of PPT adoption (chapter five). FD tends to offer simplified messages through practical demonstrations which the farmers can translate and apply easily in their own setting. This may also be a justification as to why FD was most preferred by the less educated category of farmers. Some previous studies categorized early adopters to be more educated than late adopters, but Midgley and Dowling, (1993) acknowledge that even non-innovative individuals can adopt a technology at an early stage of diffusion if they are exposed to the right pathways.

In other cases, the impact of extension and other information sources was found to reduce at the later stages of diffusion since a large proportion/percentage of adopters have adopted (Llewellyn, 2007). This implies that quality information is critical at the early stage of diffusion since information is prevalent and easier to access at little or no cost via contact with neighbours at later stages. The delay in adoption exhibited by the interaction variable (chapter five) is probably due to a rational wait for more quality information rather than attitudinal or social barrier to change. If farmers are exposed to the wrong pathways at the beginning, they are likely to wait until they have learnt from reliable sources for them to decide whether to adopt or not.

7.4. Integration of various dissemination pathways

It is important to recognize that each pathway has an important role to play in increasing farmer knowledge and promoting adoption and should therefore be integrated. This is a fact that has been ignored by previous studies. Results in chapter four and chapter five show the effects of other pathways such as radio, FF, print and *baraza* were insignificant in the three adoption models. Although most of these pathway(s) had limited role in influencing adoption, they played an important role in awareness creation. Initial information source by farmers might not necessarily be from field staff officers but rather from their neighbours (see Table 5.1). Most farmers seem to have received the first information about PPT from their neighbours (Fellow farmers), followed by the radio. Even for general farming information, farmers tend to consult other farmers more (see appendix 1). Feder *et al.* (1984) acknowledged that farmers trust other farmers for simple knowledge but would tend to go for other pathways if the message is complex.

Although awareness was not modelled in this study, the results support previous studies. For example, Feder and Slade (1985) acknowledge that use of mass media sources would be limited in promoting adoption of knowledge intensive technologies but can be utilized as a support to the other information dissemination channels. Derbakow and Mcbride,

(2001) found that media sources and other farmers were more important in the awareness stage, but other intense sources were required at later stages of adoption.

Considering the variability among farmers and their personal preferences as indicated in chapter three, it is likely that no single delivery method is suitable for everyone (Richardson, 1995). This imperatively supports argument by Garforth and Usher (1987). Instead, there is forthright need to combine pathways in order to take advantage of each pathway's strength in initiating the adoption process. Results in chapter six shows that FDs are relatively cheap mechanisms of training farmers and mostly preferred by the farmers. FT and FFS on the other hand are relatively expensive in the initial stages but have the distinct benefits such as knowledge retention and constant interaction. Organizations should consider using the pathways at different stages of the adoption process. For example, FDs can be used in the initial stages of dissemination in order to speed up the adoption process, while FFS and FT can be used to reinforce the messages at later stages.

Delivery of information is very relevant at the initial stages of technology adoption. At later stages, access to information becomes easier since it is possible to learn from a neighbour. Since not all farmers attend trainings in FDs, mass media sources such as radio can be used for awareness creation. Perhaps to echo the words of Seaman Knapp (1831-1911) "*what a man hears he may doubt, what he sees he may possibly doubt, but what he does himself he cannot doubt*". Dissemination requires numerous methods and teaching tools each of which has its place and they supplement one another. Together they provide the stimulus for interest, desire, action and achievement.

Factors influencing technology adoption are many and interact in a complicated manner. Their choice depends largely on the policy question at hand. Although this study mainly focussed on the dissemination pathways, other factors such as socio-economic characteristics of the farmer, farm attributes, institutional and spatial factors were included in the model in order to control for their effects. Some of these factors were found to have a significant relationship with adoption measures. However, the marginal analysis in chapter four indicated that the information pathways had much more impact on adoption than the other variables. This finding is very important as it demonstrates the key role of availing information. In a study on factors influencing adoption of dairy technologies in Kenya, Makhoha *et al.* (2007) concluded that some variables such as education may be important in understanding extension messages but specialized information from different sources is more critical to adoption than formal education. This puts a lot of weight on the role played by information pathways on the adoption of a technology. This further raises the need to include farmers in the effort to design an effective dissemination strategy. By choosing the most preferred pathway for passing the information, one is likely to obtain high adoption levels of the technology in question, and therefore improve productivity.

In conclusion, the findings from this study have implications for private and public information providers challenged to better understand farmers' pathway preferences in order to improve their reach of targeted client audiences. The fact that agricultural information is more ubiquitous than ever before makes it increasingly more important that farmers be given quality information, delivered in the proper format, and at the right time. A better understanding of farmer information preferences and the effects they have on adoption provides new opportunities for agricultural professionals and extension educators to design effective strategies for disseminating farming information to their clientele.

7.5. Suggestions for further research

This study was carried out in one region of the country. Other districts in Kenya, Uganda and Tanzania where PPT has been disseminated were not sampled and a study can be carried out to extend the research in those areas. The study was also technology specific and therefore the applicability of these results in other technologies may require validation of results. In addition, the analysis in this study was based mainly on push-pull farmers who were directly trained using the various pathways. Farmers from villages beyond the push-pull villages were not sampled, and therefore it was difficult to estimate the extent of diffusion emanating from the trainings. The opportunity cost of training (both farmers and trainers) was not taken into account when evaluating the efficiency of different pathways. The characteristics of the pathways used were not evaluated. For example, why would farmers prefer FD more than FFS and FT? A study needs to be carried out to assess the effects on pathway characteristics on farmers' perception.

Different studies have been conducted to look into the direction and magnitude of the influence of different factors on farmers' adoption decision of agricultural technologies. In most cases, locality has been found to vary where at one time it is found to hinder adoption and to favour adoption of the same technology in another locality. Although some known determinants tend to have general applicability; it is difficult to develop a universal model of the process of technology adoption with defined determinants and hypotheses that hold in all cases. The dynamic nature of the determinants and the distinctive nature of the areas make it difficult to generalize what factors influence which technology adoption. This may call for site specific and/or technology specific studies to validate.

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APPENDICES

Appendix 1: Weighted score index of farmers' general farming information sources per district

	Overall N = 489	Homabay N = 120	Kisii N = 121	Busia N = 120	Bungoma N = 128
Other farmers	0.23	0.26	0.24	0.23	0.21
Field days	0.16	0.18	0.17	0.12	0.16
Extension	0.15	0.20	0.15	0.13	0.15
Radio	0.13	0.08	0.18	0.13	0.13
Farmer field schools	0.12	0.14	0.09	0.13	0.11
Barazas	0.08	0.04	0.09	0.08	0.09
Research institutions	0.05	0.03	0.02	0.07	0.07
Agricultural shows	0.04	0.02	0.05	0.04	0.04
Agricultural libraries	0.02	0.02	0.01	0.04	0.02
NGOs	0.02	0.03	0.01	0.02	0.01

Appendix 2: Weighted index of contribution of dissemination pathways to PPT adoption

	1	2	3	4	5	6	7	8	9	10	Index
FD	1	9	27	12	32	37	46	81	46	57	0.22
FFS	1	1	2	15	30	19	25	55	47	59	0.17
FF	0	11	5	24	45	42	45	48	28	20	0.16
FT	2	2	2	2	14	32	30	52	34	46	0.15
Print	9	24	20	31	46	31	23	26	11	2	0.10
Radio	8	33	53	59	54	28	9	9	2	0	0.09
ICIPE extension officer	1	0	1	3	4	6	6	9	12	42	0.06
Baraza	13	27	18	32	13	7	7	4	2	1	0.04
Government extension	0	0	0	1	0	0	0	0	0	4	0.00
Total	35	107	128	179	238	202	191	284	182	231	1.00

Appendix 3: Farmers stated reasons for not adopting PPT

	Overall N = 89	Homabay N =25	Kisii N = 21	Busia N = 9	Bugoma N = 34
Lack of planting material	48	56	67	33	35
Insufficient information	24	20	10	11	41
Not interested	13	12	14	11	18
Rented Land	7	0	10	44	0
still preparing	6	12	0	0	6
Labour intensive	1	0	5	0	0

Appendix 4: Farmers stated reasons for withdrawing from PPT

Reasons	Overall n = 105	Homabay n = 22	Kisii n = 34	Busia n = 32	BGM n = 17
Destroyed by animals	20	50	18	6	12
Lack of inputs	15	5	6	41	0
Labour intensive	14	23	12	13	12
Lack of extension follow up	12	0	21	6	24
Insufficient Knowledge	10	0	6	6	35
Land scarcity	7	5	9	9	0
High cost of inputs	5	0	15	0	0
Rented plot taken	4	5	9	0	0
Lack of interest	4	9	3	0	6
Other commitments	4	5	0	9	0
Changed enterprise	2	0	0	3	6
Destroyed by drought	2	0	3	0	6

Appendix 5: Variance inflation factor (VIF) multicollinearity test results for the ordered probit model

Variable	VIF	1/VIF
Seceduc	4.77	0.21
Prieduc	4.64	0.22
Ptseceduc	2.12	0.47
Bungoma	1.93	0.52
Busia	1.64	0.61
Kisii	1.64	0.61
Inc_lev3	1.6	0.63
Incl_ev2	1.38	0.72
Landsiz	1.31	0.77
Age	1.28	0.78
Distarmac	1.16	0.86
Grpmember	1.12	0.90
Pptadopt	1.07	0.93
Tenure	1.06	0.95
Mean VIF	1.91	

Appendix 6: Variance inflation factor (VIF) multicollinearity test results for the two limit tobit

Variable	VIF	1/VIF
FFS	6.64	0.15
*FT*FD*	6.27	0.16
*FS*FD*	6.18	0.16
FT	5.99	0.17
Seceduc	5.20	0.19
Prieduc	5.02	0.20
FD	2.98	0.34
FF	2.58	0.39
Bungoma	2.31	0.43
Pseceduc	2.27	0.44
Kisii	2.24	0.45
Inc_lev3	1.99	0.50
Busia	1.92	0.52
Inc_lev2	1.56	0.64
TLU	1.50	0.67
Landsiz	1.44	0.69
Age	1.39	0.72
Distarmac	1.34	0.75
Credit	1.27	0.78
Print	1.26	0.79
Grpmember	1.23	0.82
Gender	1.20	0.83
Hhsize	1.20	0.84
Baraza	1.17	0.85
Tenure	1.08	0.92
Mean VIF	2.78	

Appendix 7: Variance inflation factor (VIF) multicollinearity test results for the duration model

Variable	VIF	1/VIF
*FT*FD*	6.78	0.15
*FS*FD*	6.29	0.16
FT	5.54	0.18
FFS	4.95	0.20
Seceduc	4.92	0.20
Prieduc	4.92	0.20
FD	2.89	0.35
Kisii	2.63	0.38
Bungoma	2.51	0.40
Pseceduc	2.31	0.43
Busia	2.16	0.46
Inc_lev3	1.96	0.51
Inc_lev2	1.61	0.62
TLU	1.45	0.69
Landsiz	1.43	0.70
Age	1.41	0.71
Distrmac	1.33	0.75
Credit	1.30	0.77
Print	1.26	0.79
Grpmember	1.23	0.81
FF	1.22	0.82
Hhsize	1.21	0.82
Baraza	1.21	0.83
Tenure	1.14	0.88
Mean VIF	2.65	

Appendix 8: Questionnaire
1. BACKGROUND INFORMATION

District ____________________

Division ____________________

Locations ____________________

Sub-locations ____________________

Household Number ____________________

Distance from the main road ____________________

Distance from the market ____________________

Enumerator (Name) ____________________ Starting time __________

Questionnaire Serial Number [_____] Ending time __________

Date (dd/mm/yy) _/___/200_

Supervised by ________________ Date ___/___/200_

The overall objective of the survey is to assess the economics of different dissemination channel used to promote Push-Pull Technology for the control of stem borers and *Striga*. The study is collaborative between International Centre for Insect Physiology and Ecology (ICIPE) and Egerton University. The information will help in coming up with targeted dissemination strategy that will ensure increased adoption, hence increase yields and improved household welfare.

2. HOUSEHOLD CHARACTERISTICS

1. Name of the main farmer____

2. Name of household head (If not the main farmer)____________________

4. Marital status [_] 1. Married 2. Single 3. Divorced 4. Widowed 5. Other (specify)______

6. Gender of the main farmer 1. Male 2. Female

7. Age of the farmer (years) __________________

8. Level of education of farmer [___]1. None 2. Primary 3. Secondary 4. Post secondary.

9. Main occupation of the household head [___]1. Farming 2. Off farm business 3. Formal employment 4. Informal employment 5. Others (specify)______________

10. Religion [___]1. Christian 2. Muslim 3. Others

11. Current total number of household members [_____]

3. FARM CHARACTERISTICS

1. Land Tenure system [___]1. Communal 2. Own 3. Rented 4. Others (specify)__________

2. Total land Owned (Acres)__________________

4. CROP AND LIVESTOCK ENTERPRISES ON THE FARM

1. Indicate livestock kept in your farm (**Provide information for the last one year)**

Livestock category	**Owned this date last year**	**Number currently owned**
Mature cows		
Mature bulls		
Heifers		
Calves		
Sheep		
Goats		
Pigs		
Rabbits		
Grade Chicken		
Local Chicken		
Others, specify		

2. Indicate crop enterprises on farm in the last one year

Type of crop	Acreage/number
Food crops	
Cash crops	

5. FARM SOURCES INCOME

1. Indicate sources of income in the last one year (2007)

Source	**Amount per month (Ksh)**	**Total per year(Ksh)**
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		
Others:Specify..................		

7. INFORMATION ON PUSH-PULL TECHNOLOGY (PPT)

1. When did you hear about push pull for the very first time? (Indicate the month and the year)___________

3. Which was your very first source of information about PPT? [___]***(Tick only one source)***

   1. Radio 2. Farmer field school 3. Field day 4. Print (Pamphlet, brochures, posters) 5. Farmer teachers 6. Others specify

4. After your hearing about PPT for the first time from the source you have mentioned, did you start practicing **(adoption) [_____]** 1. Yes 2. No

   If yes, answer the following questions; If no, go to question no. 9

5. After how long did you start practicing PPT from the first hearing? (**Speed of adoption**)

   [____]1. Months 2. 3 months 3. 6 months 4. 12 Months 5. Others (specify)____

6. Indicate the year you started practicing push-pull technology _______________

9. If you did not start practicing PPT after your first hearing, did you search for more information from other sources? 1. Yes 2. No

10. If yes, which other sources did you receive information about PPT? [_____]

   1. Radio 2. Farmer field school 3. Field day 4. Print (Pamphlet, brochures, posters) 5. Farmer teachers 6. Others specify

11. After the accumulating information from these sources, did you start practicing? [_____]

1. Yes 2. No

12. If yes, after how long did you start practicing PPT from your **first** hearing?

1. 6 months 2. 12 months 3. 18 months 4. Others (specify)____________

13. Indicate the year you started practicing PPT______________

14. **Initial** area under PPT____________acres

15. **Current** area under PPT ____________acres

21. If you have never started practicing PPT at all, but you have heard about it, give reasons for not practicing *(Enumerator try to probe for explanation especially related to the type and source of information)*

1. Not interested
2. The information I got was not enough (specify the source)
3. Others(specify)______________________

If the farmer got the information from a radio;

1. Which radio channel 1. KBC 2. Local radio station 3. others (Specify)__
2. Which radio programme ___________________
3. Language offered ______________
4. Time the programme aired ______________
5. Did/would you adopt PPT after listening to the radio 1. Yes. 2. No
6. How relevant/adequacy is the radio in helping you make the decision to adopt PPT 1. Very relevant/adequate 2. Relevant/adequate 3. Not relevant/adequate

If the farmer got the information from **Farmer Field school**

1. Name the FFS _________________________
2. Are you a member 1. Yes 2. No
3. Did/would you adopt PPT by attending an FFS? 1. Yes 2. No
4. How many times did/would you attend an FFS before adopting PPT ________
5. How relevant/adequacy is FFS in helping you make the decision to adopt PPT 1. Very relevant/adequate 2. Relevant/adequate 3. Not relevant/adequate

If the farmer got the information from **Farmer-teacher**

1. Name of the farmer teacher_______________________
2. Did/would you adopt PPT after attending lessons from a farmer teacher? 1. Yes 2. No
3. Number of contact lessons before adopting PPT_______
4. Type of contact 1. Individually at the farm 2. Group of farmers

5. How relevant/adequacy is the **farmer-teacher** in helping you make the decision to adopt PPT 1. Very relevant/adequate 2. Relevant/adequate 3. Not relevant/adequate

If from **Field days**

1. Where was the field day held______________________________
2. Who were the facilitators 1. ICIPE staff 2. Government Extension staff 3. Others (specify)_______________
3. Did/would you adopt PPT after attending a field day 1. Yes 2. No
4. Number of field days attended before adopting PPT_______________
5. How relevant/adequacy is the **field day** in helping you make the decision to adopt PPT 1. Very relevant/adequate 2. Relevant/adequate 3. Not relevant/adequate

If from **Print media** (brochures, pamphlets, posters)

1. Indicate the source of print material. 1. From ICIPE staff 2. From extension officers 3. Issued during agricultural shows (specify) 4. Issued at an FFS 5. Issued at a field day 6. Others (specify)____________
2. Did/would you adopt PPT after reading a print material
   i. Brochure 1. Yes 2. No
   ii. Pamphlet 1. Yes 2. No
   iii. Poster 1. Yes 2. No
3. How relevant/adequacy is the Print media in helping you make the decision to adopt PPT 1. Very relevant/adequate 2. Relevant/adequate 3. Not relevant/adequate

8. DISSEMINATION PATHWAY PREFERENCES

1. Given a choice of selecting a dissemination pathway for receiving information about PPT, indicate in the table below your preferred dissemination pathway which would give you relevant/adequate information that can lead you to adopting PPT without necessarily going for more information

Dissemination pathway	1= Not preferred	2 = Somehow preferred	3=Most preferred
Radio			
Farmer field school			
Field days			
Farmer- teacher			
Print			
Baraza			
Other farmers			

2. In the table below, score each of the given dissemination pathways against each of the given criteria in a scale of 1-5, with one being the lowest score and 5 the highest. *(Enumerators ask farmers opinion for each pathway against the given criteria)*

Dissemination pathway	**Ease of access**	**Ease of use**	**Depth of content**	**Accuracy**	**Reliability**	**Timeliness**
Radio						
Farmer field school						
Field days						
Farmer- teacher						
Print						
baraza						
Other farmers						

9. HOUSEHOLD ASSEST OWNERSHIP

Household asset	**Number currently owned**	**Unit Value**	**Total value (Ksh)**
Radio			
Television			
Farm implements			
Tractors			
Jembes			
Hoes			
Pangas			
Slashers			
Others relevant to farming			

10. ACCESS TO CREDIT FACILITIES

1. Have you accessed any type of credit for farming purposes in the last one year?

[___] 1= Yes 2=No

2. If yes, fill the table below

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

11. MEMBERSHIP OF COMMUNITY ORGANIZATIONS

1. Are you a member of any community organization/association?

[___] 1= Yes and 2 = No

2. If yes tick which ones? [_____}

1) Cooperative society 2. KWFT 3. Women group 4. Producer group (specify which one) 5. Others (specify)______________

3. What services do you get from the organization you belong to? [_____]

1. Loans 2. Labour 3. Credit 4. Others (specify)__________

12. EXTENSION SERVICES

1. Did you have an extension contact in the last one year? [____] 1 = Yes and 2 = No

2. If yes frequency of contact [____]

1. Once in a week 2. Once in two weeks 3. Once a month 4. Once in three months 5. Not regular

3. Gender of agent making usual contacts [____] 1. Male 2. Female

4. Usual type of contact [_____] 1. Individual 2. Group

5. Types of Extension messages given by the agents.

13. INFRUSTRUCTURE (DISTANCES IN KILOMETERS)

1. What is the **distance** from your home to the nearest **shopping centre?** ____________
2. What is the **distance** from your home to the nearest **tarmac road?** ____________
3. What is the **distance** from your home to the nearest **health centre?** ____________
4. What is the **distance** from your home to the nearest **public telephone services?** ____
5. What is the **distance** from your home to where you can **tap electricity?** ____________
6. What is the **distance** from your home to where you can get **piped water?** _______
7. What is the **distance** from your home to **public/private extension services**? _______

Thank you for your time.