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The Effectiveness of Dissemination Pathways on Adoption of "Push-Pull" Technology in Western Kenya

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Abstract

Push-pull technology (PPT) is currently and widely promoted as a control measure for stemborers, *Striga* weed and soil fertility improvement in maize fields in western Kenya in order to improve on cereal production. Since it is a new and relatively knowledge-intensive technology, access information about its efficacy is critical for maximum adoption and continued use. Given that different technologies may need different pathways for adoption, this study sought to identify the most effective dissemination pathway(s) for scaling up the technology among many farmers. A two limit Tobit regression was used to analyze data from 491 respondents randomly selected from four districts in western Kenya. The results indicated that chronologically field days (FD), farmer field schools (FFS) and farmer teachers (FT), had the greatest impact on the probability that a farmer in the study area would adopt PPT and at enhanced intensity of adoption. Efforts to disseminate PPT should therefore target the use of demonstrations through field days to intensify adoption. FT and FFS where appropriate can be used as alternative pathways to reinforce extension messages.

Keywords: effectiveness, dissemination pathways, push-pull technology, uptake
JEL: C41, D10, D80, O33, Q16

1 Introduction

Food security in Kenya is linked to attaining sufficient maize supply at household level. However, sustainable maize production is faced with numerous challenges which have the potential to upset livelihood of many households both in rural and urban areas. Among these challenges, the infestation by cereal stemborers (e.g. *Chilo partellus* Swinhoe and *Busseola fusca* Füller) and the parasitic *Striga* (particularly *Striga hermonthica* and *Striga asiatica* Orobanchaceae) weed are very critical. These pests are rated as the most important biotic challenges in smallholder maize production in western Kenya. In Kenya, it is estimated that stemborers causes between 20-80% maize yield losses, while *Striga* weed causes up to 100% maize yield losses annually under severe infestation levels (KHAN et al., 2001). The monetary losses are enormous and have been estimated to be close to US$ 40.8 million annually (KANAMPIU et al., 2002; KHAN et al., 2008a). Most of the recommended control methods such as hand weeding and use of herbicides are considered insufficient, unaffordable and unfriendly to the environment, in addition to having limited appropriateness and acceptance by smallholder farmers in the region (BERNER et al., 1995; WOOMER et al., 2004). However, the 'push-pull' technology (PPT) developed by the International Centre of Insect Physiology and Ecology (*icipe*) and partners has been preferably rated by farmers in the simultaneous control of these biotic constraints (KHAN et al., 2001). This technology involves intercropping maize with fodder legumes in the genus *Desmodium* and planting around this intercrop Napier grass (*Pennisetum purpureum,* Schumach) as a trap plant. Volatile chemicals released by desmodium repel stemborer moths (push component) while allelo-chemical released by its roots suppresses *Striga* weeds (KHAN et al., 2000; TSANUO et al., 2003; KHAN et al., 2008a, 2008b). Napier grass on the other hand releases chemicals attractive to stemborer moths (pull component) (KHAN et al., 2000; CHAMBERLAIN et al., 2006).

With effective control of these biotic stresses, a significant cost-benefit return of 2.2 in the PPT relative to 0.8 for non-PPT has been reported (KHAN et al., 2001; KHAN et al., 2008a). The technology is relatively knowledge-intensive and its dissemination has been facilitated by a series of dissemination pathways including farmer field schools (FFS), field days (FD), farmer teachers (FT), fellow farmers (FF), print media, public *barazas* and radio programs (KHAN et al., 2008a; AMUDAVI et al., 2008; AMUDAVI et al., 2009). These dissemination pathways can be classified depending on the nature of information delivery. FFS are defined as "schools without walls" which stemmed from adult education principles and evolved to become a distinct approach that builds on the process of group learning and community action. This participatory extension method recognizes the need to involve farmers in the technology development and transfer. Participating farmers 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 (ASIABAKA, 2002). Field days (FD) on the other hand are day-long events where interested farmers are invited to a particular field or plot and specific information about the technology are demonstrated and discussed. The 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, 1982**).** Farmers 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. One limitation about the field days is the inadequate time for effective interaction between the facilitators and the farmers.

Farmer teachers (FT) refer to on-farm training of farmers by other farmers who have a set of skills and knowledge to provide. The method capitalizes on existing local social networks, based on the belief that experienced and skilled farmers are the people best suited to train other farmers. The FTs are trained so as to motivate other farmers, help them to improve their skills and share their know-how. The trainees familiarize themselves with the technology since training takes place in the field where they have the opportunity to see how things are done, they do them, make mistakes, learn from them 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. Using fellow farmers (FF), an approach also referred to as farmer-to-farmer diffusion, is a common and important vehicle for diffusing new technology. The approach exploits the 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. Finally, *Barazas* are public gatherings of people widely used to mobilize communities, particularly when there is information to pass about a new project or technology introduced in an area. KITETU (2005) and NJUGUNA et al. (2007) acknowledged the importance of *Baraza* in mobilizing farmers and passing information about a new technology. The main disadvantage of *Baraza* as a method of passing information is that it has been traditionally used by the top-down approaches where experts pass on information and programs down to rural communities unchallenged. In

Barazas, the group gathered is usually big and this leaves little room for interactive talk, questions or other topics outside the schedule set for the day by the experts. Given the mixed effects of these dissemination methods and the limited funding for agricultural research and extension systems in Africa, the challenge then is to identify the most effective pathway(s) for up-scaling PPT to ensure maximum adoption.

Previous studies have shown that farmers' perceptions and attitudes towards emerging technologies are influenced by a number of factors, with the nature of information sources being of particular importance (e.g. LYNNE et al., 1988; ADESINA and ZINNAH, 1993; MCBRIDE et al., 1999). Moreover there is significant variations among technology dissemination pathways, which consequently translate to varied impacts on adoption levels (DABERKOW and MCBRIDE, 2001; GERVAIS et al., 2001; MAUCERI et al., 2005). Dissemination of technologies using different pathways is resource driven and therefore it would be expected that the varied technology adoption levels would have an implication on the cost effectiveness of the pathways being used. The challenge, therefore, is to determine the most effective and economically feasible pathway(s) where resources could be concentrated in order to reach many farmers and achieve economies of scale in technology adoption.

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' decision to adopt a given technology (RICKER-GILBERT et al., 2008; DOSS, 2006). Different technologies have different attributes of knowledge and information requirement sets. These sets are likely to objectively determine the types of dissemination pathways to use, if the adoption of the technology in question is to succeed. For relatively 'knowledge-based' innovations like PPT, the uptake is likely to depend on how extensive and intensive farmers are trained and the effectiveness of dissemination pathways used (PADEL, 2001). If ineffective pathways are used, farmers are likely to spend more time searching for more relevant information thus increasing the information search costs. This, therefore, implies the 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, contingent on resource availability. Given that information is packaged and presented differently in different dissemination pathways, there is likelihood of variations on the effects these pathways could have on technology adoption (DABERKOW and MCBRIDE, 2001; MAUCERI et al., 2005). There is therefore an additional need to determine these differences in order optimize the use of those pathways that have greatest impact on adoption and within the realm of available resources.

Several studies have shown the impact of different information sources on farmers' probability of adopting a particular technology. For example, information from crop consultants had the largest impact on adoption of precision farming than media sources in the United States (MCBRIDE et al., 1999; DABERKOW and MCBRIDE, 2001), while farmer field schools had the greatest impact on adoption of integrated pest management (IPM) than 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 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, they clearly demonstrate that technology adoption could be influenced, among other factors by the dissemination pathway.

In sub-Saharan Africa, there is dearth of evidence on how the various dissemination pathways influence and determine technology adoption. In Kenya for example, KHAN et al. (2008a) established that exposure to a variety of extension methods significantly influenced likelihood of PPT adoption. This study, however, did not assess the magnitudes these extension methods had on adoption. Elsewhere, DADI et al. (2004) did not clearly 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. Extension contact alone may not promote adoption if information dissemination pathway being used is ineffective or inappropriate (AGBAMU, 1995). 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.

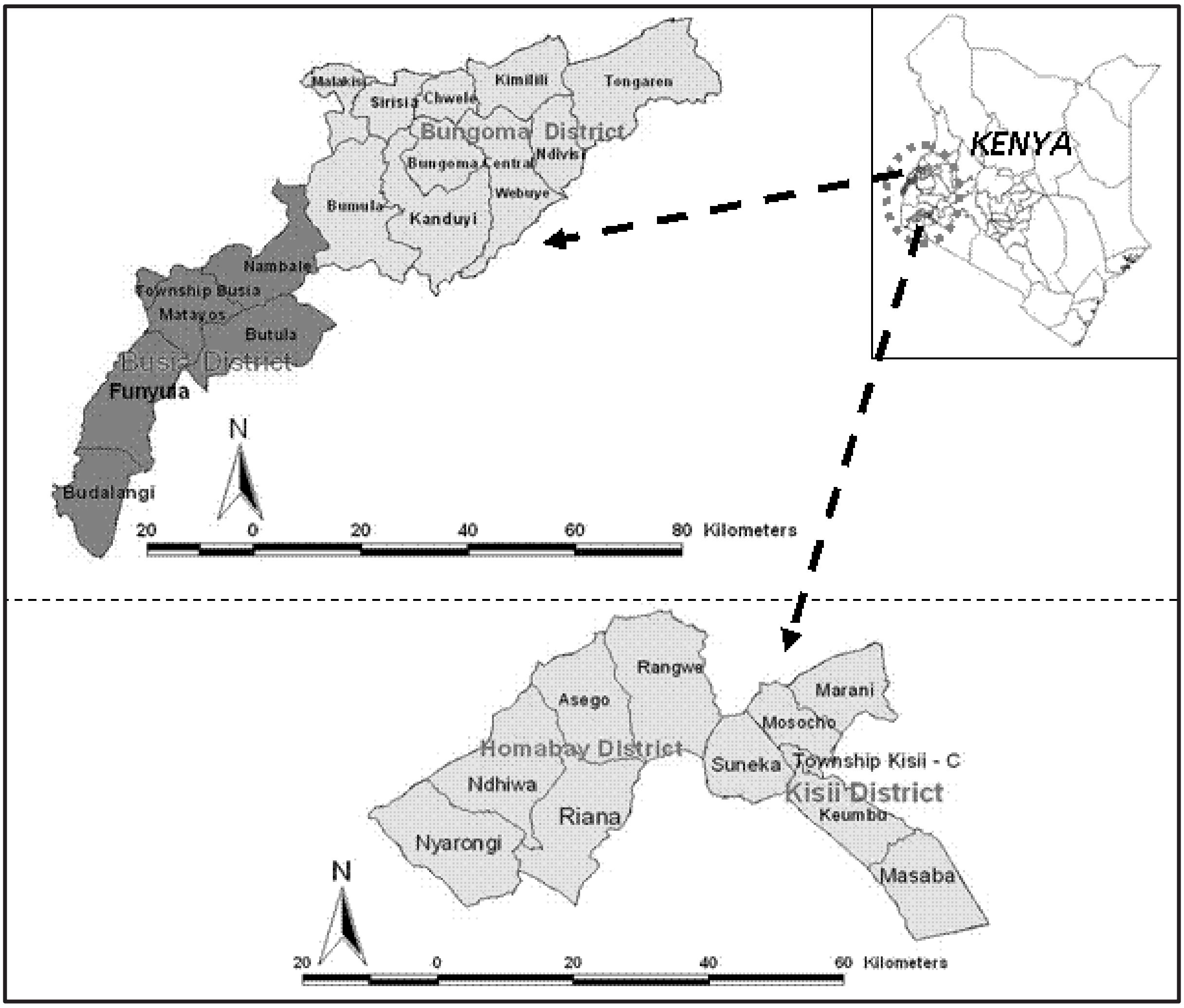
This study sought to establish the effectiveness of various dissemination pathways on PPT technology adoption, with the aim of identifying evidence based and effective strategy for enhanced dissemination of knowledge intensive technologies such as PPT.

2 Methodology

2.1 Study Area

Four districts (see figure 1) were selected in Western and Nyanza provinces of Kenya where PPT has been promoted using different dissemination pathways. These districts were Homabay, Kisii, Busia and Bungoma. Administratively, Homabay and Kisii districts are located in Nyanza province while Bungoma and Busia are in Western province. Homabay lies between 1,220 m and 1,560 m above sea level (asl); receives 500 mm to 1,000 mm annual rainfall, temperatures ranges between 17.1 °C to 34.8 °C (minimum and maximum, respectively) and has an area of 1,155.5 square kilometres with an estimated human population of 293,676 (GoK, 1997a). Kisii district lies between 1,600 m and 2,000 m asl, receives 1,350 mm to 2,100 mm, temperature ranges between 10 °C to 30 °C (minimum and maximum, respectively) and covers an area of 645 square kilometers with an estimated population of 488,910 persons (GoK, 1997b). Bungoma district covers 2,063 square kilometres with an estimated human population of 763,656 persons; altitude ranges between 1,200 m and 2,000 m asl with mean annual rainfall varying from 1,250 mm to 1,800 mm and temperatures ranges between 21 °C to 25 °C (GoK, 1997c). Busia district has an area of 1,262 square kilometers with an estimated human population of 369,459 persons, the altitude varies from 1,130 m to 1,375 m asl, mean annual rainfall is 1,500 mm per annum and temperatures range from 14 °C to 30 °C (GoK, 1997d).

Figure 1. Map of the study region



Source: generated from ArcGIS using georeferenced survey date (2009)

2.2 Sample Selection and Data Collection

Primary data were collected through a household survey in 2009 at least 10 years after the PPT was first introduced in western Kenya in 1997, using a structured questionnaire. A purposive sampling strategy was used, according to CARMINES and ZELLER (1988) to select the districts with predominant use of PPT to control the stemborers and *Striga* weed. Purposive sampling ensures that certain important segments of the target population are represented and also allows selection of rich information that provides insight into the issues of central importance to the research (PATTON, 1990). A sample frame, consisting of all the farmers who had received information on PPT through different pathways in the target districts, was prepared from project records kept at ICIPE. The sampling frame included both adopters and non-adopters who had received the information on PPT. From the sampling frame, 516 farmers were randomly drawn using a Research Randomizer accessible at www.randomizer.org. However, due to non-response and non-accessibility to some respondents, data were obtained from 491 farmers. Before the administration of the questionnaire, the respondents were informed about the objectives of the survey while the enumerators were trained on the objective and contents.

Using the structured questionnaire, data on general household and socio-economic characteristics (e.g. age, education, gender, farm ownership, land size, total household income) and on institutional and infrastructure endowments (e.g. group memberships, access to credit) were collected. For adopters, the intensity of PPT adoption was captured by recording the current land size under the technology. Information on the use of and access to seven dissemination pathways was collected from respondents. The seven pathways included: Baraza (public meetings), Radio, FFS, FD, FT, print material (pamphlets, brochures) and FF. The respondents were asked to indicate whether they had heard about PPT through any one of the dissemination pathways. Answers to this question were recorded as 1 if the respondent indicated having heard from any pathway and 0 if not. These responses formed the binary variables representing the dissemination pathways that were included in the Tobit model regression model.

2.3 Model Specification, Variable Description and Analysis

To assess the impacts of dissemination pathways on the adoption decisions (level and intensity), we used a two limit Tobit model. The model is preferable to binary adoption models in situations where the decision to adopt involves a simultaneous decision-making process, especially, one regarding the decision to adopt and the intensity of adoption (FEDER and UMALI, 1993). In addition, the dependent variable in the current study was the proportion of land under PPT and lay between 0% and 100%. This model has been applied in previous studies to assess the factors influencing the probability of adoption and intensity of technology adoption (e.g. FERNANDEZ-

CARNEJO et al., 2001; CHUKWUJI and OGOSI, 2006; SCHROEDER et al., 2007; HONG XUE et al., 2009). The stochastic model underlying Tobit as used in this study is expressed as follows:

(1) $$Y_i^* = \beta_i X + \varepsilon_i$$

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, $\varepsilon \sim N(0, \sigma^2)$. In reality, we observe Y_i which is censored between 0 and 100 and is determined as:

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

In equation (2) 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 coefficients 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 be the case in an ordinary regression. In addition, each estimated marginal effect from the Tobit model includes both the influence of the explanatory variable on the probability of adoption as well as on the intensity of adoption. As such, we adopted the formula by MCDONALD and MOFFIT (1980) to decompose the relevant effects of changes in the explanatory variable on the dependent variable as used in other studies (e.g. FERNANDEZ-CARNEJO et al., 2001; CHUKWUJI and OGOSI, 2006; AKINOLA et al., 2010). The following empirical model was estimated:

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

Using equation (3) we estimate the coefficients of the variables that influence adoption intensity (PPTINTEN), which in this study is used as a proxy for dissemination pathway effectiveness. In this study we posit that the decision to adopt PPT is subject to the information constraints reaching a certain threshold, among other constraints. The information threshold, which is a product of an underlying utility maximization, is arrived at through a process of information gathering. This information reaches the farmers via different pathways which are likely to influence the decision to adopt a technology at different levels. At the threshold a farmer may decide to adopt the technology or not. Besides, other socio-economic, institutional and spatial factors may influence the farmers' decision to adopt. These factors were, therefore, included in the model in order to determine their effects on adoption and the intensity of adoption. The description and the expected signs of the variables in equation (3) are presented in table 1. The choice of these explanatory variables was mainly based on the general working hypothesis and partly on empirical findings from literature.

The main focus of the study was on dissemination pathways through which PPT information is delivered, and each of them, either singularly or simultaneously, was expected to have a positive effect on adoption. This is because information reduces uncertainty and farmers who are better informed about an innovation are more likely to adopt it than those with less information. Dissemination pathways were specified as a series of binary variables (1 if the farmer had received the information from a particular pathway, and 0 if otherwise). In this case, radio as a dissemination pathway, was used as a control variable in the model. To capture the effects of interactions between the pathways in the analysis, multiplicative interactive variables were included in the model. In our case, two interaction variables namely: FT*FD and FFS*FD, were included in the regression model. The inclusion of these interactive variables in the model was informed by the fact that FTs, FD and FFS are likely to reinforce the absorptive capacity of information thus delivered in a complimentary manner. Specifically, FTs and FDs were used to train other farmers, while sometimes ICIPE researchers used selected FTs to train farmers in an FFS as well. This means that the effects of these dissemination pathways on the dependent variables are likely to be interactive and possibly inseparable. Furthermore, preliminary descriptive statistical analysis showed that these two interactive variables had the highest number of observation, while the other interactions had very few observations to sustain any meaningful regression analysis.

As noted earlier, farmers' decision to adopt a practice is not only influenced by how and from where she received the information, but also by a variety of socio-economic factors. For this reason, several socioeconomic variables were included in the model. Human capital was represented by age and education and reflects the social aspects of the farmer and their ability to obtain and evaluate information about an innovation (FERNANDEZ-CARNEJO and MCBRIDE, 2002). Age is described as a composite of the effect of farming experience and planning horizon and can either be positive or negative (ASRAT et al., 2004). 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, we assume that older farmers have more farming experience through which they can use to discern economic benefits of the technology. Education is used as a proxy for farmers' ability to acquire and effectively use information (GERVAIS et al., 2001). An educated farmer is more likely to accept a new farm technology compared to a farmer with no formal education. This variable was, therefore, assigned *a priori* positive sign. 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, gender was assigned *a priori* positive sign.

The effect of land size 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 on the adoption process. FERNANDEZ-CARNEJO and MCBRIDE (2002) 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. Household size 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. Credit constraints are expected to have a negative effect on adoption of capital intensive technologies, but for PPT the effect may be different since the technology is less capital intensive.

Previous studies have reported the direction of group membership to be unclear since farmers are likely to form positive or negative attitude towards an innovation through group contacts (e.g. NKAMLEU, 2007). For this reason, the direction of group membership may not be well defined. Distance to the tarmac road 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 given *a priori* negative sign. The importance of livestock as an economic resource is represented by the number of Tropical Livestock Unit (TLU)[1]. It is hypothesized then that the more

[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).

TLUs a farmer has, the larger the probability of adoption of PPT. Dummy variables representing the districts of study were also included to control for the regional effects on adoption of PPT.

Table 1. Description of model variables

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

[1] Ksh (Kenya Shilling) conversion rate was 1 US$ to Ksh 75 at the time of survey

Source: field survey data (2009)

Before estimating the model, it was necessary to test for multicollinearity among the variables. Variance inflation factor (VIF) was computed to detect multicollinearity among the variables used in the model. 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 that multicolinearity exists (MADDALA, 1993). All the other variables in the model had a VIF less than 10 which satisfy the rule of the thumb.

3 Empirical Results

3.1 Descriptive Results

Table 2 presents the results of the descriptive analysis of the key variables describing farmers' characteristics. Chi-square (χ^2) or F-tests were used where appropriate for statistical significance or otherwise, for the differences among the various categories. For most of the variables, the differences were statistically significant across the categories. Of the total respondents, 84% were adopters and 16% were non- adopters. Females constituted 57% and male 43% of all the respondents. The mean age of the respondents was 44 years for the overall sample. A majority of the respondents had attained at least primary education (51.5%) while the rest had secondary education 35.5%, post secondary 6.9% and informal education 6.3%. Average household size was 7 persons and average land size was 3.9 acres (or 1.56 ha).

The percentage land under PPT was on average 5.2% of the total land size. The average Tropical Livestock Units (TLUs) were 2.6 units and the average distance to a tarmac road was 4.9 kilometers. On average, farmers had received information from four different pathways. In terms of social capital, 86.5% of the farmers belonged to organized groups. About 41.8% of them had access to credit. Household income category was grouped into three levels, with 31.4% of the respondents falling under income level 1 (< Ksh 20,000); 35% under income level 2 (Ksh 20,000 to Ksh 40,000) and 33.4% under income level 3 (> Ksh 40,000) (1 US$ = Kshs 75).

3.2 Tobit Regression Results

Table 3 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. 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.

Table 2. Descriptive results of farmers receiving information from different pathways

Demographic variable		**Respondents districts**					
	Sample N = 491	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 (%)							*10.52****
Adopted	84	80	80	93	83		
Not adopted	16	20	20	7	17		
Education level of the farmer (%)							*34.62****
No formal education	6	8	10	7	1		
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 (%)							*42.18****
Level 1 (< Ksh 20,000)	31	48	31	27	20		
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****
Credit access (%)	42	70	35	65	63		*36.67****
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***	
Percentage of land under PPT	5.2 (8.3)	3.4 (3.9)	5.7 (7.7)	7.1 (10.5)	4.8 (9.4)	4.30***	
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***	
Dissemination pathway[1] *used* (%)							
FD	76	68	80	73	81		*7.7***
FFS	57	54	32	64	77		*53.21***
Print	51	48	52	40	63		*13.9***
Radio	57	39	53	83	55		*59.95***
FF	59	63	55	68	51		*9.0***
Baraza	28	9	33	26	45		*40.6****
FT	44	42	48	52	36		*7.22**

*** P< 0.01, ** P<0.05, * P<0.1, figures in the parenthesis are the standard errors associated with the means.

[1] Pathways for information dissemination; FD = Field Days, FT = Farmer Teachers, FFS = Farmer Field Schools, FF = Fellow Farmers

Source: field survey data (2009)

Table 3. Two limit tobit maximum likelihood estimates and marginal effects results on PPT adoption

Variables[1]	Coefficients		Marginal effects					
			Unconditional expected value		Conditional on being censored		Uncensored condition	
	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
*FSS*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[2]	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
Statistics								
Log likelihood	-1517.13							
Number of observations	487							
LR chi2 (25)	98.72							
Prob >chi2	0.000							
Pseudo R2	0.032							

Significant at 1% ***, at 5% ** and at 10%*. [1] See table 1 for the description of variables.
[2] 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).

Source: field survey data (2009)

The MEs indicate that FD had the highest impact on both the probability 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 3.79% for the whole sample and 2.68% by adopters. Additionally, the probability of PPT adoption is likely to increase by 26.8% if farmers are trained in FDs. FFS took second position with an expected intensity adoption by the sample of 3.56%, 2.52% for adopters, and 22.2% increase in probability of PPT adoption, while training by FT would lead to 3.13% increase in expected intensity of PPT adoption of the overall sample, 2.21% increase in acreage under PPT for adopters and 18.1% increase in the probability of adoption. The multiplicative interaction variables included in the model were not significant.

Other variables that were found to be significant were land size, which was inversely related to 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), distance to a major access road (tarmac road), which was inversely related to the adoption measures (-0.125 for the overall sample, -0.088 for the adopters and -0.008 on probability of adoption) and regional dummies, which were positive but the magnitude varied across districts.

4 Discussions

This study assessed the effectiveness of different dissemination pathways as used in promotion and on PPT uptake. The study controlled for the effects of the socio-economic, institutional, farm and regional factors in order to isolate the effect of dissemination pathways on adoption decisions. The results from the descriptive statistics indicate that farmers in the study area are middle aged and the literacy levels are relatively high, as most farmers had at least attained primary level education. This implies that these farmers are able to recognize the importance of an improved innovation such as PPT and its embedded benefits. The regression results provide insights into factors influencing the probability and intensity of adoption of PPT.

The positive relationship observed for FD, FFS and FT is consistent with the study expectations. The fact that FD had the highest impact on both the probability and intensity of adoption could be attributed to FDs' nature of stimulating the interest of many farmers with a strong likelihood that majority of the participating farmers would adopt the technology. In a related study, over 80% of farmers who attended FDs were able to start and subsequently manage PPT without further on-farm demonstrations (AMUDAVI et al., 2008). This implies that FDs are an important and effective venue for passing information about a new technology, a move through which many farmers are reached at shortest time possible. The fact that the majority of the farmers are able to adopt a new technology without further field demonstrations suggests that the use of FD could be a reliably effective option for information delivery. The results further demonstrate the strength of FFS in influencing adoption although the coverage was not as high as that of FDs, and hence the lower adoption levels and intensities. However, farmers' participation in FFS offers a good avenue for interactive learning, knowledge accumulation and subsequent information sharing. 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) approaches compared with media sources. This therefore implies that use of FFS can also be an effective information delivery pathway, but perhaps as an alternative to the FDs which are more effective. Although FTs are an important farmer led extension method, they have not yet reached optimal levels due to limited facilitation and lack of extension training to carry out the dissemination process (AMUDAVI et al., 2009). This perhaps explains why its impact on adoption was relatively low compared to FD and FFS.

The non-significance of the factors representing farmers' characteristics on the intensity of PPT adoption was attributed to inclusion of more variables representing information sources. Several studies (e.g MAUCERI et al., 2005; LANGYINTUO and MUNGOMA, 2008) have shown that some socioeconomic factors only affect adoption of a technology to some degree, but when the variables representing the source of information are added, the effect from these factors become insignificant. This implies that while farmer characteristics may significantly influence technology adoption, from a wider perspective, access to information, especially through specific means, has much more significant impact on adoption than any household factor. This finding is relevant in guiding extension practitioners on how to improve technology promotion. It further implies that provision of quality information through effective means is critical for maximum adoption of a new innovation rather than the mere understanding of socio-economic factors. This observation may however be technology specific since some technologies are less knowledge intensive. Validation of this finding for different technology setups may therefore be important.

The inverse relationship observed between farm size and adoption of PPT was considered desirable, especially for Nyanza and western provinces which comprise mainly smallholder farmers (mean land sizes = 3.9 acres, table 2). This is because; this group of farmers is more vulnerable to the *Striga* and stemborers attack resulting in major economic losses. The recommended conventional control 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 unaffordable to these resource poor farmers (KHAN et al., 2001). Compared to these conventional control methods, PPT is relatively affordable 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 DABERKOW (2003) observed that increasing farm size was increasing 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.

The inverse relationship observed for distance to a major access road (tarmac road) and adoption measures may 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. The variations of regional dummies reflects the heterogeneity of resource base across 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 (FERNANDEZ-CARNEJO et al., 2001).

5 Conclusion and Implications

This study has demonstrated that dissemination pathways had a major impact on the adoption of PPT more than did the 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 technology adoption than others. The fact that FDs had the highest impact on PPT adoption implies that they should be considered as a relatively effective dissemination pathway with a significant potential of enhancing the farmers' ability to intensify uptake of new/improved technologies. However, a combination of pathways can be used in order to utilize each pathway's individual advantages. For example, FFS has an advantage of providing intensive learning, while FTs have the advantage of having knowledge of the social network within the community. These two approaches (FFS and FT) could compliment each other as alternative pathways to FD. The information generated from this study could have a broad applicability to other technologies. However, generalizing the effects that these different pathways would have on adoption of other technologies can be complicated by the nature of their characteristics. It may, therefore, be difficult to develop a universal dissemination model that holds true in all cases without technology specific studies to validate these results. Also, 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 the potential adopters of PPT, and also 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 avail information to those farmers in the remote areas in order to enable them make decision to adopt or not.

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