

Push-Pull Technology and Determinants Influencing Expansion among Smallholder Producers in Western Kenya

Amudavi, D.M.^{1,2*}

^{1*} International Centre of Insect Physiology and Ecology,
P.O. Box 30772, Nairobi, Kenya:
Tel: +254 5922216;
Fax: +254 59 22190
damudavi@mbita.mimcom.net

Khan, Z.R.¹

Midega, C.A.O.¹

Pickett, J.A.³

Lynam, J.⁴

Pittchar, J.¹

² Egerton University, Njoro, Kenya

³ Rothamsted Research, Harpenden, Hertfordshire AL5 2JQ, UK

⁴ Kilimo Trust, East Africa

Abstract

Several constraints limit farm productivity among most smallholders in western Kenya. A novel integrated management system called 'push-pull' technology (PPT) has been developed by ICIPE and partners in mitigation. It entails inter-cropping maize with a stemborer moth repellent forage legume, silverleaf desmodium (push), and planting around the intercrop an attractive trap crop, Napier grass (pull). Striga emergence and seed bank is also significantly reduced through chemical mechanisms by desmodium root exudates. This study assessed the influence of an integrated habitat management strategy called Push-pull technology (PPT) on maize productivity and factors influencing its expansion among smallholder farmers in western Kenya. The technology significantly reduced production constraints from 17.7 to 6.4 out of 28 units, translating into 64% mitigation. In spite of this, intensification or expansion has largely been hampered by limited access to Desmodium seed for the 'push' component and knowledge/information on PPT. Econometric findings revealed a robust and positive effect of large households, longevity of technology use, membership in productive farmer groups and organizations and residence in medium potential areas on PPT expansion, suggesting considerable scope for the technology to contribute to food security and poverty alleviation. These findings signal the need to strengthen both formal and informal institutions to develop desmodium seed production and market systems to help increase PPT uptake and expansion.

Key words: 'Push-pull' technology (PPT), expansion, desmodium seed, Kenya.

Introduction

Maize, *Zea mays* L., serves as the main staple crop and important source of income for the smallholder households in western Kenya region (Ajanga and Hillocks, 2000). The region however, generally experiences low agricultural productivity, high levels of poverty and food insecurity (Bünemann et al., 2004). Low maize productivity in the region is partly due to cereal stemborers and parasitic weed, *Striga* (Khan et al., 2008), low and declining soil fertility due to continuous cropping (Sanchez, 2002), and poor delivery of agricultural extension services (Kamau et al., 2000). Given the rapidly growing rural populations with densities ranging from 150 in low potential areas (e.g., Suba district) to 900 persons per sq km in high potential areas (e.g., Vihiga district) and demand for cereals and the gap between potential and actual yields (Pingali and Pandey, 2000), it is essential to address these constraints.

The International Centre of Insect Physiology and Ecology (ICIPE) in Kenya and partners (Rothamsted Research in UK, the Kenya Agricultural Research Institute (KARI), and the Kenya Ministry of Agriculture), have developed a novel, integrated cropping system referred to as push-pull technology (PPT) (Cook et al., 2007) in mitigation. The technology is based on a stimulo-deterrent diversionary strategy (Miller and Cowles, 1990), where insect pests are repelled from a harvestable crop and are simultaneously attracted to a ‘trap’ crop (Hassanali et al., 2008). It involves intercropping maize with fodder legume desmodium (*Desmodium uncinatum*) and planting Napier grass (*Pennisetum purpureum*), as a trap crop around the crop field. Volatile chemicals naturally emitted by the desmodium repel the stemborer moths away from the maize field (push) while those released by the Napier grass attract them (pull) (Khan et al., 2000). Because stemborer moths prefer Napier grass to maize for oviposition (Khan et al., 2006; Van den Berg, 2006), majority of the eggs laid are consequently trapped by the Napier grass leaving the maize crop protected. Poor nutrient composition of Napier grass and its sticky sap, and abundant natural enemies associated with the grass inhibit full larvae development (Van den Berg, 2006; Khan et al., 2007). The desmodium also inhibits *Striga* growth through effects of nitrogen fixation and soil organic matter, ground smothering, and chemical allelopathy. Some of the allelochemicals produced by desmodium roots stimulate *Striga* seed germination while others inhibit development of *Striga* and subsequent attachment to maize roots (Khan et al., 2002; Tsanuo et al., 2003), leading to continual depletion of *Striga* seed bank in the soil.

Although PPT may confer multiple benefits and hence stimulate the desire to get it to wider target of farmers, expected targets may not be reached according to the theory of “livelihood strategies” (Chambers and Leach, 1989). This theory cautions that not all farmers are “profit-maximizers” but “welfare (utility) maximizers”, pursuing multiple objectives, including secure provision of food and essential goods and services, savings and social security (i.e. secure access to subsistence goods and productive resources). Thus, whereas some studies have examined reasons for adoption or dis-adoption of new technologies (e.g., Feder, et al., 1985; Adesina and Baidu-Forson, 1995; Kalule, et al., 2006; Marennya and Barrett, 2007), few have investigated factors for intensified use (expansion) of new technologies. Expansion here refers to increased multiple cropping in the cultivable area under the PPT to maximize on PPT benefits.

Purpose and Objectives of the Study

The objective of this study was to assess how PPT influences maize production constraints and establish factors influencing its intensified use in order to proffer policy implications on how to effectively disseminate the technology among smallholder farmers in western Kenya and beyond. We, therefore, assessed: (1) farmers’ ratings on the severity of maize

production constraints before and after adoption of PPT; (2) the benefits derived from PPT; (3) demand for desmodium seed, and (4) factors influencing decisions for PPT expansion.

Methods and Data Sources

The study was conducted between December 2006 and January 2007 in 15 districts in western Kenya (Table 1) (Jaetzold and Schmidt, 1982, 1983). The region has a warm and humid climate that supports various crops and livestock. Its soils are N and P-deficient due to continuous cropping and inability of smallholder farmers to invest in fertilizers (Onduru et al., 2001), aggravating severity of the two major biotic pests, stemborers and *Striga*, which are a menace in all the districts, except in Trans Nzoia where only maize stemborers are present.

Table 1

Location, Agroecological Zones (AEZ), and Population Density of the Study Districts

District	Meters above sea Level (m)	Agroecological Zone	Mean annual rainfall (mm)	District coordinates	Pop. density (persons/km ²)
Suba	1200 – 1600	UM 1	700-1150	0°20'-0°52' S, 34° 10'-15E	148
Bondo	1135-1350	LM1-2, LM3-4	750-1200	0°25'-0°2' S, 34°0'-34° 33' E	246
Nyando	1135-1300	LM4	800-1200	0°-0° 15' S, 34°80'- 35°75' E	270
Teso	1135 - 1300	LM1-2, LM3-4	700-1500	0°1'-0°46' S,	325
Busia	1200 - 1500	LM1-2, LM3-4	1200-1700	33°54'-34° 26' E	338
Bungoma	1500 - 2500	UM1, UM2-3, UM4, LM2-3	630-1600	0°25'-0° 53' S, 34°21' - 35°04' E	424
Siaya	1135-1500	LM1-2, LM3-4	1200-1800	0°26' to 0° 18' S, 33° 58'-34°33' E	316
Rachuonyo	1280-2100	LM1-4, UM2-4	740-1200	0°17' -0°36' S, 34°26' E	325
Homa Bay	1163 - 1219	UM1-2, LM1-4	740-1200	0°40' -0° S, 0° -34°50' E	249
Kuria	1140-1600	UM1-2, LM1-4	800-1400	1° 5' - 1°22' S, 34°22' - 34°43' E	261
Migori	1135-1700	LM1-5, UM1-2	700-1800	0°40' -0° S, 34°-34°50' E	257
Kisii	1600-2000	UM1, LH1-2	1350-2100	0°30'-0°58' S, 34°38'- 34° E	758
Vihiga	1300-1500	LM1 – UM1	1800-2000	34°30' -35° 0' E, 0° -0° 15' N	886
Butere- Mumias	1240 - 1641	LH-LM1-2	1600-2800	0°09' -0° 20'S, 34°29' -34°33'E	508
Trans Nzoia	1600-3800	LH3	850-1000	0°52' -1°18' S, 34°38' - 35°23' E	231

Note. UM - Upper Midland; LM- Lower Midland; LH-Lower Highland; UH-Upper Highland

Data and Methods

Data were collected using a cross-sectional household survey on a sample of 900 PPT practicing farmers, 60 selected from each of the 15 districts. The dataset included personal and household characteristics (age, sex, highest education attained by the farmer, farming experience, household size, and group memberships) and farm characteristics (farm size, land tenure, and livestock). To estimate the impact of PPT three indicator measures were used: 1) perceived reduction in

production constraints, 2) level of farmer inquiry about and uptake of PPT, and 3) farmers' willingness to purchase desmodium seed. Seven production constraints on farms (stemborer infestation, Striga infestation, low soil fertility, soil erosion, low soil moisture, fodder shortage, and low maize yield) were rated on a 5-point Likert scale (0=no problem, 1=minor problem, 2=moderate problem, 3=serious problem, 4=very serious problem) "before" and "after" PPT adoption. Additional issues investigated also included the constraints to adoption of PPT.

To estimate the determinants of decision-choice in technology adoption a binomial or multinomial variable approach can be adopted, using either a latent variable or random utility factor (Rogers, 1995). The former was used in which there is an unobserved latent variable that underlies the observed binary dummy variable of expanding or not expanding the cultivatable area under PPT. A logistic regression analysis was used to test this through the equation:

$$Y_i = \beta_0 + \beta_{i1}X_{i1} + \beta_{i2}X_{i2} \dots, \beta_{ik}X_{ik} + u_i \quad (i=1 \dots k; \quad i = 1, \dots, N)$$

Where Y_i is a binary variable equal to 1 if there is expansion (otherwise zero). The conditional mean of y given the independent variables X_i ($i=1 \dots k$) is $E\{Y_i\} = \mu_{y|x_i} = \pi_i$, where $\pi_i = \Pr(Y_i = 1|x_i) = \pi_i$ (x_i)= $\Pr(x_i \geq 1)$. β_0 and β_i are the coefficients estimated using the explanatory variables while u_i is an independently distributed error term.

Results and Discussion

Basic Socio-Economic Characteristics

About 49% of the respondents were female-headed (Table 2). The average age of the household heads was about 45 years. About 86% were married while 12% were widowed. Over 52% had primary education, 34% secondary education, and 6.5%, college or tertiary formal education.

Table 2

Description of Socio-Economic Characteristics, Technology Use and Residence (N=887)

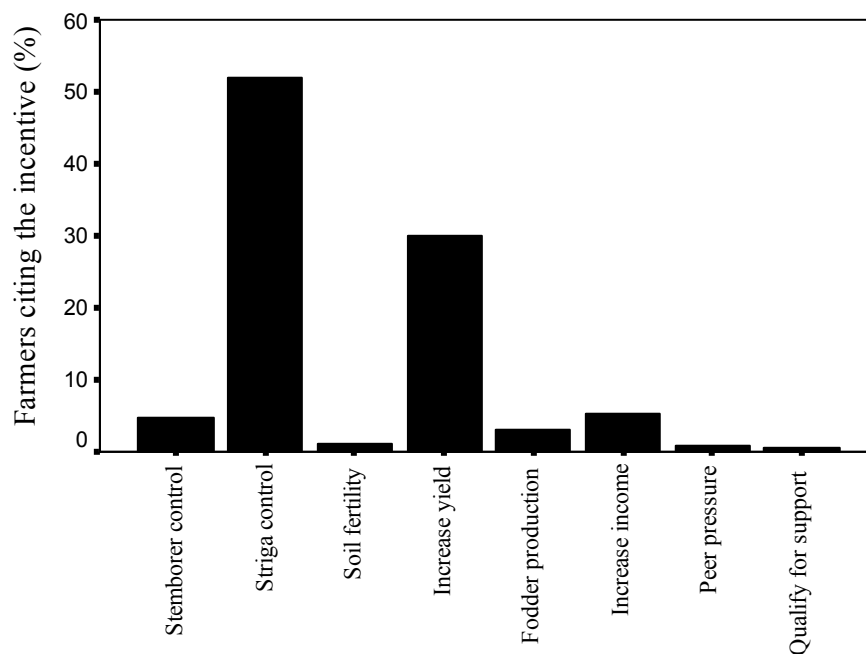
Variable	Proportion (%)	Sample Mean	Sig.
Female household head (yes=1)	49.1		NS
Married (yes=1)	85.7		**
Widowed (yes=1)	12.0		**
Age of farmer (years)		45.3(12.1)	**
Primary education (yes=1)	52.3		***
Secondary education (yes=1)	33.7		***
College/Tertiary education (yes=1)	6.5		***
Household size (number)		6.5 (2.8)	**
Farming experience (years)		18.5 (11.4)	**
Land size (acres)		3.98 (4.16)	***
Land tenure (yes=1)	46.5		***
Total livestock units (TLU) (unitless index)		2.2 (1.9)	***
Longevity of technology use (years)		1.15 (1.4)	***
Membership in productive groups (yes=1)	62.2		***
Medium agroecological zone (AEZ) (yes=1)	42.7		***
High agroecological zone (AEZ) (yes=1)	27.1		***

Note. Figures in parentheses represent standard deviations. Statistically significant levels at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$. TLU is Tropical Livestock Units. A TLU is typically taken to be equivalent to 250kg of annual with bull=0.7, cow=0.6, steer=0.5, heifer=0.4, calf=0.2, shoat=0.1, lamb or kid=0.03 (ILCA, 1990).

A typical household had seven members and owned about 3.98 acres of land, with 47% having title deeds. The respondents had average farming experience of 18.5 years and about 2.2 total livestock units (TLU). About 62% belonged to groups that provided benefits and services related to agriculture, environment, or rural development. About 43% resided in medium, 32% in low, and 27% in high potential areas. The farmers had been using PPT for over one year (over two cropping seasons) in all districts except in Trans Nzoia which has one cropping season in a year. There were significant differences in all the variables tested, except gender of household head, suggesting existence of a correlation between the variables and decisions to expand the PPT.

Incentives and Benefits for Adopting PPT

Figure 1 shows the incentives that stimulated PPT adoption. Striga control was cited by a moderate majority of the respondents, 52%, as the main reason for the technology's adoption.



Incentives for adoption of push-pull technology

Figure 1. Main incentives for farmers' adoption of PPT.

This was followed by increase in maize yield, which is directly related to Striga control, as indicated by a third of the respondents. Opportunities for increased income and stemborer control were mentioned by 5.4% and 4.7% of the respondents respectively. Other reasons, though not significant are shown in Figure 1. Table 3 shows statistically significant reduction in the constraints self-assessed by the respondents across the 15 districts. Farmers in Rachuonyo district realized the greatest reduction followed by Homa Bay, Bungoma, Kisii and Bondo farmers in that order. Overall, the constraints changed from 17.7 to 6.4 units before and after adoption of PPT respectively; representing 64% mitigation by the technology.

Striga infests 2.4 million hectares of smallholder maize farmland in sub-Saharan Africa. In Kenya, the weed infests over 210,000ha of maize farmland, thereby reducing farm productivity

and driving several rural households in the region into extreme poverty (AATF, 2007). The PPT seems an appropriate technology for such a problem. However, as noted by Scherr (2000) the resource constraints of the poor, their small scale of production and their exposure to high risks mean that technologies targeting such farmers must demonstrate, in addition to other desirable attributes, potential for incremental adoption and adaptation, protection of food security, and low risk of crop failure. On-farm studies have demonstrated that PPT controls both *Striga* and cereal stemborers, key constraints to increased maize yields (Hassanali et al. 2008; Khan et al., 2008).

Table 3

Farmers' Ratings of Severity of Farm Constraints Before and After PPT Adoption (N=887)

District	Average rating of severity of aggregate constraints		
	Before adoption of PPT (B)	After adoption of PPT (B)	Difference (B-A)*
Homa Bay (n=60)	21.80 (3.085)	6.00 (4.705)	15.80 (5.464)
Kisii (n=60)	22.10 (3.727)	7.42 (4.366)	14.68 (6.152)
Trans-Nzoia (n=60)	17.77 (1.835)	7.02 (2.678)	10.75 (3.333)
Vihiga (n=60)	18.88 (2.841)	8.60 (3.733)	10.28 (4.720)
Butere-Mumias (n=60)	17.40 (4.081)	6.88 (3.330)	10.52 (4.144)
Bungoma (n=59)	17.00 (5.031)	1.91 (2.699)	14.96 (5.247)
Rachuonyo (n=60)	24.40 (4.047)	4.35 (3.526)	20.05 (5.967)
Siaya (n=60)	17.55 (2.702)	10.30 (4.126)	7.25 (4.887)
Teso (n=59)	15.68 (3.345)	5.64 (2.172)	10.03 (3.778)
Nyando (n=49)	17.88 (2.266)	10.56 (3.792)	7.11 (4.001)
Kuria (n=60)	20.27 (2.106)	8.25 (2.047)	11.98 (2.431)
Migori (n=60)	13.50 (4.497)	5.13 (1.827)	8.37 (3.906)
Suba (n=60)	10.78 (3.867)	3.05 (1.561)	7.83 (4.113)
Busia (n=60)	12.93 (3.861)	7.72 (3.087)	5.22 (4.833)
Bondo (n=60)	16.43 (3.600)	2.58 (1.999)	13.65 (4.616)
Total (N=887)	17.62 (4.961)	6.41(4.026)	11.23 (6.010)
F-Statistical Test	F=63.540; p<0.001	F=35.875; p<0.001	F=43.338; p<0.001

Note. * Differences are statistically significant at 1%. Figures in parentheses represent standard deviations.

Dissemination and Constraints to Adoption of PPT

We sought to find out whether there were farmers in the study area who in spite of the technology's benefits had not adopted it in their farms (Table 4). Over 70% in most of the districts responded in the affirmative except in Busia (45%), Suba (53.3%), Bungoma (62.1%) and Rachuonyo (65%). Table 4 also showed that a PPT farmer communicated the technology to about 9.04 fellow farmers with about 3.11 of them eventually adopting it. This translated to a 34% adoption rate and indicated evidence of farmer-to-farmer influence. Five districts (Butere-Mumias, Kuria, Bungoma, Homa Bay and Siaya) had more farmers than the average seeking information about the PPT. Similarly, in five districts (Trans Nzoia, Vihiga, Bungoma, Teso and Kuria) more farmers than the average who had adopted PPT. Highest adoption rates per year (for most districts, two seasons) were observed in Kuria, Vihiga, Trans Nzoia and Bungoma.

Given the required management of PPT, we examined the constraints limiting its adoption. About 46% cited lack of access to desmodium seed and 26% lack of knowledge/information (Table 5). Other constraints included insufficient labour (19%), gender disparity in making farm investments decisions (14.5%), inability to intercrop with food legumes

(12.5%), lack of extension follow ups (9%), unfavorable climatic variability heightening associated economic risks (4%), and lack of funds to purchase inputs (3%).

Table 4

Farmer-to-Farmer Extension of PPT During an Average of Two Seasons, 15 Districts, Western Kenya

District	% who mentioned that their neighbors knew benefits of PPT	Farmers Neighboring Adopters of PPT		
		Number who inquired about PPT	Number who eventually adopted PPT	Adoption rate (%)
Homa Bay	98.3	10.22	2.05	20.0
Kisii	81.7	3.53	2.35	66.6
Trans-Nzoia	78.3	9.20	5.13	55.8
Vihiga	100.0	8.87	5.92	66.7
Butere-Mumias	91.7	25.03	1.74	7.0
Bungoma	62.1	10.31	4.11	40.0
Rachuonyo	65.0	3.88	1.42	36.6
Siaya	85.0	10.75	2.98	27.7
Teso	94.9	7.68	3.14	40.9
Nyando	83.7	4.22	0.45	10.7
Kuria	91.7	15.10	8.25	54.6
Migori	70.7	4.22	1.81	42.9
Suba	53.3	7.00	2.17	31.0
Busia	45.0	8.42	1.92	22.9
Bondo	88.3	6.33	2.71	42.8
Average per district	79.3	9.04	3.11	34.4
Statistical test	$\chi^2 = 142.054, p < 0.001$	$F = 7.098, p < 0.001$	$F = 9.029, p < 0.001$	

Table 5

Farmers' Perception of Constraints Limiting Spontaneous Uptake of PPT, 15 Districts, Western Kenya

Constraint	% Farmers indicating the constraint ^a
Lack of access to desmodium seed	45.8
Lack of knowledge or information about the technology	26.2
Labour requirement in PPT establishment	18.9
Lack of sufficient decision making by women farmers	14.5
Inability to intercrop with food legumes	12.5
Lack of motivation due to failure of extension follow ups	9.2
Unfavourable climatic variability associated economic risks	3.9
Lack of funds to purchase inputs	2.6
Inability of the technology to be applied on large farms	0.5

Note. ^aThe summation of the percentages apportioned to the mentioned constraints to Push-pull technology uptake for each respondent is more than 100% because some respondents gave more than one constraint.

Demand for Desmodium Seed in PPT Uptake

We investigated the demand for desmodium seed as measured by willingness to purchase different amounts of the seed. Figure 2 showed that the majority of the respondents (98%) were willing to purchase the seed if it were made available with 65% willing to purchase 100-250gm quantities, enough seed to cover a plot of 20m by 20m to a quarter of an acre (ICIPE, 2007).

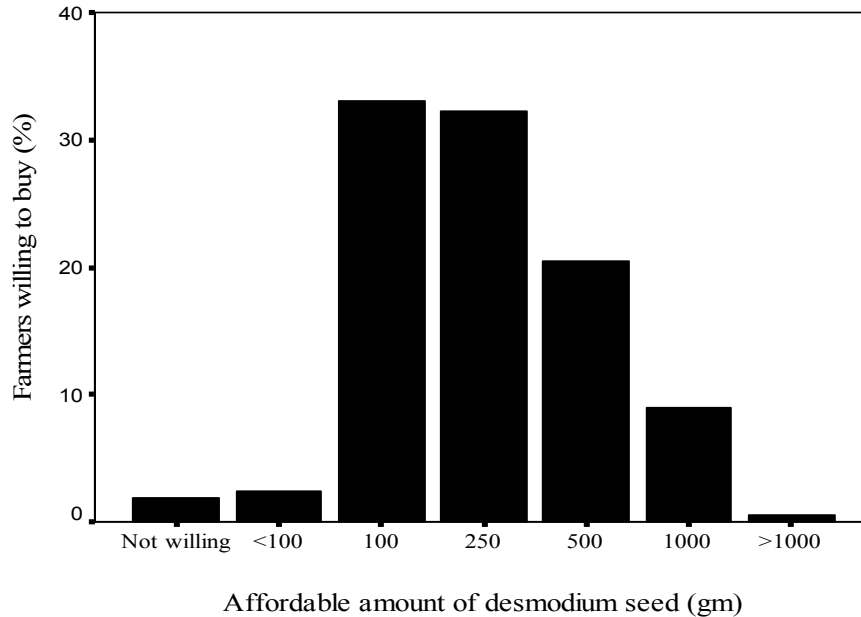


Figure 2. Farmers willing to purchase different amounts of desmodium.

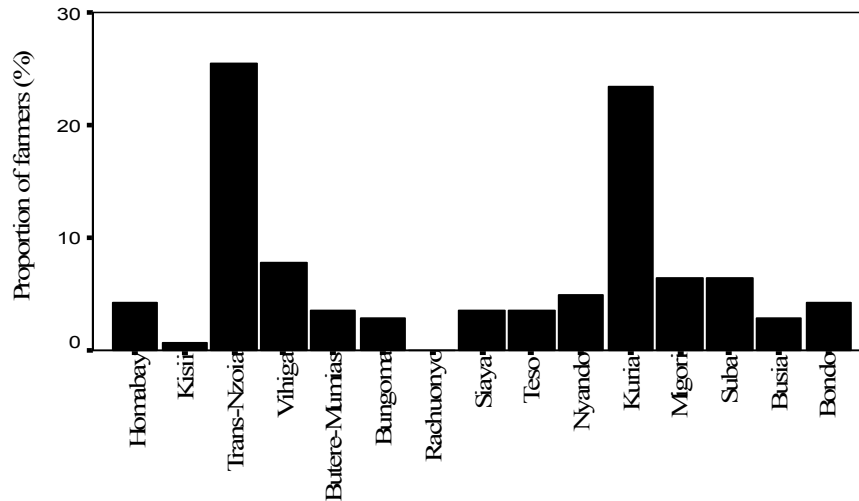
About a fifth of them were willing to purchase 1/2kg seed while less than a tenth were willing to purchase at least a kilogram. The propensity to purchase the seed appeared to be responsive to quantity demanded beyond an atypically low range. Thus increasing the quantity from 500gm costing about USD 10 to 1000gm costing about USD 20 reduced potential buyers from 20.5% to 9.2%. The farmers in our study were typically non-commercial subsistence farmers. Preference for small seed quantities by such farmers is a useful strategy to avoid the risk of crop failure (Jones et al., 2001). The willingness to purchase desmodium seed suggests that a formal seed supply system is needed provided there is a widespread promotional effort to expose many farmers to the PPT.

Determinants of PPT Expansion Among Farmers

We sought to find out the trend of intensified use of the technology and whether all farmers were equally likely to undertake PPT expansion. Figure 3 showed that there is a significant intensified use of PPT in all districts except in Rachuonyo. On average, 16% of the farmers had expanded PPT use. In Trans Nzoia, Kuria and Vihiga 60%, 55% and 18.3% of the farmers respectively had expanded with marginal expansion in the rest of the districts. A logistic regression showed that none of the socioeconomic variables were significant (Table 6). However, the number of household members increased the probability of PPT expansion by a factor of 2.9 ($e^{1.056}$) times per unit increase in household size, suggesting that increased proportion of land put under PPT can be a response to increased population pressure. The longevity of PPT on the farm significantly increased the likelihood of PPT expansion by a factor of 4.3 per unit increase in every year the farmer enjoyed the benefits of PPT while membership

in productive groups increased it by a factor of 8.5. Farmer's residence in medium agroecological zones (AEZ) compared to low AEZ increased the likelihood by a factor of 11.5.

The findings support those by Oduol and Tsuji (2005) that as land pressure becomes severe, farmers increase crop intensity through land use practices and technologies that increase productivity and efficiency. As indicated by Boserup (1965) growing populations manage to adapt by changing their production methods to preserve and improve the fertility of their land. Under such conditions, farmers seek options that maintain soil fertility in order to sustain their crop-livestock integration (Rovere, et al., 2007).



Distribution of farmers expanding push-pull technology use

Figure 3. Proportion of farmers who have expanded PPT across districts.

Table 6

Logistic Regression Output for Expansion of Acreage Under PPT (N=887)

Independent variable	Dependent variable: Expansion (1=Y, 0=N)	
	β	Exp(β)
Constant	-3.953 (.751)**	.019
Gender of main farmer (1=F, 0=M)	.301 (.213)	1.352
Age of main farmer (years)	.006 (.011)	1.006
Primary education of main farmer (1=Yes, 0=No)	-.304 (.400)	.738
Secondary education of main farmer (1=Yes, 0=No)	-.140 (.435)	.869
College/Tertiary education of main farmer (1=Yes, 0=No)	-.777 (.647)	.460
Household size (Count)	.055 (.035)*	1.056
Farming experience (years)	-.004 (.012)	.996
Land size (acres)	-.001 (.005)	.999
Ownership of title deed (1=Yes, 0=No)	.171 (.216)	1.187
Total Livestock Units (Unitless)	.063 (.054)	1.065
Longevity of technology use (years)	.374 (.063)**	1.454
Potential of technology (Unitless index)	.007 (.018)	1.007
Membership in productive group (1=Yes, 0=No)	.759 (.231)**	2.137
Residence in medium AEZ (1=Yes, 0=No)	.892 (.308)**	2.439
Residence in high AEZ (1=Yes, 0=No)	.110 (.356)	1.116

Omnibus Tests of Model Coefficient	Chi-square = 88.769; df = 14; P <.001
Summary of Model: -2 Log likelihood	638.497
Nagelkerke R Square	.169
Overall Percentage (%)	82.5

Note. Statistically significant levels: * p < 0.10; ** p < .05; Figures in parentheses represent standard deviations.

The influence of membership in productive groups suggests that poor farmers who may be excluded from key institutions that provide access to investment resources may face serious livelihood consequences. Farmer organizations and groups, if properly managed can enable members to access resources to overcome short-run liquidity constraints and reduce risk associated with new technologies, and hence non-participation disadvantages the poor who may not afford upfront memberships requirements (Amudavi, 2007; Mendola, 2007). Membership in farmer organizations provides opportunities for farmers to achieve more rapid technology adoption for improved management at the local landscape as well as farm scale.

Conclusion, Educational Importance, and Implications

The PPT reduces production constraints of Striga and stemborer infestation, soil erosion and low soil fertility, low soil moisture, fodder shortage, and low maize yield. Of these, Striga control was the main reason for adoption of PPT. This means that if it is not dealt with in time, it can become a serious livelihood threat to smallholder farmers who largely depend on land for their livelihood. However, two limiting constraints to use and expansion of PPT are non-availability of desmodium seed and limited information/knowledge on PPT. There is rapid diffusion of PPT through farmer-to-farmer extension and many farmers are willing to purchase the desmodium seed if it is made accessible. Empirical results suggest that large households, longer experience with PPT, membership in farmers' groups and organizations and residence in medium potential areas are factors likely to accelerate expansion of PPT. Surprisingly, we found little evidence of influence of socioeconomic factors such as education, land size and size of livestock (TLUs) on the PPT expansion.

These findings provide some useful policy implications. Given the complexity of the technology, farmers need to be trained on how to manage risks associated with the technology in order to make investments more attractive. Because memberships in farmer groups and organizations increase farmers' likelihood to devote more of the limited cropping land to PPT there is need to support and work with such organizations. Linking such organizations to the private sector (seed companies and stockists) may improve the local seed market. Moreover, the spontaneous farmer-to-farmer diffusion of PPT and the inability of this sector to meet the demand for desmodium, impute the need for increased formal seed sector intervention. Workable interventions that include pricing, marketing and increased accessibility of this multifunctional technology to wider target groups are crucial to easing some of the key constraints limiting agricultural productivity of smallholder agriculture in Western Kenya and beyond.

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