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Gender specific perceptions and adoption of the climate-smart push–pull technology in eastern Africa

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ABSTRACT

The performance of the agricultural sector in many developing countries has been rated as below average, in particular the staple cereal crops whose productivity is limited by both biotic and abiotic factors. Furthermore, underperformance by the agricultural sector has in part been attributed to the inability of women to access resources, yet they represent a crucial resource in agriculture and the rural economy through their roles as farmers and entrepreneurs. These challenges can be overcome by understanding gender roles and perceptions, and aligning innovations to fit the preferences of specific gender. This study evaluated gender specific perceptions and the extent of adoption of a climate-smart push–pull technology for controlling stemborers, African witch weed (*Striga* spp.), and improving soil fertility in drier agro-ecological zones where these constraints are quickly spreading. The findings show that slightly higher percentage of women (98.6%) perceived the technology as effective compared to men (96.7%). Women also highly rated the beneficial attributes of the technology such as increased cereal production (97.3% of the women vs 94.6% of men), decline in *Striga* spp. weed (97.2% women vs 92.4% of men), increase in soil fertility (95.9% of women vs 90% of men), increase in fodder production (94.1% of women vs 91.3% of men) and increase in cereal and fodder production even with drought (82.3% of women vs 66.5% of men). The findings show that, women who are the most vulnerable of the smallholder farmers, are bound to benefit from the technology, mostly because its attributes favors their (women) preferences.

1. Introduction

Low production of the main staple crops and livestock remain a key challenge in achieving food security in Africa and this has resulted in high food and nutrition insecurity, malnutrition and poverty, particularly for the resource-constrained smallholder farmers, mostly women, practicing rain-fed agriculture (Gurney et al., 2006; World Bank, 2007). The parasitic African witch weed (*Striga* spp.), lepidopteran stemborers, *Chilo partellus* Swinhoe (Lepidoptera: Crambidae) and *Busseola fusca* Füller (Lepidoptera: Noctuidae) and degraded soils have been classified as the main causes of dismal cereal production in Africa and this has been aggravated by climate change and unpredictable rainfall (Smil, 2000; Kfir et al., 2002; Sauerborn et al., 2003; Okalebo et al., 2006; De Groote et al., 2010; Midega et al., 2013). The push–pull technology, developed by the International Centre of Insect Physiology and Ecology (ICIPE) and partners has been accepted as a low-cost conservation agriculture method that manages these constraints simultaneously and has been well adopted in the higher potential areas, with farmers reporting doubled and tripled cereal yields and more fodder for their livestock (Cook et al., 2007; Khan et al., 2000, 2008c, 2001, 2006; Khan and Pickett, 2004; Hassanali et al., 2008). However, the performance of the original conventional push–pull technology, that utilized silverleaf desmodium, *Desmodium uncinatum* (Jacq.) DC as the repellent intercrop against stemborer moths and the Napier grass *Pennisetum purpureum* (L.) Schumach. as a trap crop, was limited by the increasingly hot and dry conditions associated with climate change (Midega et al., 2010; Khan et al., 2010, 2014; Pickett et al., 2014). This necessitated its adaptation by incorporation of a drought-tolerant trap plant *Brachiaria* spp., particularly the commercial hybrid, *Brachiaria* cv mulato II, commonly known as brachiaria, and intercrop with drought tolerant species of green leaf desmodium, *Desmodium intortum* (Mill.) plants (Khan et al., 2014; Pickett et al., 2014; Midega et al., 2015), now termed as the 'climate-smart' push–pull system,

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which extends its benefits to smallholder farmers in a wider range of agro-ecological zones in sub-Saharan Africa (SSA).

Since its adaptation and subsequent dissemination in the drier agro-ecological zones, the adoption pattern and farmers' perceptions have remained unclear, yet this is important for a successful up-scaling plan. Farmers' perceptions are considered subjective but have direct influence on decisions to adopt new technologies and are therefore very relevant in economic modeling (Adesina and Baidu-Forson, 1995; D'Antoni et al., 2012). Rogers (1995) noted that technology characteristics such as perceived usefulness, ease of use, compatibility, observability and trialability, are key influential factors affecting farmers' attitudes and perceptions towards adopting the proposed new technological innovations. Moreover, the importance of gender in influencing farmers' perceptions of new technologies has been emphasized as men and women experience their social, economic and environmental reality in different ways (Brody et al., 2008). The importance of gender is reflected in the different roles played by both men and women in farming systems often defined by culture and context within the country. Although men and women carry out different roles in farming, both make important contributions to agriculture with women contributing over 50% of agricultural labor besides other reproductive roles (FAO, 2011). In addition, the different social expectations, roles, status, and economic power of men and women can influence perceptions which in essence affect adoption patterns.

Farmers' perception of new technologies and adoption cannot be separated. At the center of this interaction is the household member who makes decisions on whether or not to adopt technologies and this decision is dependent on how farmers perceive the technology (Van de Ban and Hawkin, 1988). Effective dissemination and adoption of new innovations can therefore be achieved if there is complete knowledge of how the technologies are perceived. In theory, farmers' adoption behavior have been explained using three paradigms; the innovation-diffusion model which assumes that while the technology is technically and culturally suitable, information asymmetry and high search cost may limit its adoption (Feder and Slade, 1984; Smale et al., 1994; Shampine, 1998); the economic constraint model which further argues that in the short run, input fixity such as access to credit, land and labor restricts production flexibility and therefore conditions technology adoption decisions (Aikens et al., 1975; Smale et al., 1994; Shampine, 1998); and the adopters' perception paradigm, which suggests that the perceived attributes of the technology conditions adoption behavior of farmers implying that even with full information, farmers may subjectively evaluate the technology (Kivlin and Fliegel, 1967; Ashby and Sperling, 1992). Other studies by Adesina and Zinnah (1993) and Prager and Posthumus (2010) also observed that in light of prevailing socio-economic environment, farmers' subjective perceptions of a new technology may condition their adoption behavior. Kaimowitz and Merril-Sands (1989) further acknowledged that farmers are not passive consumers of technologies but active problem solvers and therefore getting feedback from them is desirable. Consequently, farmers' attitudes and perceptions cannot be ignored since they can enable or inhibit adoption of the new technology. In view of this, understanding different genders' perceptions of a given technology is crucial in the generation and diffusion of new technologies.

Studies on farmers' perceptions and attitudes can be utilized to assess impacts of agricultural research and provide information for policy reform (Olwande et al., 2009) and understanding farmers' perceptions of a particular technology shapes the subsequent actions taken in technology dissemination. Morse and Buhler (1997) acknowledged that lack of information about farmers' knowledge, perceptions and practices could hinder further establishment of effective pest management methods. Indeed, the need to understand farmer knowledge systems was recognized as a basis for development of pest management technologies adapted to local farmers' situations (Van Huis and Meerman, 1997; Norton et al., 1999). Therefore, understanding farmers' perceptions and specifically from a gender point of view will enhance access to and benefit from productivity enhancing technologies, which is critical in achieving food security in Africa (AGRA, 2013).

The objective of this study was therefore to investigate different genders' perception of the climate-smart push–pull technology, particularly understanding farmers' opinion on its effectiveness and benefits hitherto. The special focus on gender was intended to allude to the existing differences between men and women in the perceptions of the technology with an expectation of catalyzing gender awareness in technology dissemination targeting each group of farmers from a point of view of their preferred technology attributes. Previous studies by Khan et al. (2008a) evaluated farmers' perception of the push–pull technology in Kenya based on the conventional push–pull type. With the new attributes of the climate-smart push–pull type and its expansion thereof in drier agro-ecological zones, there is likelihood of variations in socio-cultural and bio-physical factors that may influence farmers' responses.

2. Methodology

2.1. Sampling and data collection

This study was conducted in drier agro-ecological zones (Midega et al., 2015) of Kenya, Uganda, Tanzania and Ethiopia where the climate-smart push–pull technology is being promoted since its adaptation in 2011. Cross-sectional data were collected using a structured questionnaire using a team of enumerators recruited and trained by each country. This study was conducted in April 2014 at least two years after the adaptation and initial dissemination of the technology. One weakness that might occur in this study is that it was carried out at the point when the adoption status was still relatively low, hence the small sample size. Low adoption was attributed to the stage of dissemination, as well as a possibility of farmers waiting to accumulate more knowledge since the technology is considered relatively knowledge intensive. In actual fact, this study was a follow-up of the *ex ante* study conducted in 2012 (results now published as Murage et al., 2015) and was necessitated by the need to understand how farmers perceived the new climate-smart technology in order to plan for its expansive dissemination and scaling up. Sampling therefore targeted early adopters from the push–pull villages and apart from Kenya where dissemination had started slightly earlier, the number of farmers who had taken up the technology in the other selected countries was still small. In view of this, we sampled and interviewed 461 respondents; 282 in Kenya, 42 in Ethiopia, 105 in Tanzania, and 32 in Uganda, which was approximately half of the number of adopters in each country at the time of survey. The questionnaire focused on gender disaggregated socio-economic characteristics of the respondents, farm attributes, major crops grown and their constraints, perceived technology attributes and determinants of the extent of adoption of the technology, reasons for adoption, sources of information, observed benefits of adoption and constraints, and willingness to expand and continue using the technology.

2.2. Model specification and data analysis

A combination of descriptive and econometric analysis was used to summarize the data. The main responses on the attributes of climate-smart push–pull technology were summarized using descriptive analysis and cross-tabulation, disaggregating each variable by country and by gender. A tobit model was used to evaluate the extent of adoption using the land size under the technology as the dependent variable (*Adop_exte*). The predictors included in the model were age of the farmer (*Age*), gender of the farmers (*gender*), education level (*Educ*), land size (*landsze*), information sources variables (*inf_adopter, inf_NGO, inf_fieldday, info_extension*) and farmers' perception of the effectiveness of the technology (*perc_adopt*). The empirical model was:

$$\begin{aligned} Adop\_exte = {} & \beta_0 + \beta_1 gender + \beta_2 Age + \beta_3 Educ + \beta_4 landsze \\ & + \beta_5 \mathrm{inf}\_adopter + \beta_6 \mathrm{inf}\_NGO + \beta_7 \mathrm{inf}\_fieldday \\ & + \beta_8 \mathrm{inf}\_extension + \beta_9 perc\_adopt \end{aligned} \tag{1}$$

Which is theoretically presented as follows (Greene, 2003);

$$Y^* = X\beta + \varepsilon \tag{2}$$

where Y^* is a latent variable that is unobservable, β is a vector of unknown coefficients, X is a vector of independent variables, and ε is an error term that is assumed to be independently distributed with mean zero and a variance of σ^2.

3. Results and discussions

3.1. Socio-economic and farm characteristics

Some of the socioeconomic factors and farm characteristics of the sampled population are summarized in Table 1. Farmers' socio-economic characteristics are known to influence perception and adoption of new technologies (Adesina and Zinnah, 1993). The literacy level among the respondents was relatively high with over half of the overall respondents having attained primary level education. The majority of the women in the overall sample had primary level education (61.4%) compared to 57.7% for men. Nonetheless, more men (12.6%) had attained college education compared to women (9.5%). The trend was almost similar in all countries apart from Ethiopia where high level of illiteracy among women was observed. Though culturally, women in Africa have been deprived of opportunities to further their education due to household roles, the observed trend is positive towards empowering women in agriculture. Education exposes farmers to more information and enables them to accumulate knowledge about new technologies, and hence their perceptions on new technology attributes are expected to be different from those of the less educated farmers. This variation in education is likely to have a significant effect on perception on technology attributes given that more educated farmers are more able to understand the benefits of a new knowledge-intensive innovation. Female respondents were slightly older (48.7 years) than male respondents (45.4 years) in the overall sample. Highest age was observed in Kenya where farmers averaged 49 years.

The results further portray a community of smallholder farmers who practiced mixed farming. The average farm size was 0.79 ha for the female farmers and 0.99 ha for the male farmers in the overall sample. Average land sizes were higher in Tanzania (1.34 ha for women and 1.77 ha for men). Interestingly, the land parcels were larger for women than men in all the other countries which might indicate a paradigm shift where women farmers are now able to access larger land parcels for crop production. Though women are slowly being seen as overtaking men in the farming sector, their rights to access, manage and own key resources still vary and this affects their productivity (AGRA, 2013). Our results show that livestock keeping was mainly a male domain with women recording 74.1% of livestock keepers and men 79.8% in the overall sample (Table 1). With exception of Tanzania where more women (76.7%) kept livestock compared to men (61.6%), in all the other countries, livestock keeping was mainly a male domain. In many African communities, owning the large ruminants such as dairy cows, breeding bulls and draught animals is seen as a man's activity. Where women own livestock, it is usually limited to the small ruminants and poultry.

3.2. Farmers' rating of constraints and technology adoption

The perceived strength of particular constraints is likely to influence farmers' decisions to try new technologies or not. The major farming constraint perceived by both men and women was low cereal yields (Table 2). Women perceived poor soil fertility and *Striga* weed as the second and third constraints (96.3% and 95.9% respectively), while men rated *Striga* weed and stemborers as the second and third constraints (93.4% and 93.2% respectively) (Table 2). This disparity in the ranking of constraints among the men and women is linked to the different perceptions based on the socio-economic circumstances. More women than men rated drought, flooding, pest and diseases and limited land for cereals as a

Table 1
Socio-economic and farm characteristics of the farmer disaggregated by gender.

	Kenya		Ethiopia		Tanzania		Uganda		Overall sample	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Level of education (%)										
None	2.2	2.0	100	31.7	6.7	2.7	11.1	4.3	3.6	7.5
Primary	56.7	46.1	0	65.9	86.7	76.7	77.8	34.8	61.4	57.7
Secondary	30.6	33.3	0	2.4	0	8.2	11.1	52.2	25.5	22.2
College	10.6	18.6	0	0	6.7	12.3	0	8.7	9.5	12.6
Average age of the farmer (years)	49.93 (0.835)	49.04 (1.163)	39.0 (0)	34.41 (1.348)	44.79 (1.787)	46.87(1.51)	38.0 (2.824)	44.86 (2.66)	48.69 (0.758)	45.42 (0.828)
Average land size (hectares)	0.68 (0.04)	0.65 (0.06)	1.00 (0)	0.55 (0.04)	1.34 (0.193)	1.77 (0.29)	1.15 (0.65)	0.75 (0.09)	0.79 (0.05)	0.99 (0.10)
Livestock ownership (% Yes)	75.0	92.2	0	90.0	76.7	61.6	55.6	65.2	74.1	79.8
Dairy cows owned (% Yes)	33.3	41.2	0	82.9	40.0	28.0	0	30.4	32.7	43.2
Dairy goats owned (% Yes)	11.1	13.7	0	22.0	20.0	16.0	33.3	56.5	13.2	19.9
Zebu cattle owned (% Yes)	55.6	69.6	0	63.4	36.7	38.7	11.1	8.7	50.9	53.1
Number of dairy cows owned (mean)	0.65 (0.09)	0.62 (0.09)	0.00 (0)	1.18 (0.12)	0.67 (0.19)	0.60 (0.15)	1.67 (1.11)	1.78 (0.47)	0.62 (0.08)	0.72 (0.07)
Number of dairy goats owned (mean)	0.25 (0.06)	0.45 (0.15)	0.00 (0)	0.35 (0.12)	0.73 (0.37)	0.49 (0.15)	0.22 (0.22)	0.61 (0.44)	0.38 (0.09)	0.58 (0.09)
Number of Zebu cattle owned (mean)	1.58 (0.17)	2.18 (0.21)	0.00 (0)	2.20 (0.62)	4.30 (1.48)	5.07 (1.07)	–	–	1.89 (0.25)	2.91 (0.37)

Figures in parenthesis are standard errors.

Table 2
Percentage of farmer rating different constraints by gender.

	Kenya		Ethiopia		Tanzania		Uganda		Overall sample	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Stated constraints (%)										
Low cereal yield	99.4	98.0	100	95.1	90.0	92.0	100	87.0	98.2	94.6
Poor soil fertility	98.3	95.1	100	75.6	83.3	90.7	100	78.3	96.3	88.8
Striga weed infestation	97.8	100	100	100	86.7	82.7	88.9	87.0	95.9	93.4
Stemborers damage	87.0	94.9	100	87.8	93.3	100	66.7	73.9	87.1	93.2
Drought	90.1	98.0	100	65.9	30.0	49.3	66.7	91.3	80.6	76.5
Flooding	33.0	42.0	0	4.9	0	0	0	4.3	29.7	21.1
Other pest and diseases	29.2	34.7	0	0	0	0	11.1%	21.7	27.3	19.6
Limited land for cereal	29.2	32.7	0	0	0	0	0	4.3	26.3	15.0

constraint (80.6%, 29.7%, 27.3%, and 26.3% respectively) as opposed to 76.5%, 21.1%, 19.6%, and 15% of men. Although the percentage of women ranking the different constraints was slightly higher than that of men, it is evident that both men and women did emphasize on the problem related to food shortages and food insecurity. In classical adoption studies, the adoption process follows awareness, interest, evaluation, acceptance, trial and finally adoption in a continuous sequence of events, actions and influences that intervene between initial knowledge about an idea, product or practice, and the actual adoption of it (Lionberger, 1960; Rogers, 1983). Awareness of a need is generally perceived as a first step in the adoption process (Rogers, 1983). Our study suggests that the variations in farmers' perceptions of the constraints may be a function of awareness of both constraints and solutions, and access to resources required to implement the solutions. For example, in many instances, women are deprived of access to major agricultural resources (AGRA, 2013) and therefore may have different perspective of constraints. The constraints which in one way are interrelated are key determinants of whether the technology will be adopted or not. A previous study by Murage et al. (2015) observed that farmers who perceived *Striga* infestation as a serious problem on their farms were more willing to adopt climate-smart push–pull as opposed to those who perceived it as not a problem.

3.3. Rates and reasons for climate-smart push–pull technology adoption

Fig. 1 shows the percentage of adopters in 2012 and 2013. It is evident that there was more adoption in 2013 compared to 2012, which according to adoption theory reflects an early stage of adoption curve, representing basically the innovators and early adopters of the technology. As the awareness level increases and knowledge about climate-smart push–pull accumulates, it is expected that the adoption level will also increase exponentially and probably eventually plateau. Literature on adoption shows a logistic trajectory over time as the stock of knowledge about a technology increases in a population (Griliches, 1957; Lionberger, 1960; Rogers, 1983; Alston et al., 1995). At the time of survey, most of the respondents had practiced the technology for a minimum of three cropping seasons which is a reflection of quick and rapid adoption process. A greater proportion of females adopted in 2012 than in 2013 compared to males (46.4% of women, to compared 29.4% of men adopted in 2012, while 70.5% of men compared to 53.7% of women adopted in 2013). The most plausible explanation for this observation would be women's immediate motivation to try out new innovations to tackle the overarching constraints of *Striga* and stemborers which affected them more directly than men. Indeed, women rated these constraints higher than men. On the other hand, it can be argued that men tend to takeover enterprises that seem to have promising financial benefit as would be the case with the expected cereal yield increase, some of which can be sold to the market or the expected income from the sale of excess milk coming from fodder availability. Previous studies by Burton et al. (2003) and Murage et al. (2011) observed that being a female farmer accelerated the speed of uptake of new innovations.

On average men allocated larger portions of their land (0.12 ha) to climate-smart push–pull technology compared to women who allocated 0.08 ha (Table 3). The results further show that average

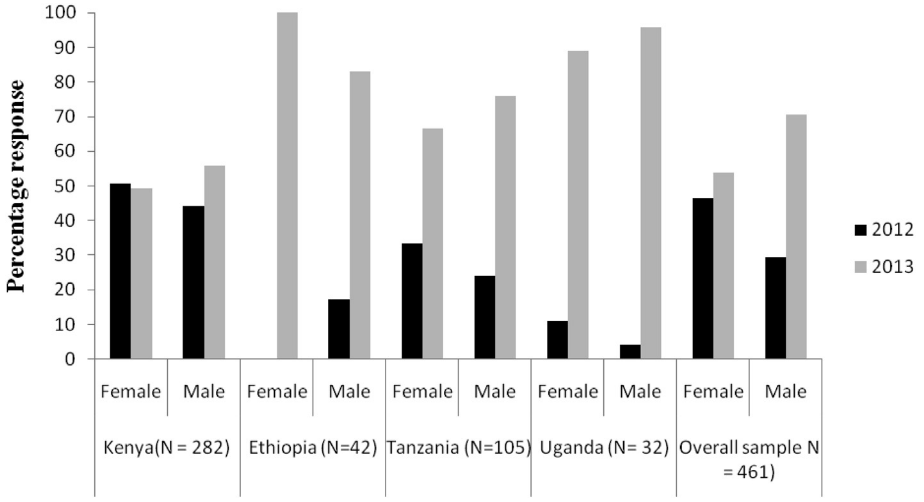

Fig. 1. Percentage of farmers adopting climate-smart push–pull technology in each year.

Table 3
Climate-smart push–pull technology adoption and perceived benefits by gender.

	Kenya		Ethiopia		Tanzania		Uganda		Overall sample	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Land size under the technology (ha)	0.07 (0.01)	0.10 (0.03)	0.09 (0)	0.13 (0.01)	0.14 (0.03)	0.16 (0.02)	0.05 (0.01)	0.06 (0.01)	0.08 (0.01)	0.120 (0.01)
Maize yield before using the technology (t/ha)	0.50 (0.04)	0.61 (0.07)	0.56 (0)	1.01 (0.18)	1.21 (0.51)	1.10 (0.25)	0.29 (0.07)	0.99 (0.25)	0.58 (0.07)	0.86 (0.09)
Maize yield after using the technology (t/ha)	2.20 (0.14)	2.49 (0.23)	1.39 (0)	3.04 (0.29)	2.71 (0.69)	3.19 (0.42)	1.14 (0.26)	2.92 (0.88)	2.21 (0.14)	2.83 (0.19)
Reasons for adopting climate-smart push–pull										
To increase cereal production	100	100	100	43.9	93.3	85.3	77.8	82.6	98.2	84.1
To control *Striga* infestation	100	100	100	100	83.3	84	100	100	97.7	95.0
To improve soil fertility	99.4	100	100	26.8	76.7	70.7	100	100	96.3	78.1
To control stemborer infestation	98	100	100	53.7	93.3	97.3	55.6	60.9	95.2	87.1
To cope with drought (low rainfall)	100	100	–	–	23.3	40	88.9	82.6	87.7	61.0
To increase fodder production	90	96.7	–	41.5	70	56	66.7	47.8	85.5	68.7
Main sources of information										
Extension officers	77.8	82.4	100.0	68.3	43.3	45.3	66.7	56.5	72.7	66.0
Non-governmental Organizations (NGOs)	1.1	0	0	17.1	43.3	41.3	0	0.0	6.8	15.8
Early Adopters	15.6	12.7	0	9.8	13.3	12.0	33.3	21.7	15.9	12.9
Field days	5.6	4.9	0	4.9	0	1.3	0	21.7	4.5	5.4

maize yields per hectare after adoption of climate-smart push–pull technology in some cases, more than tripled for both women and men farmers. The average maize yield for women increased from 0.58 t/ha to 2.21 t/ha while for men increased from 0.86 t/ha to 2.83 t/ha after planting climate-smart push–pull technology. A majority of women (98.2%) cited the need to increase cereal production as their main reason of adopting the technology, followed by controlling *Striga* (97.7%), improving soil fertility (96.3%), reducing stemborer infestation (95.2%), to cope with drought (87.7%) and to increase fodder (85.5%). Men on the other hand ranked *Striga* as the main reason for adoption (95%), followed by controlling stemborers (87.1%), to increase cereal production (84.1%), improve soil fertility (78.1%), to cope with drought (61.0%) and to increase fodder (68.7%). The reasons for adoption varied differently in different countries and by gender, a fact attributable to the perceived levels of severity of each constraint and the expected benefits which are likely to be influenced by socio-economic characteristics and in turn influence farmers' perceptions (Prager and Posthumus, 2010).

3.4. *Sources of information*

The efficiency of technologies generated and disseminated depends on effective communication which is the key process of information dissemination. Understanding where farmers source information and the preferred pathways is quite significant in enhancing technology up-scaling and adoption as this would aid in solving the problem of information asymmetry. Our study shows that extension officers were the main source of information for the majority of adopters overall (72.7% women and 66% of men) (see Table 3). This corroborates past studies on farmers' information seeking behavior where extension was ranked as the most important and most preferred information source which significantly influenced adoption (Pender et al., 2004). In Tanzania however, NGOs were a major information source as reported by 43.3% of women and 41.4% of men. Other sources of information include early adopters (15.9% women vs 12.9% men) and farmers' field days organized by public and civil extension agents (4.5% and 5.4% of women and men respectively). This pattern of variation in information sources reflects possible differences in accessibility to various sources among the different genders, and this could be dictated by their manner of daily operations and systems of interactions. Given their intensive household and farming roles, women have less time to go out to village meetings and hence extension officers are their main source of information who in most cases visits the farmers in their premises. Women also easily access information from other farmers who may have adopted the technology. The higher percentage of men being reached out by NGOs compared to the female may be a result of the construed misconceptions among policymakers and even farmers themselves that women are not the main farmers (World Bank and IFPRI, 2010). This seems to underscore the International Fund for Agricultural Developments' (IFAD) statement that although female farmers are primary contributors to the world's food production and security, they are frequently underestimated and overlooked in development strategies (IFAD, 2003).

3.5. *Perception on technology effectiveness and benefits*

One factor that affects technology adoption and expansion is farmers' perception of a technology's attributes and its effectiveness (Adesina and Zinnah, 1993; Rogers, 1995). In the overall sample, 98.6% women and 96.7% of men rated the technology as very effective (Fig. 2). Although this question was not included in the questionnaire, evidence from the informal discussions in the field during the survey indicated that women preferred the climate-smart push–pull that utilizes brachiaria compared to the conventional push–pull technology that utilized Napier grass, since it is easier to handle especially when cutting the grass for fodder. Other main attributes of climate-smart push–pull technology rated by the farmers are presented in Table 4, which outlines the benefits observed by the respondents upon adoption. The most beneficial attributes for women were increased cereal production (97.3%), followed by decreased *Striga* weed infestation (97.2%) and improved soil fertility (95.9%). This trend was almost similar to what men perceived as the most beneficial attributes. Our results corroborate those of Midega et al. (2015), who observed that adoption of climate-smart push–pull technology led to an 18-fold reduction in *Striga* weeds (between 80.6% and 99.9%) between 2013 and 2014 and 6-fold reduction in stemborer infestation. Other beneficial attributes of the technology were increased cereal and fodder during drought and increased milk production. Though minimal in this case, the observed disparities indicate that either men or women have different thoughts and aspirations in relation to the expected benefits, and this is likely to be influenced by the circumstance under which each gender is operating. In view of this, related to the constraints in question, women seem to be more affected by *Striga* infestation as they provide the bulk of labor for manual uprooting of *Striga*. Subsequently, the reduction in yields, hunger and malnutrition disproportionately affect women and

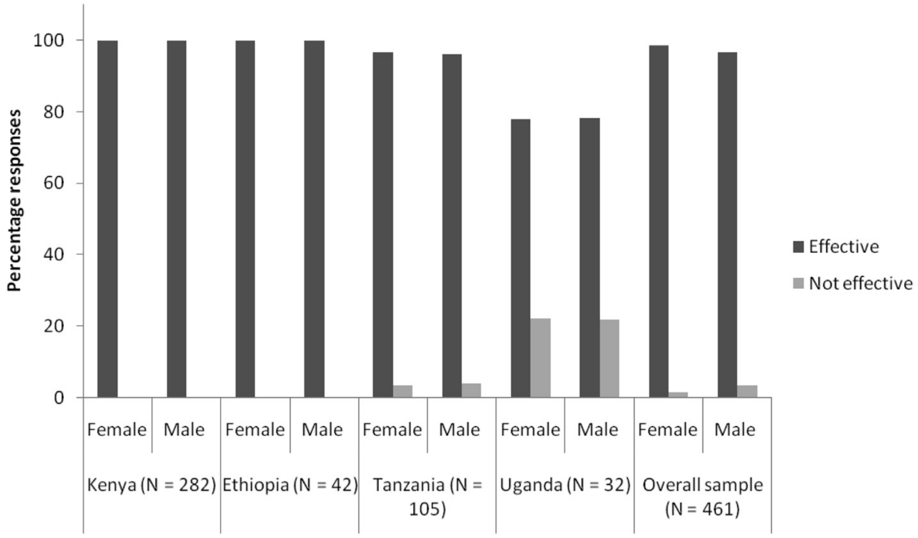

Fig. 2. Farmers rating on effectiveness of climate-smart push–pull technology.

children more than the men (World Bank, 2007). In addition, women bear the burden of feeding their livestock with the limited sources of fodder given the constraining land sizes. The adoption of the climate-smart push–pull technology avails women with options to increase cereal yields, control *Striga* and increase fodder for their livestock *in situ*. On the other hand, men are likely to appreciate increased income as a benefit since it is men who control incomes in most households. The findings corroborate previous on-farm studies that showed that push–pull technology led to decreased *Striga* and stemborer infestation and overall increased cereal yields (Hassanali et al., 2008; Khan et al., 2008b).

3.6. Determinants of adoption extent of climate-smart push–pull

Using a tobit model, we evaluated the factors influencing the extent of adoption and our model was significant at 1% (Prob > chi2 = 0.003) as shown in Table 5. Gender of the farmer, land sizes and information sources were identified as the significant determinants of the extent of adoption of climate smart push–pull technology. The dependent variable was the land in hectares allocated to the technology. The positive coefficient of gender (Coef = 0.038) indicates that male farmers allocated larger portions of their land to the technology compared to female farmers. This could be attributable to men being the main household decision makers and thus having more access and control over land as opposed to women as is observed in many SSA. This was however surprising because women were in the majority among the adopters, although they allocated smaller portions of land. Indeed in Table 2, majority of women (26.3%) cited limited land for cereals as one of the constraints facing them. This probably explains why they allocated less land to the technology. Nonetheless, the positive relationship can be interpreted to mean more chances of expansion and continued use of the technology given that men have access and control of resources in the household. It should be noted however that women farmers have a bigger contribution to food production and should therefore not be ignored when disseminating new innovations. The results further show that being well endowed with resources such as land increased the extent of adoption as indicated by the positive coefficient of variable representing land size (Coef = 0.014). A previous study by Murage et al. (2012) showed that the extent of adoption of the conventional push–pull technology was higher in households with smaller pieces of land compared to those that had larger pieces of land. However, this is not surprising because, the majority of farmers in the higher rainfall areas where the conventional push–pull technology is more concentrated has smaller land sizes as a result of land fragmentation due to high population pressure which necessitated intensification of smallholder agriculture, compared to those in drier agro-ecological zones where the adapted push–pull is being promoted.

Further results show that the initial sources of information where farmers obtained knowledge about the technology significantly influenced the extent to which an individual can commit their land to new technologies. Compared to those farmers who received their initial information from extension officers, farmers who were trained by early adopters committed less land to the

Table 4
Gender specific perception on technology attributes and main benefits.

	Kenya		Ethiopia		Tanzania		Uganda		Overall sample	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Benefits of climate-smart push–pull (%)										
Increase in cereal production	100.0	100	100	90.2	90.0	94.6	66.7	78.3	97.3	94.6
Decrease in *Striga* infestation	100	100	100	97.6	83.3	82.4	88.9	82.6	97.2	92.4
Increase in soil fertility	99.4	100	100	75.6	80.0	90.5	77.8	69.6	95.9	90.0
Increase in fodder production	98.9	98.0		100.0	76.7	82.4	66.7	73.9	94.1	91.3
Decrease in stemborer infestation	88.5	96.0	100	75.6	90.0	91.9	11.1	47.8	85.4	86.5
Cereal and fodder production increasing even with drought	88.9	91.1	–	19.5	60.0	59.5	33.3	65.2	82.3	66.5
Increased milk production	64.3	81.6	–	53.7	63.3	59.7	11.1	26.1	61.5	64.5

Table 5
Determinants of adoption extent for the climate-smart push–pull technology.

Variables used in tobit model	Coef.	Std. err.	t	P > |t|
Gender of the farmer (*gender*) (1 = Male, 0 = Female)	0.038^{***}	0.015	2.600	0.010
Age of the farmer (*Age*) (years)	0.000	0.000	−0.150	0.880
Education level (*Educ*) (1 = None, 2 = Primary, 3 = Secondary, 4 = College)	0.000	0.000	1.240	0.216
Land size (*landsze*) (hectares)	0.014^{***}	0.006	2.350	0.019
First information source early adopter (*inf_adopter*) 1 = Yes, 0 = No	-0.058^{***}	0.021	−2.750	0.006
First information source NGO (*inf_NGO*) 1 = Yes, 0 = No	−0.035	0.023	−1.490	0.136
First information source field day (*inf_fieldday*) 1 = Yes, 0 = No	−0.053	0.034	−1.590	0.114
First information source extension (*inf_extension*) 1 = Yes, 0 = No (Reference)				
Farmers' perception on the effectiveness (*perc_adopt*) (1 = Effective, 0 = Not effective)	0.010	0.050	0.210	0.835
_cons	0.073	0.052	1.390	0.167
/sigma	0.154	0.005		
Log likelihood	209.34			
Number of observations	460			
LR chi2 (8)	23.63			
Prob > chi2	0.003			
Pseudo R2	−0.06			

Significance at 1%***, 5% **, 10% *.

technology (Coef = −0.058). This could be attributed to the extent of knowledge they received from these information sources. Although early adopters are accessible to more farmers especially women, they are likely to have less detailed information compared to extension officers. It can be argued that those farmers who receive information from early adopters may opt to commit small portions of their land to the technology as they search more information from other sources. This probably explains why more women had committed smaller land sizes to the technology compared to men. The results agrees with those of Khan et al. (2008a) who observed that extension programmes increase the likelihood of push–pull adoption compared to other accessible information sources. Anderson and Feder (2004) also acknowledged that the greatest impact of extension is realized at the early stages of dissemination of a new technology due to information disequilibrium, while in the subsequent adoption stages, farmers can easily learn from their neighbors.

3.7. Technology expansion and labor saving benefits

Expansion and continued use of a new technology is necessary to ensure maximum benefits. The results in Table 6 show no resistance by farmers to continue using the climate-smart push–pull as responded by 99.6% of men and 98.6% of women. This is a positive move towards efforts to increase food security in the region. Indeed, at least 33.5% of women and 37.3% of the men had already expanded their plot sizes from the original size, implying that these farmers found the technology to be beneficial. Expansion was highest in Tanzania (67.8% for men and 52.2% for women), followed by Kenya (39.2% for men and 32.4% for women) and Uganda (13% for men and 11% for women). Ethiopia had the least percentage of farmers who had expanded the land under the technology (2%) and this could be attributed to the fact the technology adoption was still in its earliest stages in Ethiopia.

One of possible determinants of continued use of a technology would probably be its labor requirement. With declining family sizes owing to rural urban migration, most families are faced with challenges of agricultural labor since a majority utilizes family labor. We sought to understand farmers' perception on labor intensiveness of some activities when adopting climate-smart push–pull for the first time and in subsequent seasons (Table 6). The majority of women (91.3%) perceived hand weeding of desmodium as the most labor intensive activity, while the majority of men (80.9%) perceived planting of brachiaria and desmodium as the most labor intensive activity. This would be expected given that women are the ones mainly involved in weeding activities, and hence are the most affected by the intensive labor required to maintain young desmodium crop. Other activities rated as more intensive by women were land preparation (84.8% women vs 65.7% male) and management of brachiaria (69.6% female vs 52.5% male). In Kenya, hand weeding of desmodium was seen as the most tedious activity (96%) for both men and women, while in Ethiopia and Tanzania, planting of brachiaria and desmodium were the most labor intensive.

Table 6
Other perceived attributes of the climate-smart push–pull technology disaggregated by gender.

	Kenya		Ethiopia		Tanzania		Uganda		Overall sample	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Farmers willingness to continue using the technology (Yes)	98.9	100	100	100	96.7	100.0	100.0	95.7	98.6	99.6
If farmers has expanded the area under the technology (Yes)	32.4	39.2		2.4	52.2	67.8	11.1	13.0	33.5	37.3
If technology activities were labor intensive (Yes)										
Land preparation	91.1	87.3		36.6	58.6	52.9	44.4	60.9	84.8	65.7
Planting brachiaria and desmodium	78.3	85.3		90.2	79.3	78.6	44.4	52.2	77.1	80.9
Hand weeding desmodium	96.1	96.0		32.5	69.0	68.6	66.7	47.8	91.3	72.2
Management of brachiaria	72.6	79.2		14.6	62.1	42.0	33.3	34.8	69.6	52.6
Labor saving activities after technology establishment (Yes)										
Reduced number of weeding	98.7	100		100	100	97.1	100.0	76.9	98.8	97.0
Reduced *Striga* hand pulling	100	100		100	88.2	82.4	75.0	92.3	98.2	94.8
Reduced time looking for fodder for livestock	90.6	98.8		100	94.1	88.2	100.0	69.2	91.2	93.3
Reduced labor on land preparation from second season	98.7	98.8		60.0	100.0	94.1	75.0	92.3	98.2	95.6
Reduced labor on irrigation from second season	30.6	27.8		100	23.5	27.3		15.4	28.0	24.1
Reduced labor on soil erosion control from second season	18.3	16.7		100	5.9	3.3		7.7	15.2	9.5

The above concerns have been addressed in previous studies which showed that although high labor demand was expressed at initial stages (typically the first season until desmodium is established), high economic benefits and returns to labor and land with adoption of push–pull were reported even within the first season (Khan et al., 2008d; Fischler, 2010). Indeed, from our results, farmers corroborate the labor saving attribute of the technology in the subsequent seasons once the desmodium was properly established. Overall, respondents acknowledged that from the second season onwards, there were substantial labor savings in all the activities. There was some slight variation on perceptions of labor saving amongst men and women. A slight majority of women noted significant reduction in number of weeding (98.8% female vs 97% male), reduced hand pulling of *Striga* (98.2% female vs 94.8% male), reduced labor in land preparation (98.2% female vs 95.6% male), irrigation (28% female vs 24.1% male) and soil erosion control (15.2% female vs 9.4% male). With reference to benefits related to livestock enterprises slightly more men felt that there was a reduction in time required to look for fodder (93.3%) compared to 91.2% of the female (Table 6). Equally, more men had responded by increasing the number of livestock (27.5%) after planting push–pull compared to women (21.9%) and a slight majority of men had experienced an increase in milk output (63.6%) compared to 60.1% of women.

4. Conclusion

Understanding farmers' perceptions of a new technology and the gender disparities thereof can enhance its adoption. Since the adaptation and subsequent dissemination of climate-smart push–pull technology, an evaluation of the adoption pattern and farmers' perceptions of the new stemborer and *Striga* control fit had not been conducted. Given that adoption is influenced by perceptions, and in turn this is influenced by gender, knowledge of these relationships is a prerequisite prior to intensive up-scaling. The current study sought to provide key information on adoption and how farmers perceived the adapted climate-smart push–pull technology based on its effectiveness and other accrued benefits, while disaggregating this by gender. The findings show a positive trend of adoption and subsequent yield increase which either doubled or tripled. A higher percentage of women perceived the technology as very effective compared to men, a fact attributable to the technology characteristics that seemed to favor women's preferences. More women were also willing to continue using the technology and to expand the technology which is a positive move towards reduction of the major constraints under cereal production, and therefore a step towards increased food security. The significant gender differences observed in the perceived constraints, benefits and sources of information would imply a need to focus on individual preferences when designing dissemination messages about new technologies. Specifically, tailor made training programmes can be explored to ensure that each gender is targeted via the most appropriate pathway based on its accessibility. Technology development and dissemination strategies and policy options should also take into account gender and cultural considerations in order to reduce vulnerability. The scale and form in which such information is packaged, timeliness and gender-equitable access to it, and farmers' capacity to understand and act on complex information are also important factors. While this study was weakened by the small samples of adopters, an attempt made to discern this issue is better than no attempt at all. However, further research to validate these findings is needed.

Conflicts of interest

The authors declare that we have no conflict of interest with the organization that sponsored the research work.

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