UPSCALE

UPSCALING THE BENEFITS OF PUSH-PULL TECHNOLOGY FOR SUSTAINABLE AGRICULTURAL INTENSIFICATION IN EAST AFRICA

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 861998.

D7.1:
Co-identifying (gendered) socioeconomic and policy barriers to push-pull adoption and strategies to address them

April 2024

UPSCALE

Author(s)/Organisation(s)	Alice Murage, Dave Mwangi Ireri (KALRO)
Contributor(s)	Beatrice Muriithi (icipe), Fredah Maina (KALRO)
Work Package	7
Delivery Date (DoA)	30th April 2024
Actual Delivery Date	30th April 2024
	The adoption of agricultural technologies, particularly in regions like Africa where smallholder farmers dominate, is vital for enhancing food security and livelihoods. Push-pull technology (PPT) offers a promising solution for sustainable pest control in cereal production. Despite its potential, barriers hinder widespread adoption, including gender disparities among smallholder farmers. The UPSCALE project aims to identify and overcome these barriers, focusing on socioeconomic, environmental, gender-related, and institutional factors. Using panel data collected at baseline and midline levels in Kenya, Ethiopia, Rwanda, Tanzania, and Uganda, the study analyzes PPT adoption patterns. Results indicate that older farmers, particularly women, are more inclined towards PPT adoption, with factors like education level and household size influencing adoption. Institutional factors such as access to credit and extension services also facilitate adoption. However, challenges like seed availability and knowledge gaps persist. Multinomial logit and Double Hurdle Models reveal significant factors influencing adoption patterns and expansion, emphasizing the importance of context-specific strategies tailored to each country's unique barriers and opportunities. The synthesis of key informant notes underscores common challenges across the agricultural value chain and suggests approaches to address them, including increasing awareness, improving infrastructure, and enhancing policy support. Overall, understanding gender dynamics and implementing targeted strategies are crucial for successful PPT adoption, ultimately promoting food security and gender equality in Africa.

Document Revision History

Date	Version	Author/Contributor/ Reviewer	Summary of main changes
23/02/2024	1.1	A. Murage (KALRO)	First draft
27/02/2024	1.2	D. M. Ireri (KALRO)	Data analysis and drafting
11/03/2024	1.3	F. Maina (KALRO), B. Muriithi (icipe)	Review and additions
03/04/2024	1.3	E. Poppenborg (JLU)	Review and edits
20/04/2024	1.4	D. M. Ireri (KALRO)	Review and edits
27/04/2024	1.5	A. Murage (KALRO)	Review and finalization
30/04/2024	1.5	E. Poppenborg (JLU)	Final review

Dissemination Level

PU	Public Deliverable	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	**X**

UPSCALE Consortium			
No	**Participant Organisation Name**	**Short Name**	**Country**
1	JUSTUS LIEBIG UNIVERSITY OF GIESSEN	JLU	DE
2	THE INTERNATIONAL CENTRE OF INSECT PHYSIOLOGY AND ECOLOGY LBG	ICIPE	KE
3	BAYERISCHE FORSCHUNGSALLIANZ BAVARIAN RESEARCH ALLIANCE GMBH	BayFOR	DE
4	EASTERN AFRICA FARMERS' FEDERATION SOCIETY	EAFF	KE
5	JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY	JKUAT	KE
6	KENYA AGRICULTURAL AND LIVESTOCK RESEARCH ORGANISATION	KALRO	KE
7	MASENO UNIVERSITY	MU	KE
8	FH ASSOCIATION	FH	CH
9	RWANDA AGRICULTURE AND ANIMAL RESOURCES DEVELOPMENT BOARD	RAB	RW
10	INOSENS DOO NOVI SAD	INOSENS	RS
11	UNIVERSITY OF KWAZULU-NATAL	UKN	ZA
12	LUNDS UNIVERSITET	ULUND	SE
13	SVERIGES LANTBRUKSUNIVERSITET	SLU	SE
14	UNIVERSITAT ZURICH	UZH	CH
15	TANZANIA AGRICULTURAL RESEARCH INSTITUTE	TARI	TZ
16	NATIONAL AGRICULTURAL RESEARCH ORGANISATION	NARO	UG
17	INSTITUTE FOR SUSTAINABLE DEVELOPMENT	ISD	ET
18	JULIUS-MAXIMILIANS-UNIVERSITAT WUERZBURG	UWUE	DE
19	LEIBNIZ UNIVERSITY OF HANNOVER	LUH	DE

Funding Scheme: Research and Innovation Action (RIA) ● Theme: H2020-SFS-2019-2
Project Start Date: 01 November 2020 ● Duration: 60 months

Table of contents

List of tables

List of figures

List of Abbreviations and Acronyms	
WP	Work Package
O	Objective
D	Deliverable
EC	European Commission
FTC	Farmer Training Centers
GA	General Assembly
MAC	Multi-Actor Communities of practice
NGO	Non-governmental organization
PPS	Probability proportional to size
PPT	Push-Pull Technology
SOAP	Sigomere Organic Agriculture Programme
VC	Value Chain

1 Introduction

1.1 Background

The adoption of agricultural technologies plays a pivotal role in enhancing food security, improving livelihoods, and promoting sustainable agricultural practices, particularly in regions like Africa where smallholder farmers dominate the agricultural landscape. Among these technologies, Push-pull technology (PPT) stands out as a promising approach for enhancing sustainability through controlling pests like stemborers, striga, and fall armyworm in cereal production. PPT, developed by *icipe* and partners, originally involved intercropping of a fodder legume *Desmodium spp*., including *D. uncinatum* (Jacq.), with cereals and a perimeter of Napier grass, *Pennisetum purpureum K.* (Schumach) (Khan et al., 2001). Following further research and feedback from the users, this original PPT was later adapted to climate-resilient PPT (CR-PPT) by intercropping cereals with drought-tolerant Greenleaf desmodium, *Desmodium intortum* (Mill.) Urb., and planting *Brachiaria* cv Mulato II as a border crop around this intercrop (Midega et al., 2015, 2017). A third generation PPT was later introduced with brachiaria cultivars that were more tolerant to red spider mites (RSM) (Cheruiyot et al., 2018a, b, c) as well as integrated other non-cereal crops of importance to the target agricultural communities. The mechanism for operations of PPT has extensively been described by Khan et al., 2001, 2002, 2003, Tsanuo et al., 2003, Midega et al., 2003 and Cook et al., 2007. Over the years, the technology has been introduced and adopted in various eastern African region with significant impacts in cereals yield increase (Khan et al., 2008a, b; Chepchirchir et al., 2017, 2018; Kassie et al., 2018). While this technology has the potential to increase cereal production and therefore support food and nutrition security, the successful adoption is often hindered by a myriad of barriers some of which also present numerous opportunities for advancement.

In the context of Africa, the adoption of PPT for pest control in cereal production is not only crucial for enhancing agricultural productivity but also for addressing gender disparities prevalent in the agricultural sector. Women, who constitute a significant portion of smallholder farmers in Africa, often face unique challenges and opportunities in adopting agricultural innovations. Understanding and addressing gender dynamics in the adoption of PPT is essential for promoting equitable access to resources, improving agricultural outcomes, and fostering inclusive development.

This report delves into the barriers and opportunities associated with the adoption of PPT for stemborer, striga, and fall armyworm control in cereal production across Africa, with a particular focus on gender dynamics. By examining the challenges faced by both male and female farmers and identifying strategies to overcome gender-specific barriers, this report aims to provide insights and recommendations for promoting the widespread adoption and upscaling of PPT and advancing gender equality in African agriculture.

1.2 Objectives

The objective of this task within the UPSCALE project was to identify the barriers and opportunities for adoption of PPT as a sustainable intensification practice based on agroecological principles. Specifically, Work Package 7 (WP7) Task 7.1 of the UPSCALE project sought to:

i) co-identify the socioeconomic and policy barriers to push-pull technology adoption, including gender-based barriers,

ii) Identify strategies to address the barriers.

1.3 Problem statements

Since its inception, PPT has been extensively promoted across Eastern Africa through diverse dissemination methods. These include mass media campaigns, field days, farmer field schools, and training sessions led by farmer teachers and peers (Murage et al., 2012). Initially, farmers receive complimentary seed and training starter packs from supporting institutions to showcase the technology's advantages and raise awareness. With the exception of farmer field schools where community farms may be set up for training, dissemination approaches have been strongly geared towards individual farmers, and only rarely coupled with structured community-based support networks, with individual adopters addressing obstacles of associated markets and value chains on their own. While the current adoption of PPT using this model shows promising progress in regions such as Kenya, Uganda, Tanzania, Ethiopia, and to a limited extent in Rwanda, there exists a pressing need to propel its adoption to larger scales envisioned in developmental proposals. The UPSCALE project initiative endeavors to employ a combination of established methodologies and innovative approaches to engage a wide spectrum of stakeholders. However, the success of this endeavor hinges upon a comprehensive assessment of the factors that could either facilitate or impede the widespread adoption of PPT on the envisioned larger scales. Within the framework of WP7, we scrutinize these critical factors encompassing socio-economic, environmental, gender-related dynamics, biotic and abiotic influences, and institutional variables such as access to credit, input, and output markets. Identifying and understanding these multifaceted factors are crucial steps towards devising effective strategies for overcoming barriers and leveraging opportunities to catalyze the adoption of PPT across diverse agricultural landscapes in Africa. Furthermore, the barriers and opportunities identified through this scrutiny are to be understood within the context of the technology’s present dissemination model and institutional setting. We thus aim to identify factors likely to change according to dissemination and adoption models for the technology (e.g. individual vs. community-based), and conversely, to assess if certain issues are inherent to the technology itself. This analysis could shed light on the potential efficacy of alternative adoption approaches and the intrinsic challenges of implementing the technology highlighting needs for its further adaptation.

2 Methodology

2.1 Study sites and sample size

The report uses data collected at baseline and midline levels of the project forming a two-round panel data for the analysis. The surveys were conducted in all target countries in which PPT has been upscaled, namely: Ethiopia (North Shewa, Oromia Special zone, South Welo in Amhara), Kenya (Kisumu, Vihiga, Siaya and Homabay counties), Rwanda (Nyagihaya Sector), Tanzania (Butiama, Bunda, Tarime and Rolya districts in Mara region), and Uganda (Iganga, Kamuli, Namutumba districts). Except for Ethiopia, where the midline survey was not conducted due to security concerns, the data for the two rounds of survey for the other countries was utilized for the analysis.

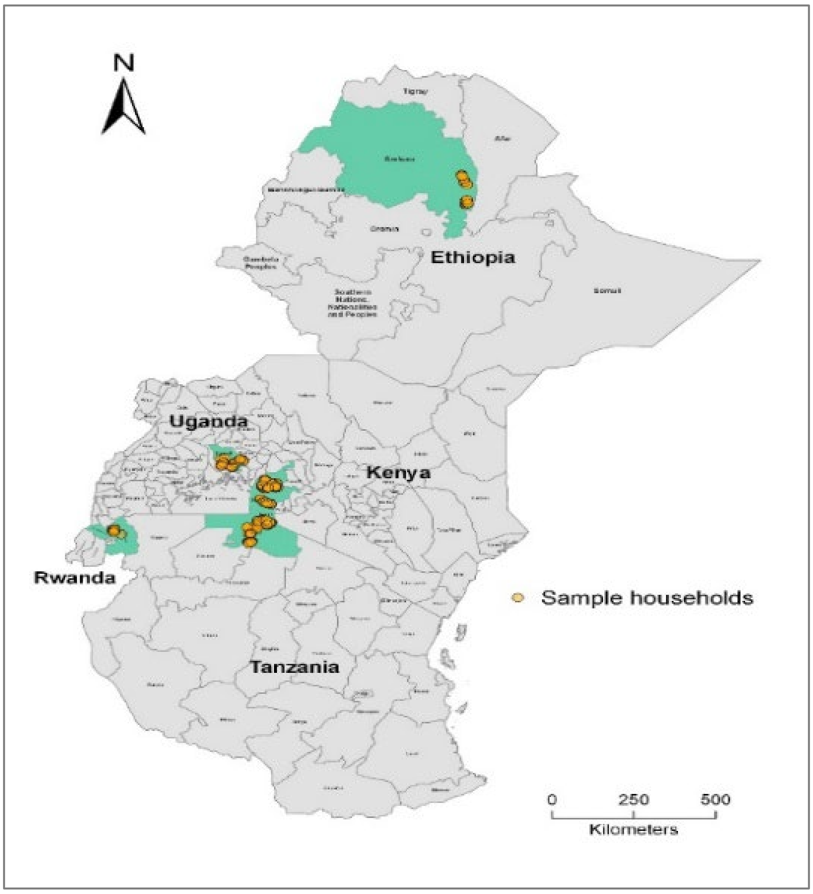

Figure 1: Map of the study sites where baseline and midline household surveys were conducted.

2.2 Sampling design and sample size

The study adopted a longitudinal survey design where PPT and non-PPT farmers within the landscape of the study area were sampled and interviewed individually. For the baseline survey, a total of 1556 farmers were sampled: 304 in Kenya, 308 in Ethiopia, 317 in Tanzania, 319 in Rwanda and 308 in Uganda. In the midline survey, the sample was 1,237 farmers: 304 in Kenya, 305 in Uganda, 299 in

Tanzania, and 329 in Rwanda. A summary of the pooled sample interviewed in baseline and midline surveys is shown in **Table 1**.

Table 1: Sample size (baseline and midline) showing the number of PPT user vs. non user respondents and the number of female vs. male respondents by country

	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	N-user	**User**	**N-user**	**User**	**N-user**	**User**	**N-user**	**User**	**N-user**	**User**
Baseline	**152**	**152**	**206**	**102**	**190**	**127**	**143**	**176**	**210**	**98**
Midline	**173**	**131**	**225**	**80**	**224**	**75**	**125**	**204**	**-**	**-**
Female	**157**		**89**		**111**		**127**		**15**	
Male	**451**		**524**		**505**		**521**		**293**	

N-user=Non PPT user; User=PPT user

2.3 Data type and data collection methods

The surveys were designed to incorporate data on critical potential barriers and enabling conditions to the adoption of PPT, with a focus on socioeconomic, gender, spatial, institutional, environmental, and policy-related factors. A criteria was identified to ensure inclusion in the baseline sampling frame of all the farmers who applied the technology or aspects of it, based on dissemination records from the *icipe* database. Using the probability proportional to size (PPS) approach, a random sample was drawn for the PPT users from the sampling frame of known users recorded in the database with a target of 150 respondents. The PPT sample was then grouped by villages and a sample for non-users was drawn in the field during the data collection exercise whereby villages with similar characteristics to the PPT sampled villages were drawn. Control villages were selected to be as homogeneous as possible with those where PPT was practiced in regard to: (1) socio-economic characteristics, (2) market access, (3) agro-ecological characteristics, and (4) presence of striga, stalk borer or fall army worm. From these villages, a random sample was drawn via transect walk with the same target of 150 respondents: starting from a given point, an enumerator will take a certain direction and pick the *nth* household for the interview, where 'n' will be determined by the population of the household and proportionate sample size of the study region (e.g. every 3rd or 5th household). No correction for gender proportions in the sample was applied. For the midline survey, a follow up was done for all baseline farmers. However, due to survey attrition, replacements were done whereby PPT farmers were replaced, with the expectation to be followed up later in the endline. Due to departing from records of previous dissemination, the tool was designed to capture data from farmers who were using PPT at the time of the survey, as well as those who had used it in the past but stopped (these are collectively defined as 'PPT users'). Both the number of practicing farmers (level of adoption) and the extent of adoption (land under the technology) were recorded. The questions included the socioeconomic characteristics of the farmer, technology characteristics, information sources, technology access, and use (see baseline questionnaire provided as part of deliverable D4.3, June 2021).

A pretest of the original tool was done in Kenya. Research assistants were recruited from each country from a pool of people in the local communities with experience administering mobile based surveys; graduates in agriculture related courses; and can communicate in local languages commonly used in the surveyed areas. The research assistants in each country were trained for three days and they also pretested the tool in the field for a day. During the training and pretesting exercise, the tool was modified with country specific details and translations. The tool was administered in English in Kenya, Uganda, Tanzania and Ethiopia; and Kinyarwanda in Rwanda. Data was collected for a month in each country.

Only household surveys were collected in the baseline, but for the midline survey Key informant interviews and Focus group discussions were also administered to different stakeholders. These included men and women farmers, input suppliers, extension, and other institutional agents, including policymakers and output market actors. Questionnaires were programmed for electronic data collection using the Open Data Kit (ODK). Additionally, barriers and opportunities were discussed through Focused Group discussion, Key informant interviews and Multi-actor community events organized in the context of WP1 (see Deliverables D1.1, 1.3, 1.4).

2.4 Data analysis and Economic models

In this report, we use the pooled data from baseline and midline, thus adopting a panel data approach. Descriptive analysis was done to summarize the relevant variables using frequencies, means and cross-tabulation comparing the users and non-users of the technology, as well as the male and female farmers who were participating in the project. For the purposes of analysis, we categorized the farmers into 7 categories based on the process of agricultural utilization framework model (Brown et al., 2017): Consistent (those farmers who had used PPT continuously for more than three years); Inconsistent (farmers who used PPT but in between seasons they would stop and use it again); Triallers (farmers who had used PPT for one season at the time of the survey, some may stop while others are assumed to continue); Dropout (farmers who used PPT previously but discontinued its use); Uninterested (farmers aware about PPT but have not tried): Expansion (farmers who have expanded PPT use on their land); Unaware (farmers who have not heard about PPT). To analyze the factors influencing adoption, we used a multinomial logit since the response variable (adoption) was categorical but not ordered. We also ran Double Hurdle Models to assess the factors influencing the extent (area) of adoption. Statistical analysis and modelling was done on Stata version 17 software.

2.4.1 Multinomial Logit Model

The multinomial logit model examined the factors affecting PPT farming method adoption among farmers. Several studies have used bivariate, logit, and probit model to determine the factors affecting the adoption of farming technologies. However, the multinomial logit model is advantageous over other models as it allows the analysis of decisions among various categories (Addison, 2023). The multinomial logit model assumes independence of choice and is mutually exclusive (Costa, 2022). Garson (2009) noted that the Multinomial logit model could be simultaneously used to compare more than one contrast: it estimates the log odds of three or more covariates.

Following Gujarati (2005), the multinomial logit model for the study was specified as follows,

$$Prob(Y_i = j) = \frac{\exp(X_i B_i)}{\sum_{j=0}^{i} \exp(X_i \beta_J)} \quad for\ j = 1,2,3..,\mathrm{m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (1)$$

$$Prob(Y_i = j) = P_{ij}(\beta_O + \beta_1 \ldots + \beta_n X_n) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \ldots\ldots\ldots.. (2)$$

Where: $Prob(Y_i = j)$ is the probability that farmers adopt the push-pull method (j), X_i is the vector of explanatory variables (age, gender, education in years, distance to the market in kilometres, ever experienced (Striga, stalk borer and fall armyworm) respectively, credit need, extension access, off-farm income, land holdings, tropical livestock units, and agricultural group membership) and β_J is the vector of parameter estimates associated with push-pull adoption.

The model was represented as follows,

$$M_{ij} = X_{ij}\beta_j + E_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3)$$

Where: M_{ij} is the vector of the adoption level of the push-pull method (j=1 for consistent adoption, 2 for semi-consistent adoption, 3 for inconsistent, 4 for triallers, 5 for dropouts, 6 for uninterested, and 7 for adoption expansion). X_{ij} is a vector of independent variables. β_j is a vector of push-pull adoption-specific parameters to be estimated. E_{ij} is, the error term assumed to have a distribution with mean 0 and constant variance.

2.4.2 Double Hurdle Models

To investigate the factors affecting the extent of PPT adoption (area under PPT) a double hurdle model was used. According to the double-hurdle model, two obstacles must be overcome to determine the percentage of land designated for PPT (Garcia, 2013). The first obstacle relates to variables influencing PPT adoption likelihood, and the second hurdle relates to extent of adoption. Each decision-making process is modeled by a different latent variable. As a result, the probit model is used in the first hurdle considering a PPT usage dummy (1=PPT user, 0=Non-PPT user), and the reduced regression model in the second where the extent of adoption is proxied by the area under PPT. The model is specified as

$y_{i1}^* = z_i'\beta + \varepsilon_i,\ \varepsilon - N(0,1)$ Probability of adoption decision (4a)

$y_{i2}^* = x \propto + v_i,\ v - N(0,\sigma^2)$ Extent of adoption (4b)

$y_i = \propto x_i' + v_i,$ if $y_{i1}^* > 0$ and $y_{i2}^* > 0$ observation mechanism (ε, v) bivariate normal with correlation between errors (4c)

Where y_i is the reported area covered by PPT; y_{i1}^* is are latent variables denoting whether or not a farm household chooses to adopt PPT; y_{i2}^* is the latent variable determining the extent of adoption of PPT, z and x are vectors of parameter estimates; and $\propto$ and β are independent, homoscedastic, and normally distributed error terms; and σ^2 is a standard deviation that takes into account heteroscedasticity throughout observations. Using maximum likelihood methods, the log-likelihood function, which is the sum of the log-likelihoods from the probit and truncated regression, is used to estimate the double-hurdle model. The specified function is a follows

$$\log(L) = \sum_{yi=0} log\left[1 - \phi\left(\frac{x_i a}{\sigma}\right)\right] + \sum_{yi>0} log\left[\phi(z_i\beta)\sigma^{-1}\emptyset\left(\frac{y_i - x_i a}{\sigma}\right)\right] \quad (5)$$

Where $yi = 0$ and $yi > 0$; indicate the lower and upper extremities, respectively, and ϕ and $\emptyset$ are the standard normal cumulative distribution function and density function, respectively. In the double-hurdle model, probit and reduced regressions contain different sets of parameters, therefore they can be assessed independently.

3 Results and discussion

The following section presents the outcomes of our analysis. We commence by delineating the descriptive analysis, illustrating two layers of the results: the comparison between users and non-users of PPT, and the comparison between male and female farmers in each country using descriptive statistics. Subsequently, we delve into the findings of the statistical models elucidating the factors influencing the levels (categories) of adoption (multinomial logit results), followed by an exploration of the factors shaping the extent of adoption, measured in terms of the area under PPT (results of the double hurdle model).

3.1 Household socio-economic characteristics

Most of the farming household heads were aged between 44 and 56 years, indicating a predominantly middle-aged farming community (**Table 2**). Notably, in Kenya, Uganda, and Rwanda, women farmers tended to be slightly older than their male counterparts. Age plays a significant role in technology adoption, often yielding a mixed effect—as a barrier or an opportunity—depending on the specific technology involved. In certain instances, older farmers may exhibit higher rates of technology adoption due to their wealth of experience and access to resources (Amudavi et al., 2009; Murage et al., 2011). Conversely, in other cases, older farmers may display a tendency towards risk aversion, attributed to their comparatively shorter planning horizons compared to younger farmers (Niassy et al, 2020). The results in **Table 2** show that PPT users in Kenya, Uganda, Tanzania and Ethiopia were older than the non-users, which may also be related to past dissemination having targeted already established farmers. Nevertheless, age is likely to play a role in adoption of PPT, with effects varying according to the mode of technology dissemination.

Table 2: Age of the household head (Years) by gender and technology use

Statistics	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Mean	56.3	54.6	54.2	49.1	49.9	53.9	52.9	48.5	44.3	46.7
SD	12.4	13.6	12.0	13.9	12.6	12.7	10.8	12.0	10.3	11.3
	N-User	User	N-User	User	N-User	User	N-User	User	N-User	User
Mean	53.3	57.1	49.6	50.4	52.4	54.8	50.0	48.9	45.8	48.3
SD	13.4	12.8	14.3	12.1	13.4	11.3	13.1	10.9	11.4	10.8

The average number of years of schooling varied across the surveyed countries, with Kenya recording the highest and Ethiopia the lowest. Moreover, male farmers generally attained more years of schooling than their female counterparts across all countries except Ethiopia. The education level of the farmer serves as a crucial determinant of technology adoption (Murage et al., 2015). As depicted in **Table 3**, users of PPT typically had more years of schooling compared to non-users, with the exception of Uganda where the years of schooling were equal. Given that PPT and similar technologies require a certain level of knowledge for operation and to grasp their benefits, low literacy levels can present a barrier to adoption. However, this obstacle can be mitigated through consistent training programs tailored to farmers, employing materials and methods that are easily comprehensible.

Table 3: Education level of household head (years) by gender and technology use

	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	N-User	User	N-User	User	N-User	User	N-User	User	N-User	User
Mean	8.8	9.4	7.1	7.1	6.8	7.3	4.7	5.1	2.5	2.6
SD	3.8	4.1	3.8	3.7	3.0	2.6	3.1	3.1	3.2	3.2
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Mean	7.1	9.8	4.4	7.5	6.2	7.1	3.7	5.3	3.7	2.5
SD	4.1	3.6	3.9	3.5	3.1	2.8	3.2	3.0	3.7	3.2

The average household size varied across the surveyed countries, with Uganda and Tanzania recording the highest sizes, while Rwanda had the lowest (**Table 4**). Notably, PPT users tended to have larger household sizes compared to non-users across all countries. The use of PPT is often associated with high labor requirements, particularly during the establishment stage, which farmers frequently cite as a barrier (Murage et al., 2015). This observation could explain why users typically had larger households, as they have more available labor to meet these demands. Large families are generally viewed as a valuable resource for technology adoption since they can contribute to labor availability. Furthermore, such larger families often require increased income to sustain their livelihoods, making them more inclined to explore new technologies that promise enhanced productivity and income.

Across all countries, male-headed households consistently had larger families compared to female-headed households.

Table 4: Household size by gender and technology use

	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	N-User	User	N-User	User	N-User	User	N-User	User	N-User	User
Mean	5.6	5.9	7.7	8.5	7.3	7.8	4.7	5.2	5.7	6.3
SD	2.2	2.7	3.3	3.1	3.1	3.5	1.9	1.9	1.9	2.1
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Mean	4.8	6.1	7.2	8.1	6.3	7.7	3.9	5.3	5.3	5.9
SD	2.5	2.3	3.5	3.2	2.6	3.3	1.8	1.8	1.6	2.0

3.2 Farm characteristics

The average area under cereals was less than a hectare across the board, except for PPT-users in Tanzania, who had larger sizes. It's worth noting that average sizes tended to be larger for male farmers compared to female farmers, with the exception of Kenya, where they were equal (**Table 5**).

Table 5: Land under cereals (Ha) by gender and technology use

	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	N-User	User	N-User	User	N-User	User	N-User	User	N-User	User
Mean	0.4	0.5	0.5	0.4	0.8	1.0	0.3	0.3	0.8	0.7
SD	0.5	0.5	0.5	0.4	0.9	1.7	1.4	1.0	0.6	0.4
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Mean	0.4	0.4	0.3	0.5	0.7	0.9	0.2	0.3	0.7	0.8
SD	0.4	0.5	0.3	0.4	0.5	1.3	0.5	1.2	0.4	0.5

Tropical Livestock Units (TLU) served as a proxy for the number of livestock maintained by households. The results indicate that PPT users had higher TLU compared to non-users across all study countries. This outcome can be attributed to the additional fodder obtained by PPT users through the technology, which ensures availability for their livestock. Consequently, these farmers are able to sustain their livestock enterprises and even expand them with availability of surplus resources. Adoption of PPT also encourages farmers without livestock to engage in the venture. Past studies have suggested that owning livestock serves as a favorable entry point for PPT adoption, thereby presenting an opportunity for further adoption and diffusion (Niassy et al., 2020).

Table 6: Tropical livestock Units (TLU) by gender and technology use

TLU	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	N-User	User	N-User	User	N-User	User	N-User	User	N-User	User
Mean	1.8	2.5	0.9	1.1	2.9	4.3	0.4	0.5	2.6	2.7
SD	2.2	2.7	1.4	1.3	5.2	6.7	0.6	1.1	2.1	2.2

	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Mean	1.4	2.4	0.8	1.0	1.4	3.8	0.5	0.5	2.1	2.7
SD	1.4	2.7	1.3	1.4	2.4	6.2	0.9	0.9	1.5	2.2

Off-farm income presents an opportunity for technology adoption, as farmers require capital to purchase inputs. In the case of PPT adoption, farmers need to acquire the initial seeds for desmodium and brachiaria, which are relatively costly due to low supply. However, the results depicted in **Figure 2** reveal mixed effects. In Kenya, Uganda, and Rwanda, the percentage of farmers with off-farm income was lower for users than non-users, suggesting that this factor did not pose a significant impediment. Conversely, in Tanzania and Ethiopia, the percentage of PPT users with off-farm income was higher, at 59% and 41% respectively, indicating that off-farm income likely played a crucial role in facilitating PPT adoption**.**

Figure 2: Percent of farmers with off-farm income by PPT use and by gender

3.3 Institutional factors

Institutional factors such as access to credit, extension services, research and development, market access, policy and regulations, infrastructure, and social networks can facilitate technology adoption. Results represented in **Figure 3** illustrate the percentage of farmers belonging to groups, serving as a proxy for social networks. It is evident that the percentage of PPT users belonging to social networks was higher than that of non-users across all study countries. This suggests that social groups provide a platform for farmers to share information and learn from each other, thereby presenting an opportunity for technology adoption.

In Kenya and Ethiopia, the percentage of female-headed households belonging to groups exceeded that of male-headed households, with all female-headed households in Ethiopia belonging to groups. In Tanzania and Rwanda, more males were members of such groups. In Uganda, the membership was equal between genders. Farmer groups represent an opportunity for more effective and cost-efficient technology dissemination.

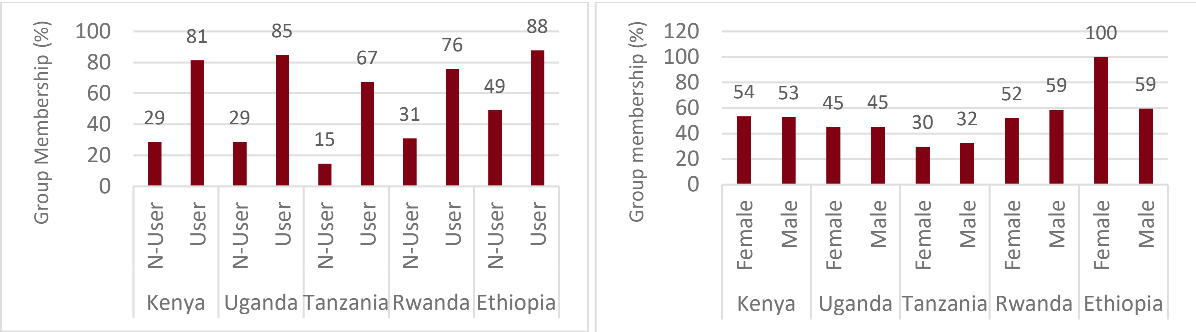

Figure 3: Percent of farmers belonging to groups by PPT use and by gender

Similarly, access to markets can serve as an incentive for farmers to adopt new technologies. Results depicted in **Figure 4** indicate that the percentage of PPT users who had access to crop markets was higher than that of non-users across the countries, except in Ethiopia where the percentage was lower.

Access to markets for the PPT crops by gender presents mixed results, with Kenya, Rwanda, and Ethiopia showing that more female farmers had access to crop markets compared to their male counterparts, while in Uganda and Tanzania, the percentage of male farmers with market access was higher.

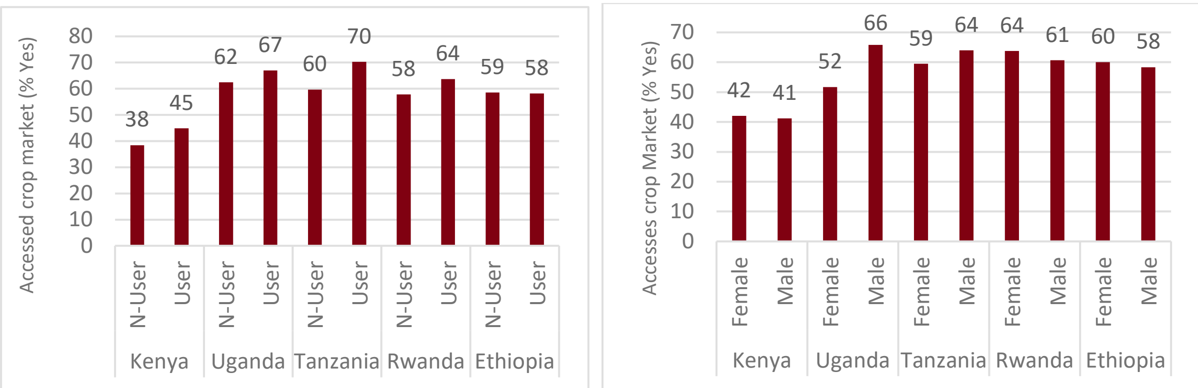

Figure 4: Percent of farmers who accessed crop market by gender and PPT use

Access to extension services is another institutional factor that can significantly influence technology adoption. Effective extension services provided by agricultural agencies or organizations can disseminate information about new technologies, offer training, and provide ongoing support to farmers. Results illustrated in **Figure 5** show that a higher percentage of non-users across the countries experienced extension constraints— farmers who needed but did not receive extension services. Conversely, among the PPT users, less than 45% in Tanzania and Uganda and less than 30% in the other 3 countries experienced extension constraints.

Regarding gender and access to extension, the results indicate that, contrary to the norm where women are often disproportionately disadvantaged in access, more male-headed households had extension constraints, except in Uganda. The presence of effective extension services offers an opportunity for farmers to learn and accelerate technology adoption.

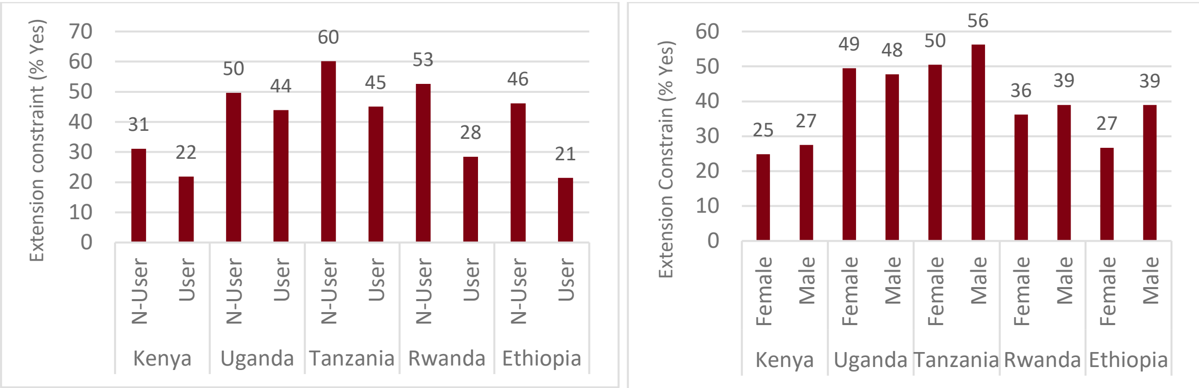

Figure 5: Percent of farmers who had extension constraint by PPT use and by gender

Farmers often require capital to invest in new technologies; therefore, access to credit facilities and loans can enable them to purchase necessary inputs and equipment, thereby facilitating technology adoption. Contrary to this notion, our results show that a higher percentage of PPT users actually experienced credit constraints, with the exception of Kenya. This could imply that these users did not rely on credit to facilitate technology adoption. Access to credit can be defined in two ways: either credit is not available at all, or it is available but expensive. In either case, farmers may not be able to access it. Facilitating farmers with affordable credit can be an opportunity for technology adoption.

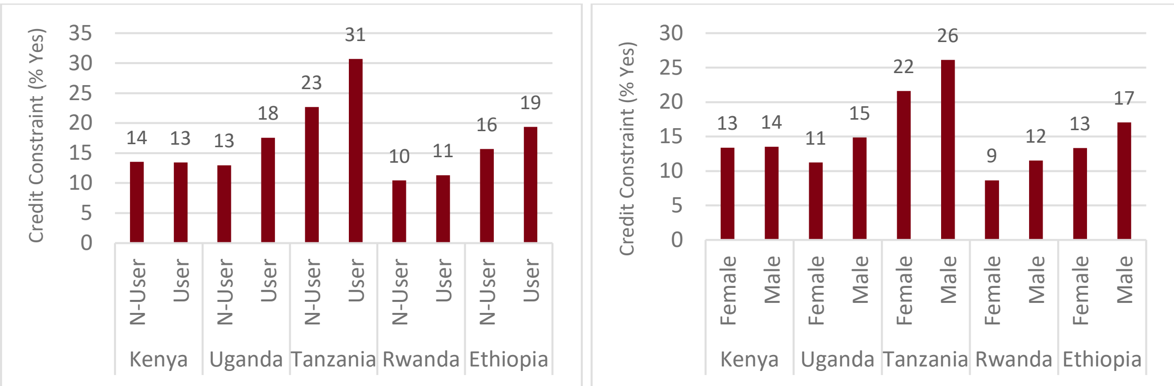

Figure 6: Percent of farmers who had credit constraint by PPT use and by gender

3.4 PPT Adoption and expansion

In this section, we delve into the comprehensive analysis of the adoption and subsequent expansion of PPT within the study countries. Our investigation provides insights into the diverse ways in which PPT has been embraced and integrated.

3.4.1 PPT adoption pattern and expansion

The adoption pattern for PPT was categorized as shown in **Figure 7**. In the overall picture, approximately 26% of the farmers were consistent, with more female farmers (31%) exhibiting consistency compared to male farmers (25.4%). The percentage of those unaware was 29%, with more male farmers (30%) being unaware compared to female farmers (24%). At least 4% had expanded, and 6% were triallers. These percentages varied across the study countries.

The percentages of farmers who were consistent were as follows: 36% in Kenya, with an equal distribution between men and women; 24% in Uganda, with 25% for females and 24% for males; 21% in Tanzania, with 20% for females and 22% for males; 35% in Rwanda, with 40% for females and 33% for males; and 6% in Ethiopia, with 20% for females and 5% for males (Note: for Ethiopia, the analysis includes only baseline data)

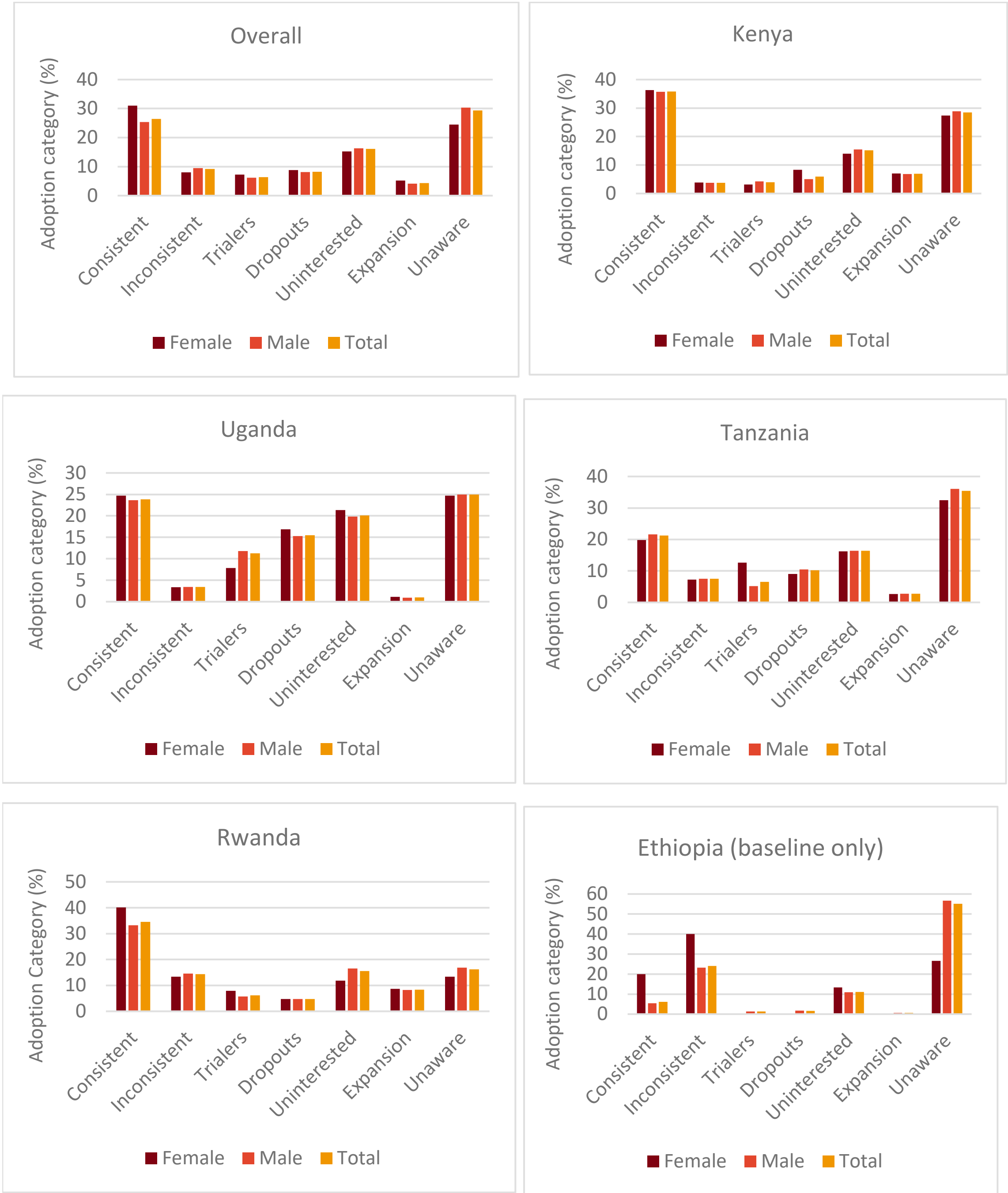

Figure 7: Adoption pattern by country in baseline and midline

3.4.2 Reasons for inconsistency in PPT adoption

The pattern in the use of PPT shows high inconsistency, with some farmers trying and subsequently dropping the technology. In **Figure 8** we demonstrate the reasons stated by farmers for their inconsistent adoption of PPT. In Kenya, the majority of women cited the major challenges to PPT adoption as difficult to manage (46%), followed by labour shortage and lack of desmodium seeds (31%

each). Men in Kenya primarily cited lack of desmodium seeds (32%), difficulty in management (29%), and lack of knowledge (25%).

In Uganda, both women and men mentioned lack of desmodium seeds (36% and 39% respectively) as a primary reason for inconsistency. Other significant reasons included lack of project support (36% for women) and lack of brachiaria seeds (27% for women, 22% for men). In Tanzania, lack of desmodium seeds was cited by 54% of women and 46% of men as the main reason for inconsistency. In Rwanda, lack of desmodium seeds was the primary reason for inconsistency among women (36%), while lack of knowledge was cited by 45% of men.

The above reasons highlight significant barriers identified across multiple countries. The difficulty in managing PPT (and especially among the female-headed households) suggests that usability issues or complexities associated with the technology may deter adoption. Additionally, the lack of desmodium seeds in Kenya, Uganda, Tanzania, and Rwanda, and brachiaria seed in Uganda, emerged as a common barrier hindering farmers' ability to implement PPT effectively. Furthermore, the knowledge gap leads to inadequate understanding of PPT's benefits and proper usage, as mentioned by farmers in Kenya, Uganda, and Rwanda, thereby limiting them from realizing the potential advantages of the technology.

Addressing the seed supply issue through improving seed distribution channels and ensuring the availability of quality seeds could encourage more farmers to adopt PPT and significantly enhance adoption rates. Further research on on-farm establishment and maintaining of desmodium seed should be conducted. Furthermore, capacity building through training and extension services to farmers, particularly on the management and benefits of PPT in line with farmers' priorities, could address knowledge gaps and increase confidence in adopting the technology.

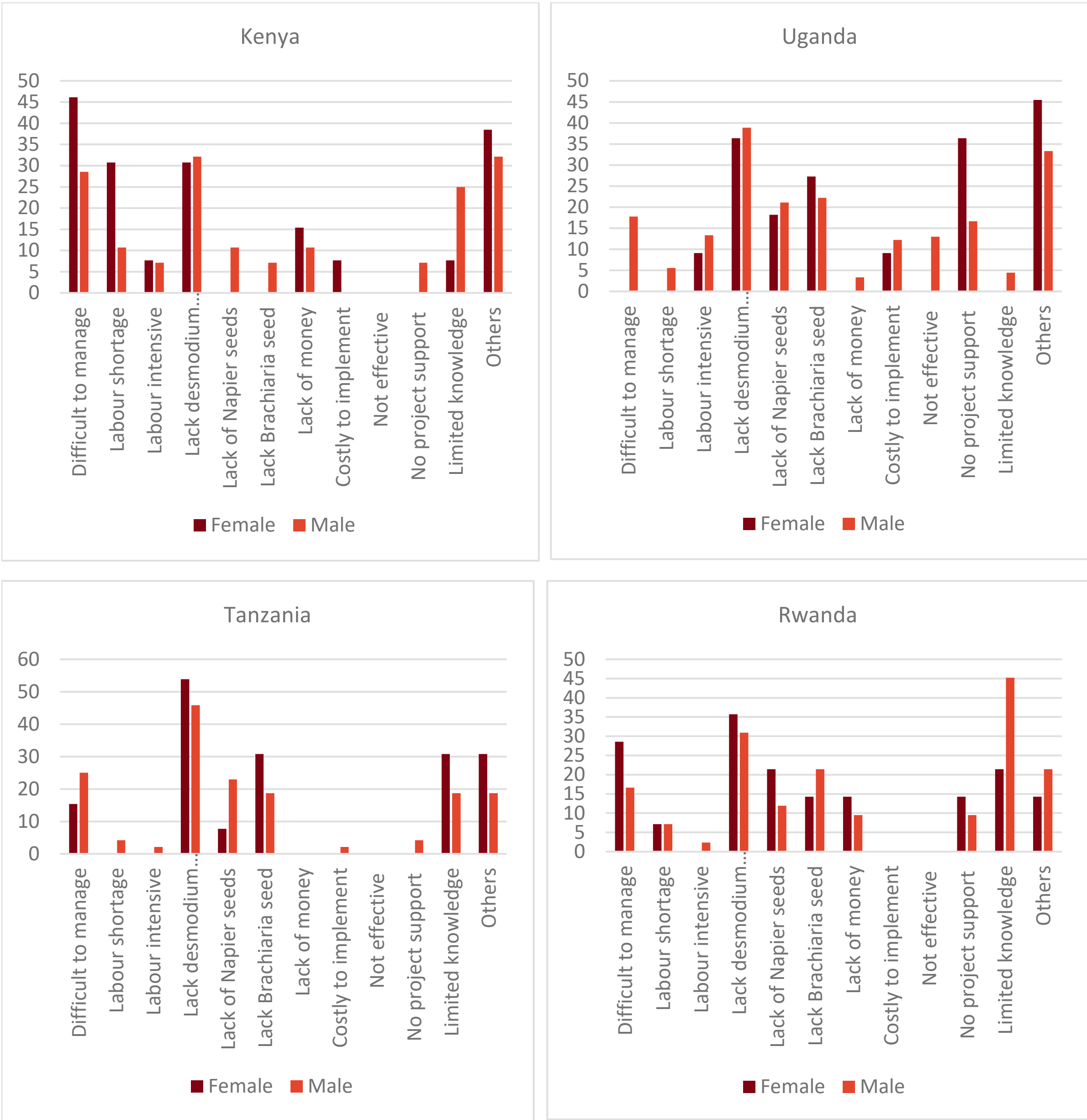

Figure 8: Farmers stated reasons for inconsistent use of PPT (%)

3.5 Determinants of PPT adoption and expansion (Barriers and Opportunities)

This section elucidates the various factors that either facilitate or impede the adoption and expansion of PPT. It offers insights derived from statistical models, thereby revealing the significant influencers shaping the trajectory of PPT integration. Both models demonstrate statistical significance, thus effectively capturing the nuanced interplay of variables under scrutiny. Through rigorous analysis, this section unveils the pivotal determinants driving or constraining the widespread uptake of PPT, offering an understanding of the complex dynamics at play.

3.5.1 Multinomial logit results on factors influencing PPT adoption patterns

Several factors promote or hinder the adoption of PPT (**Table 7**). Gender, for example, was significant across the board with a negative sign. However, the level of significance was higher for consistent and expansion parameters. It can be argued that female-headed households were more likely to retain and expand PPT compared to male-headed households. However, we also find a 5% and 10% significance in terms of inconsistency, trialler, dropouts and uninterested. Consequently, dissemination efforts for PPT should target female farmers to effectively ensure retention of the technology. However, as demonstrated earlier, female farmers generally have lower levels of literacy compared to male farmers, while PPT is known to be knowledge-intensive. Therefore, it is crucial to target women using approaches and information packaging tailored to their educational status.

The age of the household head was significant and positively associated with all adoption categories, except for expansion. As noted earlier, age can either pose a barrier or present an opportunity to technology adoption. Older farmers may perceive the technology as risky and thus may be less inclined to adopt. However, older farmers may also exhibit consistency and even expansion in adoption due to their wealth of knowledge, experience in farming, and greater access to resources compared to younger farmers. The significance levels observed for dropout and lack of interest could be attributed to risk aversion among older farmers.

Household size was found to be significant at the 1% level and positively associated with the consistent and expansion models. As hypothesized earlier, large families provide the necessary labour for establishing and managing PPT, thus such families are more likely to exhibit consistency and even expand the area under the technology. Large household size can be seen as an opportunity for PPT adoption.

The variable representing the sub-plot area was positively and significantly associated with the expansion of area under PPT at the 1% level. This indicates a direct relationship between land size and the expansion of the technology, presenting an opportunity for increased adoption.

The variable for off-farm income yielded mixed results. While it was negatively associated with the consistent model, it was significant and positively associated with inconsistency. Although off-farm income is seen as an opportunity for increased adoption, as it enables farmers to purchase necessary inputs, it can be argued that farmers with off-farm income may exhibit inconsistency as they may prioritize off-farm activities over farming. This may also explain why it was negatively associated with consistency among farmers who likely concentrate more on farming rather than off-farm activities.

Group membership also exhibited mixed results, being positively and significantly associated with all the models. While group participation has often been associated with the adoption of technologies, some studies have argued that being a member of a group can also exert negative influence (Mwaura, 2014), leading farmers to either not adopt or to dis-adopt technologies.

The Extension constraint variable did not emerge as a major challenge, as the coefficients were negative for all the models. However, farmers who were credit-constrained were more likely to exhibit inconsistency in adoption. Additionally, farmers who practiced intercropping were also more likely to demonstrate consistency and to expand the area under the technology, possibly because it provided them with an opportunity to integrate it into their existing farming systems. Similarly, farmers with more livestock were more likely to exhibit consistency and to expand the technology.

Furthermore, consistent farmers reported having fewer striga and stemborers in their plots, as indicated by the negative coefficients. However, the variables representing the county of study presented mixed results across the models

Table 7: Pooled MNL regression results for the factors Influencing PPT adoption pattern

	Consistent	Inconsistent	Trailers	Dropouts	Uninterested	Expansion
Gender (Male=1)	-0.647***	-0.441**	-0.423*	-0.521**	-0.372**	-0.780***
Age of the HHH (Years)	0.021***	0.014**	0.026***	0.021***	0.010***	0.014
Education level	0.085***	0.030	0.058**	0.072***	0.073***	0.102***
Household size	0.061***	0.067**	-0.022	0.031	0.025	0.112***
Sub-plot area	0.003	0.028	-0.052	0.004	0.053	**0.234*** **
Off-farm income	-0.236*	0.306**	-0.104	0.003	-0.084	-0.066
Group membership	3.010***	2.608***	1.700***	1.828***	0.564***	3.059***
Extension constraint (Yes =1)	-0.698***	-0.717***	-0.260	-0.119	-0.310***	-0.620***
Credit constraint (yes = 1)	0.467**	0.535***	0.162	-0.070	0.243	0.531*
Intercropping	0.398***	0.633**	0.074	-0.060	0.057	1.323***
Intercrop agroforestry	0.022	-0.354**	0.408**	0.067	0.266**	0.096
TLU	0.047**	0.055**	0.007	0.047*	0.040*	0.093***
Sub-Plot with Striga	-0.551***	-0.075	-0.091	-0.094	-0.025	-0.010
Sub-plot with stemborer	-0.281*	-0.452***	-0.100	-0.032	0.166	-0.400
Sub-plot with Fall armyworm	0.042	-0.267	0.073	-0.045	0.145	0.085
Sub-plot with soil loss	0.253*	0.059	0.181	-0.148	0.281**	-0.171
Market access	0.165	-0.045	-0.158	-0.151	0.125	0.194
Yeardummy2	-0.136	0.927***	0.825***	1.213***	0.678***	0.172
Uganda	0.139	0.489	1.698***	1.603***	0.602***	-1.456***
Tanzania	-0.011	1.183***	0.925***	0.843***	0.040	-0.745**

Rwanda	1.290***	2.814***	1.609***	1.012***	1.313***	2.240***
Ethiopia	-2.416***	1.865***	-1.102**	-1.130**	-0.228	-2.247***
_cons	-2.796***	-4.970***	-4.520***	-4.358***	-2.602***	-5.861***
Number of observation	2,793					
LR chi(χ)^2(132)	1,800					
Prob > chi(χ)^2	0.000					
Pseudo R2	0.185					

3.5.2 Double hurdle model on factors influencing the expansion of PPT

Each study country exhibited unique barriers and opportunities, as demonstrated in **Table 8**. In Kenya, the off-farm income variable was significant and negative (coeff = -0.200**), implying that adopters were less inclined to participate in off-farm activities. However, the positive coefficient for group membership (coeff = 1.030***) suggests an opportunity for utilizing group models (collective action) as accelerators for adoption. Moreover, older farmers were more frequently among adopters, indicating another potential avenue for promoting adoption (coeff = 0.011***).

In Uganda, the decision to adopt was positively influenced by group membership (coeff = 0.726***), which had a positive coefficient, presenting an opportunity for accelerating adoption through group participation. Additionally, focusing on women is also likely to accelerate adoption (coeff = -0.341**).

In Tanzania, the credit constraint variable had a positive coefficient (coeff = 0.264*), suggesting that this was not an impediment to adoption. However, extension constraint was identified as a significant barrier (coeff = -0.686***), likely hindering adoption. On the other hand, group membership and Tropical Livestock Units (TLU) were identified as opportunities for increasing adoption.

In Rwanda, extension constraint emerged as a significant barrier (coeff = -0.381**), while group membership presented an opportunity to PPT adoption (coeff = 0.750***). Additionally, the gender variable leaned towards women being more adopters (coeff = -0.257**). Previous studies have shown that a higher percentage of women perceived PPT as very effective compared to men, hence they were willing to continue using it to enjoy the accrued benefits. However, men expanded the technology more which was attributed to land availability (Murage et al., 2015).

Finally, in Ethiopia, extension constraint was identified as an impediment to adoption, while off-farm income and group membership were identified as opportunities. Focusing on women is also likely to accelerate adoption in this context.

The positive and negative influencers of area under PPT are also shown in Table 8. Based on these observations, it is important to emphasize on context-specific approaches as each country has its own unique barriers and opportunities. Strategies tailored to different demographic groups are important while targeting dissemination. Moreover, prioritizing women in adoption efforts could further boost adoption rates.

Table 8: Double hurdle model results for Factors influencing adoption

	Kenya	Uganda	Tanzania	Rwanda	Ethiopia
Decision to adopt					
Credit constraint	0.168	-0.044	0.264*	0.002	0.023
Extension constraint	-0.303	-0.111	-0.686***	-0.381***	-0.472***
Gender of decision maker	0.052	-0.341**	-0.137	-0.257**	-0.492*
Household size	0.000	0.018	0.025	0.051**	0.058*
Off farm income	-0.200**	-0.136	-0.108	0.047	0.392***
Group membership	1.030***	0.726***	0.408***	0.750***	0.766***
Age of decision maker	0.011***	-0.007	-0.005	-0.005	0.007
Tropical livestock units	0.001	0.046	0.020**	-0.012	-0.007
Area under PPT					
Credit constraint	0.040	0.001	0.164**	0.152	-0.018
Extension constraint	-0.047**	-0.059	-0.370***	-0.137*	-0.200***
Gender of decision maker	0.010	-0.121*	-0.047	-0.084	-0.191
Off farm income	-0.023	-0.031	-0.089	0.056	0.177***
Group membership	0.188***	0.288***	0.277***	0.542***	0.329***
Age of decision maker	0.002**	-0.003	-0.005*	-0.001	0.004
Tropical livestock units	0.007*	0.024	0.008	0.004	-0.005
Year of survey	-0.029***	-0.062***	-0.059	-0.022	

3.6 Synthesis of the Key Informants notes

Table 9 show the categories and gender of the key informants interviewed per country with exception of Ethiopia (where data had not been collected as at the time of drafting this report). The Key informant interviews elucidated unique barriers and opportunities at each level of the value chain as explained hereafter.

Table 9: Number of key informants interviewed by category and by gender

	Kenya			Rwanda			Tanzania			Uganda		
Key informant category	Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Total
Agro-dealer	2	4	6	1	1	2	-	5	5	2	1	3
Extension agent/Research/NGOs	3	8	11	-	2	2	3	3	6	1	1	2
Farmer federation/cooperatives	-	3	3	2	-	2	1	2	3	-	-	-
Financial institution	2	1	3	2	-	2	1	3	4	-	2	2
Lead farmer	4	2	6	-	4	4	4	4	8	3	3	6
Policy makers	-	3	3	1	2	3	2	5	7	-	-	-
Seed company	1	1	2	2	-	2	1	2	3	-	--	-
Trader (wholesaler, retailer)	2	2	4	2	-	2	3	3	6	1	2	3
Transporter	-	3	3	-	2	2	2	3	5		3	3
Total	**14**	**27**	**41**	**10**	**11**	**21**	**17**	**30**	**47**	**7**	**12**	**19**

Across Kenya, Uganda, Tanzania, and Rwanda, several common farm-level barriers to PPT adoption are evident:

1. High Cost of Seeds: In all countries, the cost of seeds, particularly desmodium and brachiaria, is identified as a significant barrier. The cost of these seeds makes them less accessible to farmers, particularly those with limited financial resources.
2. Supply Chain Challenges: Delays in the supply of seeds disrupts the availability of inputs for farmers. This can lead to uncertainties in the planning and implementation of PPT adoption.
3. Limited supply of seeds especially desmodium and brachiaria, contributing to scarcity and hindering adoption efforts. Additionally, challenges such as unsorted seeds in the supply chain further exacerbate this issue.
4. Transportation Costs: Expensive transportation costs, often exacerbated by long distances and fuel price fluctuations, pose challenges in delivering inputs to farmers. This can result in delays and increased expenses for farmers.
5. Capital Constraints: Limited access to capital and capital shortages hinder farmers' ability to invest in PPT adoption.
6. Quality Control Issues: Poor seed quality, with low germination rates and expired or incorrect inputs, undermines farmers' confidence in the technology and disrupts the adoption process.

7. Market Dynamics: Fluctuating input prices and unstable supply make it difficult for farmers to plan and invest in PPT adoption.
8. Government Regulations: Stringent government bureaucracies in input trade, as observed in Rwanda, can pose additional barriers to accessing necessary inputs for PPT adoption.

Seed production barriers

Across Kenya, Tanzania, and Rwanda, several common barriers to seed production for PPT are evident:

1. Infrastructure challenges: Inadequate infrastructure, including unreliable power supply, lack of proper cold storage facilities, and inadequate rural roads, hampers seed processing, storage, and transportation. These challenges contribute to logistical hurdles and increase distribution costs.
2. Environmental factors: Climate-related challenges, such as drought, pests, diseases, and theft concerns, affect seed production. These factors can lead to fluctuations in seed availability and quality, impacting farmers' access to reliable seeds.
3. Production costs: High production expenses, including irrigation, mechanization, fuel prices, and inflation, contribute to elevated seed prices. This can make seeds less affordable for farmers, hindering adoption efforts.
4. Quality control and regulatory complexities: Ensuring seed quality and genetic purity during production, as well as navigating regulatory complexities on seed import/export, adds to market challenges. Compliance with stringent quality control standards and addressing trade restrictions are essential for market access.
5. Competition: Competitors offering lower prices and managing diverse customer perceptions regarding seed quality and performance pose challenges for seed producers. This can impact market competitiveness and profitability.

Trade level barriers

1. Across the trade level in different regions, several common barriers to efficient trade of agricultural products, including PPT, are apparent:
2. Transportation costs and Infrastructure: High transportation costs, particularly from remote villages, coupled with poor road networks, hinder efficient transportation from rural areas. These factors contribute to delays, increased expenses, and difficulties in accessing markets.
3. Post-Harvest handling and storage: Poor post-harvest handling practices and inadequate storage facilities lead to product deterioration, affecting quality and marketability. This can result in losses for farmers and traders alike.

4. Supply chain challenges: Delays in supplies from wholesalers, fluctuating prices, inconsistent stock supply, and inadequate storage facilities contribute to uncertainties and inefficiencies in the supply chain.
5. Weather conditions: Poor weather conditions impact delivery schedules and hinder transportation, further exacerbating logistical challenges in trade.
6. Volume and collection centers: Low collection volumes, coupled with a lack of collection centers, affect market access and limit opportunities for trade.
7. Quality control and grading: Poor grading practices by farmers affect product quality and market competitiveness, leading to lower prices and reduced profitability.
8. Government taxes and policy: High government taxes, delayed payments, and lack of credit facilities add financial burdens and hinder the profitability of trade operations.

Extension

1. Limited access to extension services: Farmers face difficulties in accessing extension services due to factors such as geographic location, infrastructure limitations, or inadequate outreach efforts.
2. Insufficient facilitation for extension officers: Extension officers may lack the necessary support or resources to effectively visit farmers, hindering the dissemination of agricultural knowledge and techniques.
3. Low adoption of e-extension: Despite the potential benefits of electronic extension services (e-extension), there is a lack of widespread adoption among farmers, possibly due to issues like limited internet connectivity, digital literacy, or perceived usefulness.

Policy constraints

1. Porous border points facilitating the entry of substandard seeds: Weak border controls allow inferior quality seeds to enter the country, posing risks to agricultural productivity and sustainability.
2. Poor implementation of policies: Despite having policies in place, ineffective implementation undermines their intended impact on agricultural practices and outcomes.
3. Weak enforcement of policies and regulations: Inadequate monitoring and enforcement mechanisms result in non-compliance with agricultural policies and regulations, compromising the quality and safety of agricultural products.
4. Government regulations on access to seeds: Regulatory barriers imposed by the government may limit farmers' access to high-quality seeds, constraining their ability to improve crop yields and resilience.

5. Conflicting national agricultural policies promoting inorganic inputs: Incoherent or contradictory agricultural policies may create confusion and hinder the adoption of sustainable agricultural practices, such as organic farming or agro-ecology.
6. Regulations on seed importation: Stringent regulations on the importation of seeds may restrict access to diverse genetic resources, impeding innovation and adaptation in agriculture.

AVAILABLE OPPORTUNITIES FOR OTHER VALUE CHAIN PLAYERS TO INCREASE ADOPTION OF PPT

Farm-level opportunities

Farmers can accelerate the adoption of PPT by:

1. Increasing awareness: Launch campaigns and workshops to educate farmers about the benefits of PPT, stimulating demand for PPT seeds.
2. Facilitating stakeholder engagements: Foster dialogue between farmers and other stakeholders in the agricultural value chain to negotiate better prices for PPT products.
3. Encouraging local seed production: Promote the cultivation of PPT seeds locally to ensure their availability and reduce dependency on external sources.
4. Providing farmer training: Organize training sessions on seed production and storage techniques to enhance farmers' capacity in producing and preserving PPT seeds effectively.
5. Improving dissemination methods: Utilize various communication channels such as radio programs, field demonstrations, and farmer field schools to disseminate information about PPT and its benefits, thereby increasing adoption rates.
6. Sensitizing stakeholders: Educate stakeholders about the diverse uses of desmodium, a key component of PPT, to maximize its potential benefits in pest management and soil improvement.
7. Promoting alternative seed production methods: Encourage the use of vines and root splits for seed production to diversify seed sources and increase resilience against fluctuations in seed availability.

Challenges such as poor road networks, transportation losses, weak law enforcement, insecurity, high fuel costs, delayed payments, and low product volumes during harvesting can be addressed by:

1. Investing in infrastructure: Advocate for improvements in road networks to reduce transport costs and minimize losses during transit.
2. Strengthening law enforcement: Collaborate with local authorities to enforce laws on highways, reducing the risk of theft and improving security for farmers and their produce.

3. Addressing fuel costs: Explore alternative energy sources or advocate for government subsidies to mitigate the impact of high fuel prices on transportation expenses.
4. Improving payment systems: Work with buyers and policymakers to establish mechanisms for timely payments to farmers, ensuring their financial stability and motivation to adopt PPT.
5. Enhancing harvesting practices: Provide training and resources to farmers to optimize harvesting techniques and increase product volumes, thereby maximizing returns on their PPT investment.

Marketing level opportunities

Traders can contribute to accelerating the adoption of PPT by:

1. Training agro dealers: Provide comprehensive training to agro-dealers about PPT and preferred varieties, enabling them to effectively promote and distribute PPT products to farmers.
2. Attracting stakeholder investment: Engage stakeholders such as investors, NGOs, and development agencies to invest in PPT products and initiatives, facilitating their availability and affordability for farmers.
3. Considering subsidies for seed importation: Advocate for government subsidies or incentives to reduce the cost of importing PPT seeds, making them more accessible to traders and ultimately to farmers.
4. Improving rural access and communication: Invest in infrastructure and communication networks to improve access to rural areas, enabling traders to reach more farmers and disseminate information about PPT effectively.
5. Enhancing collection centers: Establish or improve collection centers in rural areas where farmers can easily access PPT products, facilitating distribution and increasing convenience for both traders and farmers.
6. Strengthening extension services: Collaborate with agricultural extension services to provide support and training to farmers on PPT adoption, ensuring successful implementation and maintenance of PPT practices in rural communities.
7. Community-driven extension services: Implement community-driven extension services that involve local farmer teachers, who can serve as intermediaries between traders and farmers, promoting PPT adoption and providing ongoing support and guidance.
8. Embracing e-extension: Utilize electronic extension services (e-extension) to disseminate information about PPT and connect traders with farmers, enhancing communication and knowledge sharing in remote areas.

9. Using media: Utilize various media channels such as radio, television, and social media platforms to raise awareness about PPT and its benefits among traders and farmers, facilitating adoption and market demand.
10. Policy advocacy: Advocate for supportive policies and regulations that promote the adoption and commercialization of PPT products, creating an enabling environment for traders to operate and thrive in the agricultural sector.

4 Conclusion and recommendation

This study emphasizes the crucial role of understanding socio-economic and gender dynamics in agricultural technology adoption, specifically focusing on PPT. The research highlights diverse patterns of PPT adoption and expansion among farmers across regions, influenced by various factors and encountering numerous barriers. Notably, older farmers, especially women, exhibit higher rates of PPT adoption, indicating the potential role of age in technology uptake. Additionally, while male farmers generally have more schooling, education level affects technology adoption, with PPT users typically having more years of education. Therefore, addressing literacy barriers through tailored training programs is essential for all farmers. Gender-specific factors also influence PPT adoption patterns, with female-headed households more likely to retain and expand PPT. This highlights the need for dissemination efforts to target female farmers, necessitating tailored approaches and information packaging to effectively engage women in technology adoption. Despite the potential benefits of PPT for food security and livelihoods, overcoming barriers and capitalizing on opportunities is crucial.

Common barriers identified through farmer and key informant interviews include management challenges, knowledge gaps, high seed costs, supply chain issues, and limited access to extension services. These barriers have gender-specific implications, requiring the project to consider differential impacts on women and men. At the farm level, disparities in access to resources such as capital and land hinder PPT adoption, particularly for female farmers. Addressing gender-specific barriers necessitates targeted interventions such as financial literacy training and promoting women's land rights. In terms of seed production, women may face challenges related to infrastructure and environmental factors, necessitating empowerment through capacity-building initiatives and improved access to resources. At the trade level, gender disparities in access to markets and extension services may restrict women's participation in efficient PPT product trade. Enhancing access through gender-sensitive interventions and community-driven approaches is vital for promoting gender-inclusive PPT adoption.

In conclusion, addressing gender-specific issues at each level of the agricultural value chain is essential for promoting equitable and sustainable PPT adoption. By recognizing and overcoming barriers while leveraging opportunities, stakeholders can foster inclusive technology adoption, thereby enhancing food security and livelihoods in Eastern Africa. Recommendations include improving seed distribution channels, conducting further research on seed establishment, providing tailored training and extension services, and targeting women in adoption efforts. Context-specific strategies are crucial due to unique country-level barriers and opportunities, emphasizing the importance of tailored approaches for successful PPT adoption.

5 References

Amudavi, D. M., Khan, Z. R., Wanyama, J. M., Midega, C. A. O., Pittchar, J., Nyangau, I. M., ... & Pickett, J. A. (2009). Assessment of technical efficiency of farmer teachers in the uptake and dissemination of push–pull technology in Western Kenya. *Crop Protection*, *28*(11), 987-996.

Brown, B., Nuberg, I., & Llewellyn, R. (2017). Stepwise frameworks for understanding the utilisation of conservation agriculture in Africa. *Agricultural Systems*, *153*, 11-22.

Murage A. W., G. Obare, D. M. Amudavi, Z. Khan (2012). Efficiency of push-pull Technology Dissemination Pathways for Stemborer and Striga weed Control in Western Kenya: Data Envelopment Analysis Approach Tropentag, 19-21 September 2012, Gottingen, Germany "Resilince of agricultural systems against crisis.

Murage, A. W., Amudavi, D. M., Obare, G., Chianu, J., Midega, C. A., Pickett, J. A., & Khan, Z. R. (2011). Determining smallholder farmers' preferences for technology dissemination pathways: the case of 'push–pull'technology in the control of stemborer and Striga weeds in Kenya. *International journal of pest management*, *57*(2), 133-145.

Murage, A. W., Pittchar, J. O., Midega, C. A. O., Onyango, C. O., & Khan, Z. R. (2015). Gender specific perceptions and adoption of the climate-smart push–pull technology in eastern Africa. *Crop Protection*, 76, 83-91.

Niassy, S., Kidoido, M., Nyang'au, I. M., Pittchar, J. O., Hailu, G., Owino, R., ... & Khan, Z. R. (2020). Adoption and willingness to pay for the push–pull technology among smallholder maize farmers in Rwanda*. International Journal of Agricultural Extension and Rural Development,* 8 (3), 1-15