UPSCALE

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

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D4.4: Report on Socioeconomic, Value Chain, and Governance Impacts of Upscaling Push-pull Technology in East Africa

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UPSCALE

Author(s)/Organisation(s)	Beatrice W. Muriithi (icipe)
Contributor(s)	E. Poppenborg (JLU)
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Abstract:	Over the last two decades, the push-pull technology has demonstrated significant socioeconomic impacts on both crops and livestock value chains. Despite the remarkable benefits, the adoption of the technology by farmers remains low. Therefore, the objective of this report is to provide a synthesis of the socioeconomic, value chain, and governance impacts to inform the design of evidence-based practices and policies for up-scaling push-pull technology in East Africa. We utilized baseline and midline survey data collected in the UPSCALE project in all five target countries, synthesis of insights from multi-actor communities of practice, and existing literature on the PPT impacts. Regarding socioeconomic impacts, we found a positive impact of PPT on maize yield, income, and food security. We also found that technology contributes to women's empowerment, which impacts positively both to individual and household dietary diversity scores. PPT is also a gender-friendly technology, suitable for both men and women. While the benefits of the technology through the maize value chain are documented, we identified opportunities for the expansion of PPT for enhancing the livestock value chain through the provision of high-quality fodder. The study also documented key challenges that are likely to hinder the uptake of the technology including low accessibility of seeds for the companion crops, high labour intensity at the initial stages of the technology establishment, and competition for land among other food crops. Lifting of these barriers is expected to lead to PPT benefits positively impacting yields and food security for practicing farmers, but also to enhance farmers' linkage to markets, community networks, inclusion, access to knowledge and training, and to boost cereal and livestock value chains. Other value chains may also be affected through integration of e.g. high value vegetables and other crops with PPT. At the governance level, leveraging of synergies and coordination (i) among agroecological farming initiatives including PPT, and (ii) among agricultural intensification initiatives including PPT is targeted by the relevant PPT stakeholders. Efforts in this direction are expected to streamline and increase the effectiveness of dissemination interventions, forming a blueprint for future coordinated initiatives. Further impacts of PPT upscaling include increased public and policy awareness and visibility of related practices as a viable option for farm intensification. We recommend interventions to overcome the barriers to adoption of PPT for enhanced upscaling of the benefits of the technology across different scales. **Keywords**: livelihoods, socioeconomic impacts, empowerment.

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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
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9	RWANDA AGRICULTURE AND ANIMAL RESOURCES DEVELOPMENT BOARD	RAB	RW
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18	JULIUS-MAXIMILIANS-UNIVERSITAT WUERZBURG	UWUE	DE
19	LEIBNIZ UNIVERSITAET HANNOVER	LUH	DE

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FAW	Fall armyworm
PPT	Push-pull technology
R&D	Research and development
SSA	Sub-Saharan Africa
MAC	Multi-Actor Community of practice

1 Introduction

The primary goal for upscaling agricultural technologies is to enhance productivity, and hence improve the livelihoods of the farmers. In Africa, agriculture plays a pivotal role in enhancing food security, improving incomes, and promoting sustainable agricultural practices. In Sub-Saharan Africa (SSA), cereals are considered the chief source of food among many rural households. Yet, the production and marketing of the crops face several challenges, particularly those related to biotic and abiotic constraints. Among the technologies developed to overcome some of these challenges, is the Push-pull technology (PPT). PPT addresses the triple burden of maize production, including stemborers, striga, and fall armyworm (FAW) infestation (Khan et al., 2001; Midega et al., 2015, 2017).

Over the years, PPT has been introduced and adopted in various Eastern African regions with significant impacts on cereal yield increase (Khan et al., 2008a, b; Chepchirchir et al., 2017, 2018; Kassie et al., 2018). Besides the potential to increase cereal production and therefore support food and nutrition security, a number of other impacts have been recorded and/or are expected to occur under conditions of high PPT adoption. However, successful adoption is often hindered by several barriers, while also presenting numerous opportunities for advancement.

Using the household-level survey data collected at the beginning and midline of the UPSCALE project and related literature, combined with synthesis insights from multi-actor community workshops held in 5 UPSCALE countries from 2020-2024, the objective of this report is to document the socioeconomic, value chain and governance impacts of upscaling PPT in East Africa. The socio-economic impacts are considered as first-order effects of PPT, value-chain impacts represent second-order effects, and governance is considered a third-order effect of the technology. The report also documents the barriers associated with the adoption of PPT and suggests opportunities for addressing some of these challenges.

2 Conceptual framework

Figure 1 presents an overview of the conceptual framework guiding this report. The report examines the three-level effects, which are crucial for the relationship between PPT and smallholders. The adoption of PPT is expected to lead to the reallocation of resources, particularly land, as the technology involves mainly cereals and fodder crops. Labour resources may also be affected and changes in control of the crop, which are further affected by gender dynamics within the household. The reallocation of land resources may affect the production of other crops, previously intercropped with cereals, and together affect the market surplus and income generated in the households (first-order effects). Additional income earned from the marketed surplus may be used to diversify food consumption through the purchase of other food types or on non-food expenditures such as good health and sanitation (second-order effects). Increased disposable income from the sale of surplus maize (and/or companion fodder crops), contributes to the empowerment of men and women adopting the technology, as well as increased public and policy awareness and visibility for farm intensification. (third-order effects).

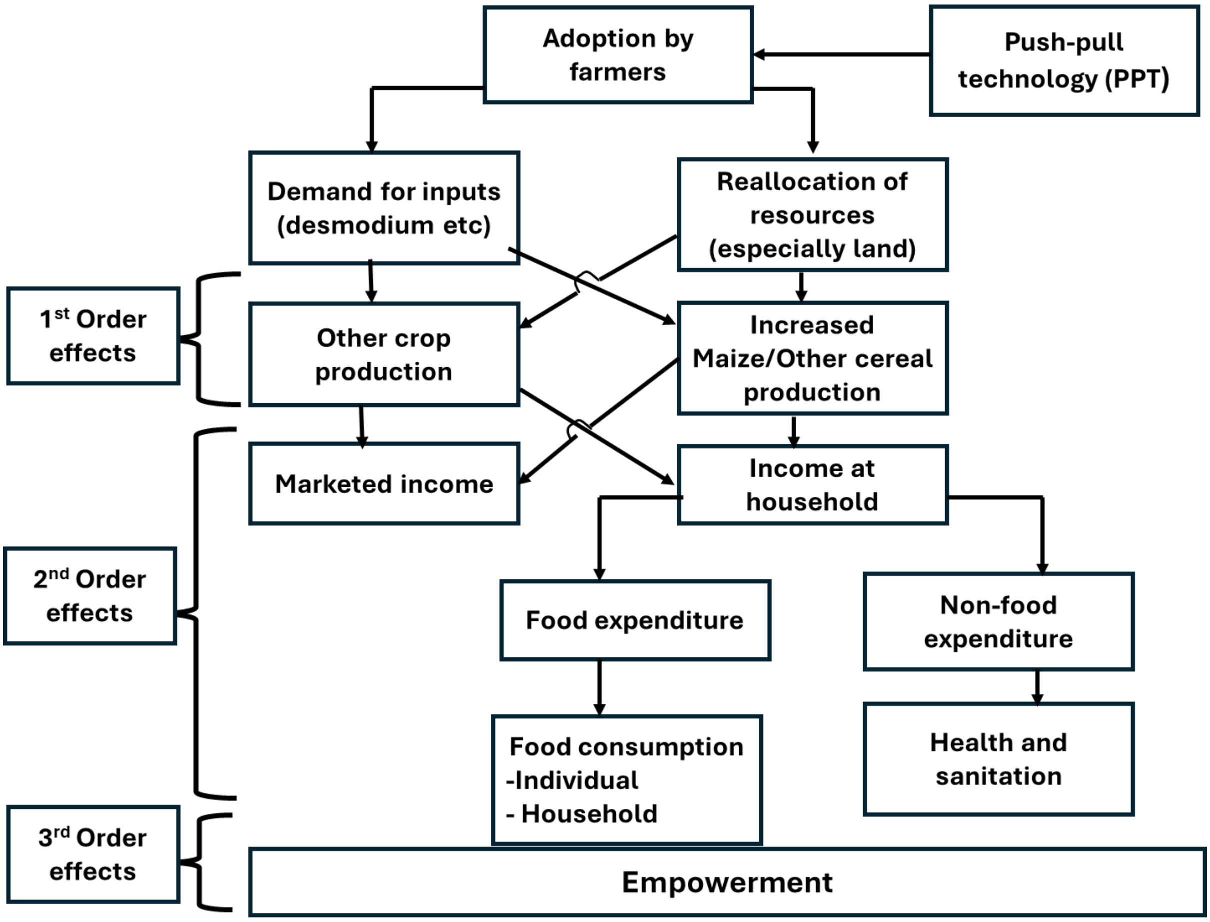

Figure 1: Conceptual framework for analysis of the socioeconomic, value chain and governance impacts of upscaling PPT in East Africa

3 Data sources

3.1 UPSCALE project household surveys

The baseline survey of the UPSCALE project was conducted in all five project countries (Uganda, Kenya, Rwanda, Ethiopia, and Tanzania) in 2022 (refer to Deliverable 7.1, April 2024 for more details on sampling design and implementation). A sample of 300 cereal-growing households (50% push-pull adopters) were randomly selected and interviewed from each country at the baseline. The survey assessed the initial adoption of PPT in the study areas and also provided sub-indicators that reflect the socioeconomic conditions (yields, knowledge, perceptions, adaptation of the technology, income, food security, and livelihood indicators) of the target communities in the study countries at the start of the project (UPSCALE Deliverable 7.1, 2024). A follow-up (midline survey) targeting the same households interviewed at baseline was conducted in 2023, in all the project countries except Ethiopia.

3.2 Literature source

The scope of this literature review is limited to PPT, with a focus on studies involving the technology across Africa. The studies are classified according to their contribution, either first, second, or third-order effects based on the conceptual framework above. The socio-economic, value chain, and governance effects of PPT have been assessed in past studies (including Chepchirchir et al. 2017; Kassie et al. 2018; Khan et al. 2008, 2014; Ogot et al. 2017). All these studies demonstrate positive and significant first and second-order effects of the PPT. Similarly, studies examining third-order effects of PPT were included (such as Diiro et al. 2018; Kassie et al. 2020; Muriithi et al. 2018).

3.3 Multi-actor communities of practice

Qualitative insights on the impact of PPT upscaling were compiled based on expert discussions in the framework of the UPSCALE Multi-Actor Community of Practice (MAC) workshops. These workshops took place yearly from 2020-2024 in each of the 5 UPSCALE countries, with an additional yearly regional workshop bringing together participants from all 5 countries (see Deliverables 1.1, Jan 2022, 1.3, July 2022, 1.4, February 2024 for detailed information on MAC events). Insights on additional value chains (Task 7.3), iterative evaluation of farmer dissemination approaches (WP8), and initial results of social-ecological modelling efforts (Tasks 4.4, 5.3) ongoing within the project timeline, flow into this discussion in the form of preliminary results, insights and expectations by expert MAC stakeholders including UPSCALE scientists and partners outside academia (Deliverable 1.1, 2022; see also the UPSCALE stakeholder database https://upscale-hub.eu/stakeholders/ and upcoming Deliverables 7.2, 1.5, April and August 2025).

4 Results and discussion

4.1 First-order effects of Push-pull technology

4.1.1 Increased crop yields

The direct effects of PPT include changes in maize yields. Previous studies have rigorously evaluated this outcome, starting with the first generation of push-pull implemented particularly in western Kenya, and the results show significantly higher grain yields than in the monoculture plots in almost all sites (Chepchirchir et al. 2017b; Kassie et al. 2018; Khan et al. 2008; Midega et al. 2015). Similarly, second-generation push-pull has given significantly higher maize yields across test sites in Kenya, Tanzania, and Uganda (Midega et al. 2015, 2018). These studies show that yields increase by 53-133% relative to the monoculture maize. Kassie et al. (2018) for instance show that adoption of PPT in western Kenya increased maize yield by 62%. Comparing maize output between PPT and non-PPT maize users, the UPSCALE baseline survey revealed that PPT users had significantly higher output per unit area in comparison with non-PPT users (Table 1). This is further substantiated by recent results of agroecological field surveys in UPSCALE WP2 and WP4, whereby yields are expected to have a lower magnitude of difference when comparing PPT with bean-intercropped maize as opposed to monocultural stands (see also Deliverable 2.2, April 2024 and 4.2 in prep.; the survey shown in Table 1 included a majority of farmers performing intercropping with beans, except in Rwanda where beans are mainly planted in seasonal rotation with monocultural maize).

Table 1: Maize output for PPT users and non-PPT users in East Africa

Variable	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user
Total output (kg/ha)	1287.5	2046.6	1592.6	2353.1	2307.3	3083.8	4643.2	5123.9	2345.1	2951.3
Average price (US$/kg)	0.30	0.31	0.17	0.16	0.25	0.23	0.18	0.20	0.30	0.41
Value of output (US$)	**410.4**	**629.3**	**228.2**	**296.9**	**503.2**	**681.3**	**628.7**	**727.1**	**841.6**	**859.5**

Source: Upscale Baseline Report, Report 3, 2022. Mwangi et al. (in prep).

The change in maize yield is attributed to various factors including suppression of striga weed, stemborer, and FAW pests, reduction of plant diseases and mycotoxins, improved soil health, and increased resilience to negative effects of climate change (Khan et al. 2001, 2014; Khan and Pickett 2004; Midega et al. 2018); see also UPSCALE Deliverable 5.3, October 2023). Witchweed (*Striga spp.*) is a root parasite that inhibits host growth and productivity of cereals, especially maize, sorghum, and pearl millet in Africa. Striga infests 40% of Africa's arable land and causes an estimated loss of USD 7-11 billion to the agricultural economy. In Africa, the Striga weed problem is intimately associated with agricultural intensification and land degradation (Sileshi et al., 2006). Past studies show that push-pull can reduce Striga weed infestation of maize by 62-85% in Kenya and Uganda, relative to monoculture maize (Khan et al. 2008; Midega et al. 2015). The control of Striga weed was rated highest among the benefits of adopting PPT in Kenya, Uganda, and Tanzania during the UPSCALE baseline survey (Table 2). Equally important constraints addressed by the PPT is stemborer and FAW infestation. Past studies show that PPT reduces stemborer infestation of maize by 66-83% across sites in Kenya and Uganda. Recently invading Africa, the FAW (*Spodoptera frugiperda*) is an invasive alien pest native to the Americas, currently affecting over 43 countries in Africa (Cock et al., 2017; Sileshi et al., 2019). The pest is estimated to cause 45-67% loss of the annual average production of maize in the affected countries (Day et al., 2017), equivalent to $ 6.2 billion annually. Using on-farm data, Midega et al. (2018) confirmed the effectiveness of the PPT in control of FAW, recording a reduction of 82.7% in average number of larvae per plant and 86.7% in plant damage per plot observed in climate-adapted push-pull compared to maize monocrop plots. Table 2 below also shows a significant number of farmers reporting PPT as a tool for control of FAW. In addition to managing Striga, stemborer, and FAW, the technology provides other synergistic benefits including enhancing soil fertility through companion crops (Chepchirchir et al. 2017b; Midega et al. 2015). Regarding climate mitigation, there is recent evidence that suggests that push-pull can provide opportunities for adaptation to climate change, while also providing mitigation benefits (see also see also UPSCALE Deliverable 5.3, October 2023 and Clough et al., *in prep*). For instance, Gugissa et al. (2022) in their study in Ethiopia indicated that push-pull farming systems are more climate-resilient than their non-push-pull counterparts. A more recent study by Mulungu et al. (*under review),* shows that the adoption of PPT resulted in the sequestration of approximately 2.7 million tons of CO_2 equivalent between 2007 and 2021, valued at $12 million in Kenya and Uganda. The build-up of soil carbon helps farming systems adapt to climate change, by increasing resilience of soils to drought and floods.

Table 2: Reasons for using push-pull technology by country (percent respondents)

	Kenya n=158	Uganda n=160	Tanzania n=160	Rwanda n=195	Ethiopia n=104	Total n=777
To control Striga	63.92	83.13	68.13	35.9	50.96	59.97
To control stem borer	22.78	55.63	52.5	63.08	77.88	53.15
Increase crop productivity only	62.03	26.25	41.88	61.54	24.04	45.30
To increase livestock fodder	33.54	16.25	35.63	45.13	59.62	36.81
To improve soil fertility	35.44	20.63	4.00	34.36	40.38	33.72
To control fall armyworm incidences	33.54	25.62	16.25	22.56	15.38	23.17
Increase livestock productivity only	20.89	1.88	13.13	22.56	13.46	14.8
Others	4.43	3.75	4.38	0.51	0.96	2.83
Adapt to the changing climate	1.90	0.00	2.5	4.62	1.92	2.32

Source: Upscale Baseline Report, Report 3, 2022. Mwangi et al. (in prep).

While the use of PPT increases the cost of production, estimated at 15.3% (Kassie et al. 2018), the net effect of income earned from surplus cereal output is positive. The author estimates net maize income increased by 39% among the PPT users compared to non-users in Western Kenya.

4.1.2 Increased livestock feed

PPT is also a livestock productivity-enhancing technology. The companion crops (Desmodium, Brachiaria, and Napier grass) provide high-quality livestock forage that increases milk production among livestock-adopting households (Kassie et al. 2018). As shown in Table 2, a significant number of farmers from Kenya (21%) and Rwanda (23%), stated that the increase of livestock productivity was their main reason for adopting PPT. Assessing the complementarities and substitutability of sustainable agricultural practices and push-pull, Muriithi et al. (2018) found a positive synergy between the technology and the use of manure. This was attributed to the fact that PPT promotes livestock and poultry enterprises, thus increasing the availability and utilization of animal manures. Cook, Khan, and Pickett (2006), Khan et al. (2008) and Midega et al. (2015) note that PPT can double or even in some cases triple livestock fodder.

4.2 Second-order effects of Push-pull technology

In this report, we consider the second-order effects of PPT as the value chain impacts associated with the technology. The additional income gained from the sale of surplus maize, or livestock feed generated through the technology, improves the disposable household's income, which is subsequently used to purchase food or non-food items. Households use the income to buy a variety of food products hence improving their nutritional security as demonstrated by Chepchirchir et al. (2017b) and Kassie et al. (2020) in their studies in Western Kenya. Kassie et al. (2020) note that adoption of PPT increased women's dietary diversity score by 46% compared to non-PPT-adopting households. The high-value animal fodder from the PPT companion crops facilitates milk production for use by the household members but also diversifies farmers' income sources (Khan et al. 2014). Assessing the economic and welfare impacts of PPT in Kenya, Kassie et al. (2018) noted that if 25% of the maize growers adopted PPT, the technology would contribute between US$ 140-142 million to the Kenyan economy, and this income would decrease poverty of approximately 149,864 people. Furthermore, a significant number of people would attain food security as demonstrated by Mulungu et al. (*under review).*

Tables 3-5 below show food security indicators computed using the UPSCALE baseline survey data. Table 3 compares the average food consumption and dietary diversity scores between PPT users and non-users across the different countries. In all the countries except Rwanda, PPT users reported higher household dietary diversity scores (HDDS) compared to non-PPT users, suggesting the former would be more food secure than the latter. Similarly, the average food coping strategy index was higher for PPT users than for non-users in Kenya, Uganda, and Tanzania.

Table 3: Average Food consumption and dietary diversity indicator scores per household

	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	Non user	PPT user	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user
HDDS	6.69	7.15	6.62	7.22	6.69	7.34	6.11	6.03	6.29	6.35
FCS	67.9	74.8	56.9	62.8	67.1	73.6	41.2	39.7	54.4	51.7

**HDDS= Household Dietary Diversity Score; FCS= Food Coping Strategy Index*
Source: UPSCALE Baseline Report 5, 2022; Mwangi et al. (in prep).

Table 4 shows the food insecurity coping strategy score by PPT adoption. The results show that the index was lower for PPT users compared to non-users in Kenya, Uganda, Rwanda and Tanzania, while the index was almost equal for both in Ethiopia. The index measures the regular behaviour response (coping strategies) of the target respondents when they cannot access enough food. Suggesting that the higher the index, the more often the respondents do not have food and hence the need to respond to non-access to food.

Table 4: Average Food insecurity coping strategy scores per household

	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user
FCSI*	19.7	10.9	22.6	16.6	18.7	11.1	48.4	39.2	7.5	7.6

FCS= Food Insecurity Coping Strategy Index
Source: UPSCALE Baseline Report 5, 2022, Mwangi et al. (in prep).

Table 5 provides a summary of the probability of a household becoming food insecure by PPT use and also across the surveyed countries. The PPT non-users from Kenya, Uganda and Tanzania were more likely to suffer moderate and severe food insecurity compared to PPT users.

Table 5: Probability of food insecurity per household

	Kenya		Uganda		Tanzania		Rwanda		Ethiopia	
	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user	Non-user	PPT user
Probability of moderate and severe food insecurity	0.68	0.53	0.60	0.49	0.50	0.37	0.78	0.78	0.26	0.30
Probability of severe food insecurity	0.14	0.05	0.15	0.06	0.17	0.08	0.38	0.35	0.05	0.04

Source: UPSCALE Baseline Report 5, 2022, Mwangi et al. (in prep).

4.3 Third-order effects of Push pull Technology

The third-order effects of PPT considered in this report are considered as the governance impact. We focus on farmer's empowerment and the role of MAC in leveraging of synergies and coordination among agroecological farming and intensification initiatives including PPT among the relevant stakeholders.

Previous studies on gender and agriculture development have often demonstrated the existence of gender gaps in technology adoption, mainly associating the gaps with limited access to productive resources between men and women. PPT has however been demonstrated to be a gender-neutral technology, and in some cases, women empowerment enhancing practice. For instance, in their study in Western Kenya, Muriithi et al. (2018) found that the gender of the farmer did not matter in the adoption of PPT. Diiro et al. (2018), investigating the relationship between maize productivity and women's empowerment in Western Kenya, found that empowerment through PPT enhanced the productivity of both female and male management maize plots, suggesting the need to promote the technology alongside women's empowerment. Using the same dataset, Kassie et al. (2020) showed that the empowered women have higher dietary diversity scores compared with women who are non-empowered and from non-PPT-using households.

Established through the UPSCALE project, MAC aims to enhance the expansion of the impact of agroecological and intensification practices including PPT beyond research. The coordination of the key actors and identification of synergies along the range of sustainable agricultural practices improves the technical performance of the innovations, research impact and technology transfer capacity, and sustainability of dissemination strategies. Furthermore, the broad representation includes actors of interest in the research and development agenda, such that ownership and agency are built over the project phase to sustain activities beyond the project, with expected and documented knock-down impacts on long-term perception and prioritization of technologies among agricultural advisors, trainers and educators, decision- and local to regional and national policy-makers. In Ethiopia for instance, by involving the Ministry of Agriculture, the MAC has been supporting the update and integration of PPT with the existing agricultural extension systems. Through the UPSCALE project coordination organization, the MAC initiated discussions with the ministry's main departments of extension on the possibilities of enhancing collaboration to mainstream PPT in the Agricultural strategy (see Deliverable 1.4, August 2024 Ethiopia MAC Workshop report). Further examples include the uptake of agronomic PPT testing with the objective of integration within national crop intensification programs by agricultural research organizations with state mandates, such as the Rwanda Agricultural Board, and impacts on the private seed sector through development of the seed multiplication value chain for Desmodium as both a valuable fodder for burgeoning livestock value chains as well as a PPT intercrop. Novel dissemination approaches for PPT developed within the project, founded on community-level adoption and strong market linkage, are furthermore expected to maintain and strengthen the density and robustness of smallholder networks, community inclusion, access to knowledge and training, and increase access to markets. At the same time, public visibility of the technology impacts and awareness by local and national policy makers are expected to enhance acceptance of the benefits offered by a portfolio of agricultural intensification approaches.

Further impacts of the efforts to upscale the PPT are more diffuse in nature but with far-reaching implications on key actors' understanding of the processes involved. Notably, insights pertaining to *how* to upscale such a technology have relevance to the range of agroecological innovations being examined for sustainable intensification potential. Ongoing active dissemination of UPSCALE project insights among regional, national and international stakeholders, including policy-makers, academia and funders, is expected to raise awareness on major issues at play, such as the non-linearities and dynamic nature of technology adoption processes (see below). Novel approaches developed through the project to tailor dissemination strategies to these insights are recognized and streamlined within the long-term strategies of participating stakeholders, particularly the relevant UPSCALE partners in all 5 project countries and associated MAC stakeholders.

4.4 Push-pull technology adoption dynamics

Similarly to many other agricultural technologies, the adoption of PPT is not static, but rather dynamic. Figure 2 shows the adoption pattern for PPT based on the UPSCALE baseline and midline survey data. Approximately 26% of the farmers were consistent, with more female farmers (31%) exhibiting consistency compared to male farmers (25.4%). Twenty-nine percent (29%) were unaware of the technology. At least 4% had expanded, and 6% were trailing behind. These percentages varied across the study countries. The consistent farmers were 36% in Kenya, 24% from Uganda, 21% from Tanzania, 35% from Rwanda and 6% in Ethiopia (Note: for Ethiopia, the analysis includes only baseline data).

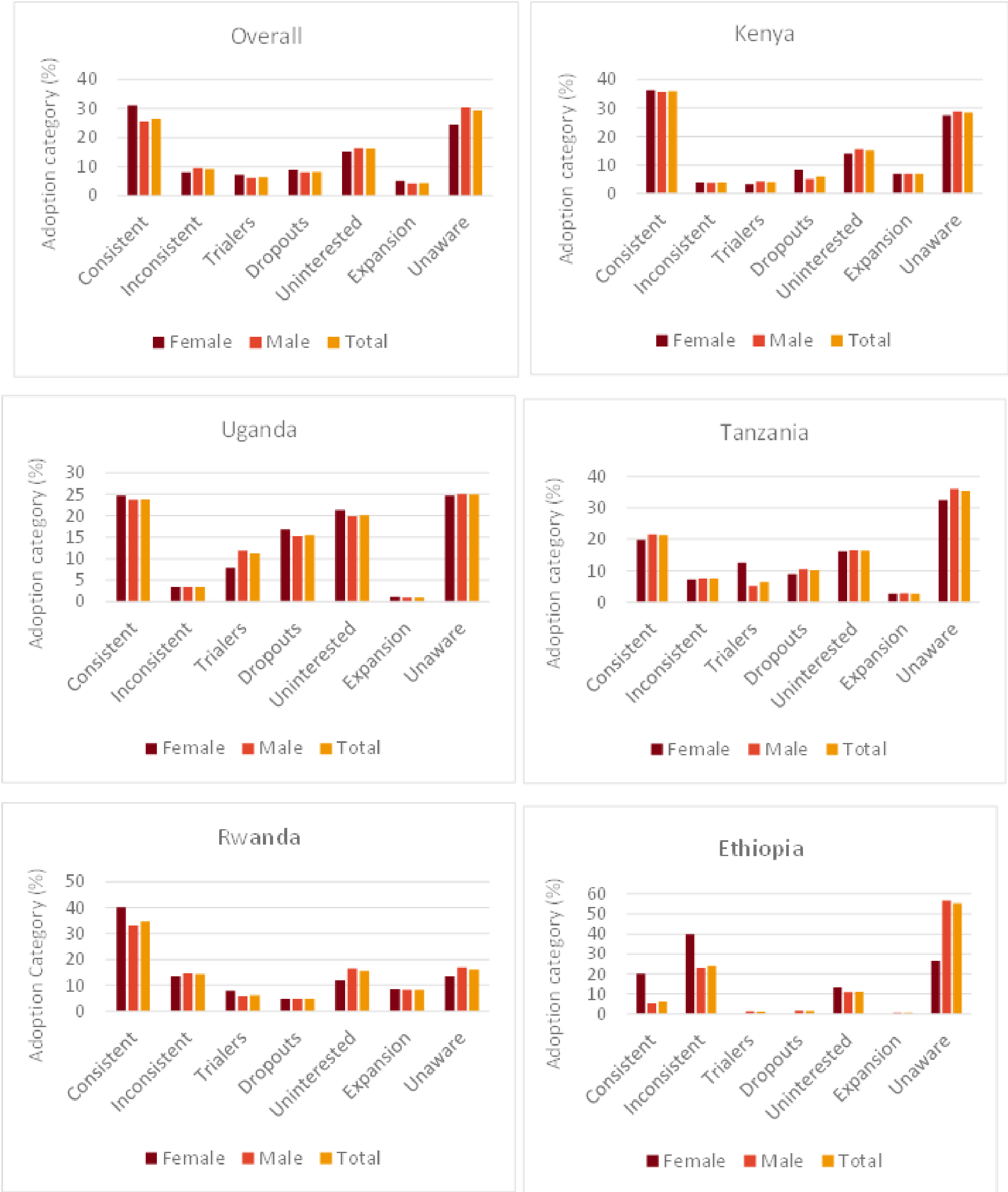

Figure 2: Push-pull technology adoption dynamics between baseline and midline surveys of the UPSCALE project: Source: UPSCALE WP7 Report, 2024

4.5 Barriers to adoption of push-pull

Previous studies have documented various barriers to the adoption of PPT. The midline survey of the UPSCALE project examined the reasons for PPT adoption inconsistencies reported in the previous section. A summary of the reasons that explain the PPT adoption dynamics is presented in Figure 3. The reasons seem to vary between men and women farmers. In Kenya for instance, the majority of women cited PPT as difficult to manage, followed by labor shortage and lack of desmodium seeds, while men cited lack of desmodium seeds, difficulty in management, and limited knowledge of the application and effectiveness of the technology. Lack of desmodium seeds topped among the reasons given by both men and women farmers from Uganda, Tanzania, and Rwanda, as well as limited knowledge of PPT's benefits. The results are consistent with previous studies including the UPSCALE baseline survey findings as well as other studies which examined the socioeconomic factors affecting adoption of PPT (e.g. Murage et al. 2011; Murage, Midega, et al. 2015; Murage, Pittchar, et al. 2015; Muriithi et al. 2018).

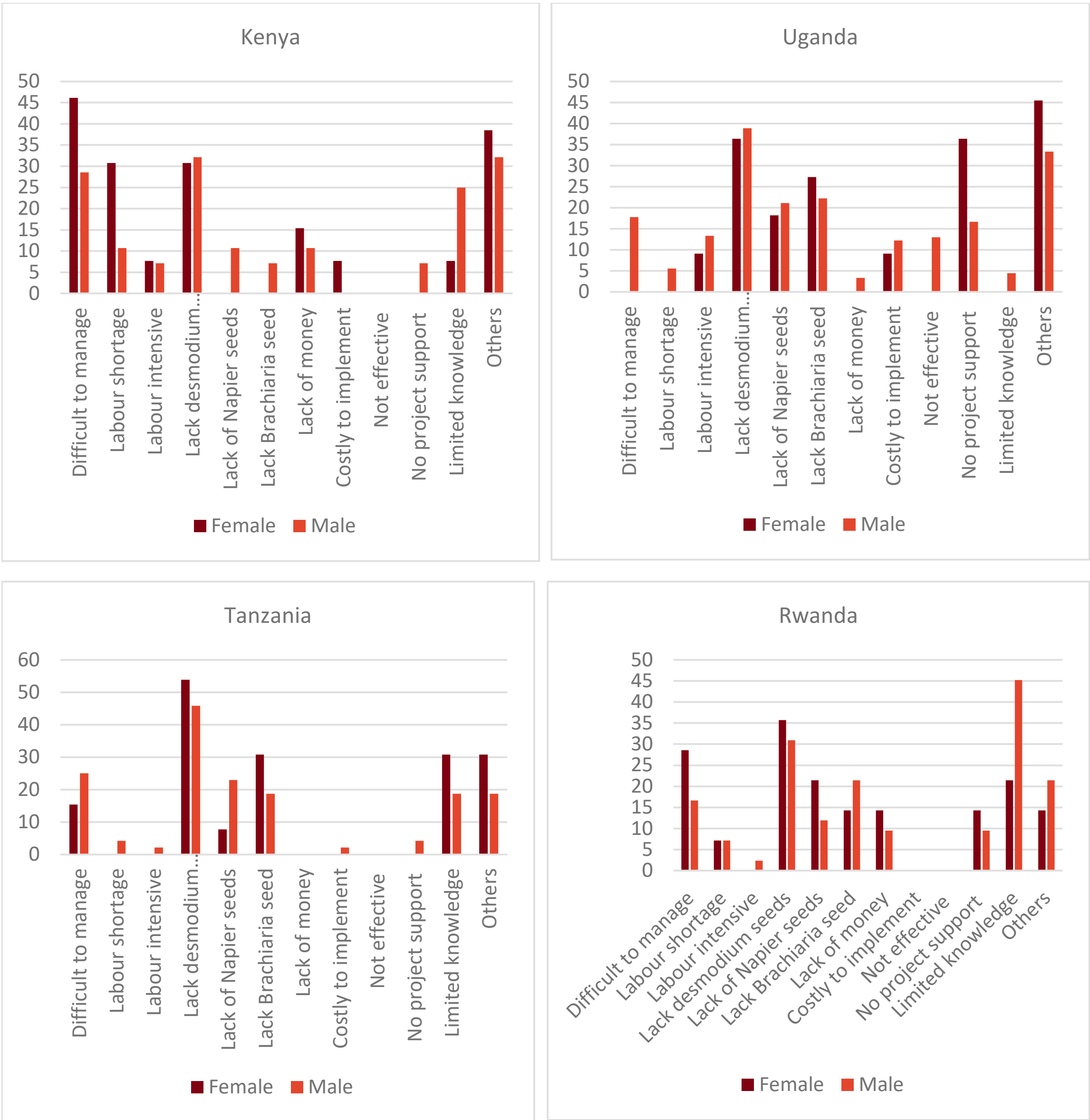

Figure 3: Farmers' perceived reasons for inconsistency in the adoption of the Push-pull Technology: Source: UPSCALE WP7 Report, 2024

Beyond the socioeconomic factors that affect PPT, the UPSCALE midline survey examined, for the first time, the potential social-psychological factors that affect adoption of the technology (Waiswa et al., 2024). This study investigated the influence of social-psychological factors on the intention to adopt or increase the land area under PPT based on the theory of planned behavior, and using the sample of 971 cereal growers interviewed in Kenya, Uganda, Tanzania, and Rwanda. The study underscores the importance of perceived limitations that shape the behavior of farmers in making decisions on whether to adopt, dis-adopt, re-adopt, expand or exit from the use of the technology. Social-psychological factors are as important as socioeconomic factors in determine the PPT adoption dynamics and hence should also be addressed in the effort to promote PPT adoption for improved agricultural outcomes.

5 Conclusions and Recommendations

Based on the assessment we conducted, we conclude that PPT significantly contributes to first-, second-, and third-level impacts. The first level impact are the direct benefits derived from the technology including increased crop yield due to suppression of striga weed, stemborer, and fall armyworm pests, as well as improved livestock productivity from high-quality feed. The second-order effects are the welfare impacts mainly from income gained from the marketed surplus of the crop and livestock products, while third-level effects involve the empowerment of men and women farmers as a result of the gains from the previous levels as well as coordination and policy impacts that go beyond the project life. While these socioeconomic, value chain and governance impacts are well documented and evident from the UPSCALE surveys (baseline and midline), the technology still suffers an anemic adoption trajectory due to socioeconomic, but also social-psychological factors. While these barriers remain an important caveat to PPT adoption, the opportunity for expanding the technology through the livestock model should be explored. Access to seeds for the PPT companion crops remains a major barrier to consistent adoption of the technology, suggesting the need for partnership with the private sector to bridge this gap. Continuous training, awareness, and promotion of the technology would overcome the knowledge gap regarding its complex mechanism in addressing the pests' challenges and benefits associated with it. The MAC initiatives through UPSCALE provide a platform to address some of these constraints through collaboration and partnership among key stakeholders along the sustainable agricultural practices value chains. The collaboration is expected to go beyond the research impact, integrate the practices into the existing extension system, and hence mainstream the adoption of sustainable agricultural practices including PPT.

6 References

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