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INTEGRATING VEGETABLES IN PUSH-PULL TECHNOLOGY: GENDERED PREFERENCES OF SMALLHOLDER FARMERS IN WESTERN KENYA

Ouya FO[1,2]*, Pittchar JO[1], Chidawanyika F[1,3]* and ZR Khan[1]

Fredrick Ouya

*Corresponding authors' email: fredrickouya@gmail.com & fchidawanyika@icipe.org

ORCID ID:
(FO)[2] https://orcid.org/0000-0002-1478-6919
(FC)[3] https://orcid.org/0000-0002-4601-768X

[1]International Centre of Insect Physiology and Ecology (ICIPE), P. O. Box 30772-00100, Nairobi, Kenya

[2]Alliance of Bioversity International & CIAT, P. O. Box 823-00621, Nairobi, Kenya

[3]Department of Zoology and Entomology, University of the Free State, P. O. Box 339, Bloemfontein, 9300, Republic of South Africa

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ABSTRACT

Transformative rural smallholder agriculture addressing biophysical constraints requires farmer-led innovations for increased technology adoption. Following the need to further intensify the cereal push-pull technology (PPT) for pest and weed control through integration with vegetables, we conducted surveys to determine suitable vegetables across three different counties in Kenya namely Homabay, Siaya, and Trans-Nzoia. Farming in these areas is predominantly maize based and introducing vegetables to the system will improve household food and nutritional security, together with income. A systematic random sampling method was used to sample a total of 124 smallholder farmers who were interviewed during field days where farmer awareness of technology was mobilised. Descriptive results showed kale (47%) and black nightshade (30%) were the most preferred high-value vegetables for integration into push-pull plots in these regions. This was followed by cowpea (15%), onion (6%) and tomato (2%) underlying the wide range of farmer preferences and priorities. There were also gender differences in vegetable preferences with men preferring capital intensive and high value vegetables, while women preferred traditional vegetables. Results from multinomial *logit* model revealed that age of the farmer, education level, gender, and farming experience were determinants of smallholder farmers' vegetable preferences for integration into the PPT plots. The contribution of these determinants to farmer preferences varied across different vegetables where the contribution of the market value of the vegetable in selection diminished with while the effect of farmers' age. Overall, male farmers preferred capital-intensive and market-oriented vegetables in compared to their female counterparts. We conclude that gender and geographic location play a pivotal role in farmers` crop selection for integration in the PPT. Targeted awareness creation pathways accounting for these factors will be critical for wider adoption of the PPT.

Key words: Food security, Multinomial Logistic Regression Model, Participatory rural appraisal, Sustainable agricultural intensification, Technology adoption

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INTRODUCTION

Pests and diseases are major hindrances to vegetable production and a threat to global food security and are major contributors to poverty and food insecurity in sub-Saharan Africa [1, 2]. It is estimated that an annual food loss due to pests can feed about one billion people [3, 4]. One of the main strategies used by farmers in sub-Saharan Africa to control pests and diseases is increasing pesticide application, despite their impact on the environment and human health [4, 5]. Push-Pull Technology (PPT) is one method which has been very effective in farmers' fields as a sustainable agricultural intensification practice (SAIP) and an integrated pest management system (IPM) helping to avert the negative effects of pesticide application.

Developed by International Centre of Insect Physiology and Ecology (ICIPE) and partners, the PPT involves intercropping cereals, mainly maize and sorghum, with desmodium for achievement of multiple outcomes. Desmodium repels harmful insect pests such as stemborers and fall armyworm (push) and suppresses infestation by the parasitic Striga weed [6, 7]. The intercrop of cereals and desmodium is surrounded by a trap plants, either Napier or Brachiaria grasses that attracts (pull) the pests away from the crop in the form of stimulo-deterrent diversionary strategy. The moths then lay eggs on the trap plants, but the larvae do not mature to form new adults [8, 9]. Desmodium also acts as soil cover, retaining water during dry period, suppresses other weeds, and fixes nitrogen into the soil [6, 10]. These companion plants also serve as supplementary fodder for livestock substantially reducing overgrazing of already degraded landscapes. Consequently, the agro-ecological advantages of PPT have resulted in trialling of other crops to determine prospects for their integration into PPT production systems. Preliminary results from research stations and farm fields have suggested the viability of integrating vegetables into PPT production systems, leading to the need to probe farmers about their willingness to adopt an integrated system and their preferred crops [11].

The ongoing climate change has led to the emergence and geographic range expansion of crop pests and, in some cases, increased their incidences and severity [11, 12]. Smallholder farmers in sub-Saharan Africa (SSA) rely mostly on rain fed agriculture for their food and cash crop production making them highly vulnerable to erratic rainfall due to changing climates. To counter this, several technological innovations including conventional and agroecological approaches to safeguard food and nutritional security. However, agriculture technology adoption by smallholder farmers in SSA, regardless of its potential productivity, is often hampered by several factors including high costs of implementation, gender-based disparities, limited knowledge and failure to account for farmers preferences or priorities during technology development [11, 13]. One way of addressing these challenges requires co-creation of sustainable agricultural intensification practices with smallholder farmers for improved uptake and subsequent productivity[14, 15]. Indeed, sustainable agricultural intensification has come to the fore and has been promoted for its potential in increasing yield with limited environmental degradation and mitigation of impacts of climate change [16, 17]. In the case of PPT, integrating vegetables as a sustainable agricultural intensification practice will improve not only smallholder farmers' resilience to climate change, but improve their food and nutritional security and potentially increasing their household income [11].

The process of farmer learning, and adoption of new innovations is complex [18], implying that vegetable-PPT integration may be challenging even when there are apparent economic and environmental benefits. This poor uptake can be largely due to uncertainties regarding risks and returns of new technologies. These factors can further be compounded by preferences and priorities that are dependent on demographic characteristics such as age, gender, farming experience, and education/literacy and farm-level characteristics such as soil fertility, land size, slope of land, and plot distance from homestead [19, 20, 21]. Other studies have reported adoption of PPT as dependent on efficiency of dissemination pathways, technology awareness, and access to farm inputs [19, 22]. These studies provide critical indicators of contribution of individual, socioeconomic, farm-level, and institutional factor in adoption of PPT.

Farmers' preferences are chief drivers of farmers' interactions with technology and adoption decisions [23, 24]. For example, farmers already exposed to a technology may choose to scale, expand, modify, or dis-adopt the innovation based on preferences influenced by experienced costs and benefits, and socio-cultural factors including group norms, preferences, and food habits [25, 26, 27, 28]. Thus, the understanding of how preferences shape farmers' decision to modify the traditional PPT components by integrating vegetables is critical for higher adoption rates. In turn, farmers will benefit from sustainable pest control, improved yields to ensure both food and nutritional security, dietary diversity and environmental benefits that align with even one health [11]. Therefore, this study investigated farmers' vegetable preferences for integration within PPT production systems.

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MATERIALS AND METHODS

Study area

The study was conducted in three counties in western Kenya, namely Homabay, Siaya, and Trans-Nzoia (Figure 1). These counties have been targets of push-pull scale-up programs by ICIPE and other development partners in recent years. Homabay and Siaya counties are some of the counties in this western region with farms heavily infested with the parasitic striga plant, a major maize production constraint. The strategic role of Trans-Nzoia in maize supply in Kenya makes the county a target for push-pull dissemination considering damaging effects of fall armyworm, an emerging threat to maize production. Maize is a staple food and, therefore, the main produced food crop in western region. The rainfall pattern in the two counties of Homabay and Siaya is bimodal with long rain which is the main season from March to August and short rain season from the month of September to December, however, it is a one-season crop in Trans-Nzoia [21]. During the seasons various crops depends on rain-fed agriculture, for instance maize and vegetables. However, these areas are dominated by maize for instance, counties in western region produce almost one-third of total maize output in Kenya [29]. Adding vegetables into PPT will improve households' food and nutritional security as well as generating employment for women and youth. Further, counties in the western regions are among the largest consumers of vegetables in Kenya, especially indigenous vegetables making vegetable integration in cereal-based production an opportunity to improve farmers' livelihood outcomes.

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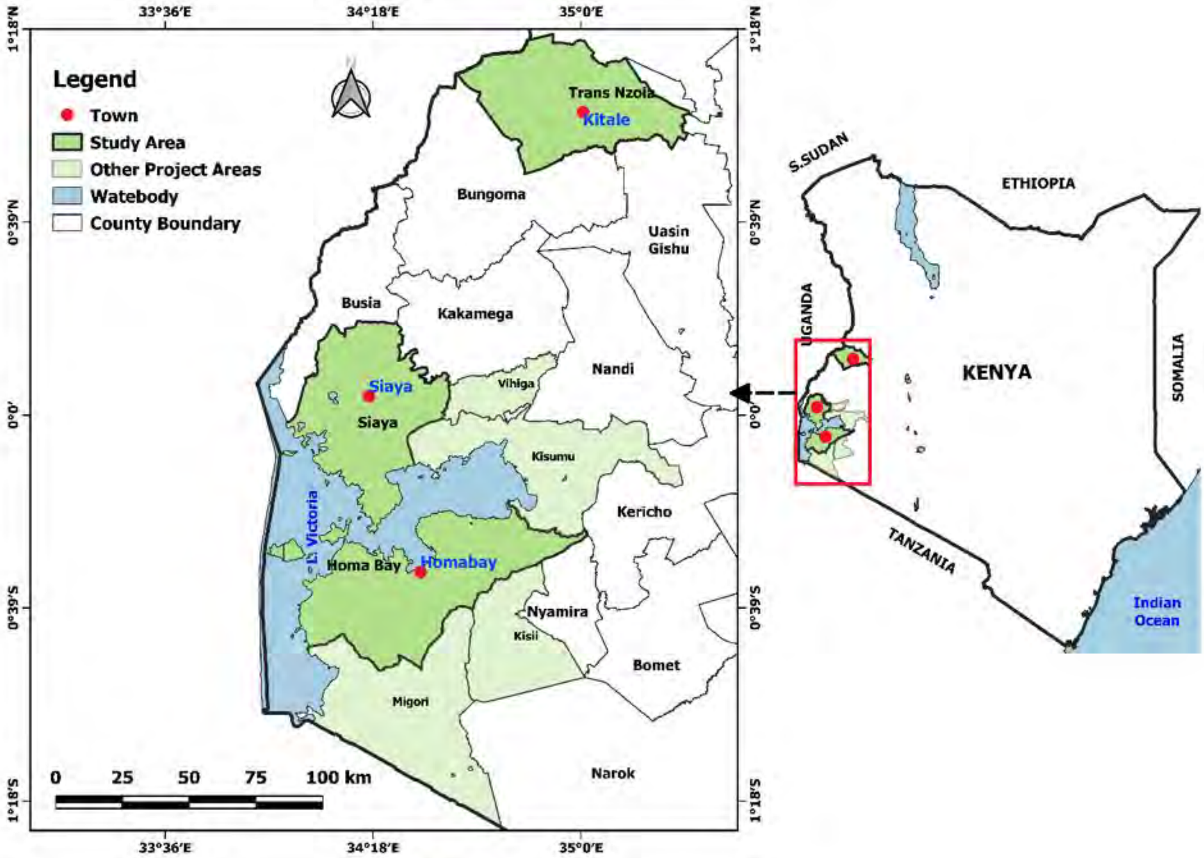

Figure 1: Map of Kenya showing study sites

Data collection

The data were derived from rapid assessment conducted in the three purposively selected counties. The data were collected during field days when awareness of technology (integration of vegetables in PPT) was created and demonstrated. The researcher emphasized the criteria for inviting farmers to the extension officers. Invited farmers included PPT adopters and non-adopters. The lists of farmers prepared by ICIPE field extension staff were used by the researcher as sampling frame from which a sample size of 124 farmers were randomly selected using the RAND command in Excel.

Mixed methods were used to collect data from farmers who attended field days in the respective counties. During the field day discussions, PPT Vegetable technology was introduced to farmers, targeting non-adopters to understand establishment of PPT plots. The field day was held in the off-season and, therefore, pictures, charts, and video footages of various PPT fields were shown to farmers. Two separate focus group discussions were conducted per every county comprising of women only and men only each attended by 10 participant farmers of different age category. Farmers were then interviewed individually using a semistructured questionnaire which was administered by trained enumerators. The rapid assessment tool captured farmers' socio-economic characteristics, vegetable production details, and their preferences in terms of preferences for vegetable being integrated in PPT plots that they were introduced to.

Model specification and data analysis

Both descriptive and econometric analyses were used to analyse the data. The main responses on preference for vegetables and their attributes were summarized using descriptive analysis and cross-tabulations. A multinomial *logit* regression model was used to evaluate the determinants of smallholder farmers' preference for vegetables using the five main vegetables selected by farmers as the dependent variable. The covariates included in the model were age of the farmer, education level of the farmer, gender of the farmers, farming experience in years, among others.

Analytical Framework

Farmers' decision to select vegetables for integration in PPT depends on the variety of vegetables at their disposal. This was done by the individual selection of the most preferred vegetable out of five which they would like to integrate into their own plot. Since farmers had more than two vegetable types to choose from, this implied that standard binary econometric models could not be used in analysing determinants of farmers' preference for vegetables to be integrated in PPT system. Thus, Multinomial Logistic Regression model (MNL) was used in analysing determinants of smallholder farmers' preferences for vegetables to be integrated into PPT. The MNL model allows projecting of more than two nominal choices [30, 31]. The study allowed farmers to choose one of their most preferred types of vegetable to be integrated into PPT and the five vegetables were kales, cowpea, black nightshade, tomato, and onion. Given the five alternatives, the probability of farmers' choosing one vegetable type or another and leaving the other four vegetable types was conditioned on an explanatory variable specified using the MNL model as follows:

$$P_{ij} = \exp(\beta_j x_i) / 1 + \sum_{j=1}^{5} \exp(\beta_j x_i) \qquad \text{for } j = 0,1,2,3,4 \qquad (1)$$

Where x_i is a vector of covariates that influence i^{th} farmer's choice of vegetable type, β_j is a parameter that corresponds to explanatory variables influencing farmer's choice of an alternative j .

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The probability of the farmer choosing kale as base category was estimated as:

$$\mathrm{P_i}|(\mathrm{j}=0|\mathrm{x_i}) = 1/\,1 \;+\; \textstyle\sum_{\mathrm{j}=1}^{5} \exp\left(\beta_{\mathrm{j}}\mathrm{x_i}\right) \qquad (2)$$

Also, the probabilities of choosing either vegetable type 1, 2, 3 or 4 was estimated as:

$$\mathrm{P_i}|(\mathrm{j}=\mathrm{m}|\mathrm{x_i}) = \exp\left(\beta_{\mathrm{j}}\mathrm{x_i}\right)/\,1 \;+\; \textstyle\sum_{\mathrm{j}=1}^{5} \exp\left(\beta_{\mathrm{j}}\mathrm{x_i}\right) \quad \text{for m > 0} \qquad (3)$$

Equations (4) can be simplified as:

$$\mathrm{P_i} = \ln(\mathrm{p_i}|1-\mathrm{p_i}) = \propto + \beta_{\mathrm{i}}\mathrm{X_i} + \cdots \beta_{\mathrm{n}}\mathrm{X_n} + \varepsilon_{\mathrm{i}} \qquad (4)$$

Where $\ln(\mathrm{p_i}|1-\mathrm{p_i})$ being *logit* of different choice of vegetable type; $\mathrm{P_i}$ is choosing kale, which is a base category and $1-\mathrm{p_i}$ is choosing vegetable type either cowpea, or black nightshade, or tomato, or onion. The term ε_{i} is an error term.

Equation (3) provides a model for vegetable types that a farmer would choose. The five possibilities were set as the dependent variables, with kale being the base category, taking the value of zero (0), while cowpea, black nightshade, tomato, and onion took the values of 1, 2, 3 and 4, respectively.

RESULTS AND DISCUSSIONS

Summary statistics

The descriptive statistics presented in Table 1 indicates key variables on farmers' socio-economic characteristics in the three study counties. The statistical tests, Chi-square (chi^2) and F-tests were used to test whether there were statistical differences in farmers' characteristics by location. The tables and charts also display the comprehensive descriptive statistics.

Gender disparities have been a concern in smallholder agricultural technology adoption in SSA where factors such as access to land, labour and capital demands, and profitability often mediate adoption patterns [11; 23]. Hence to eliminate bias due to the gender nuances, we considered both the majority and the minority group in the population to ensure a balanced representation where 58% were female and 42% were male farmers. Smallholder farming activities in most of SSA are majorly practiced by women as men often prefer getting extra income from off-farm activities. For women, vegetable farming in the region contributes immensely to rural livelihoods given its short turnover time and profitability.

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The adoption of agricultural technologies can be influenced by farmers` age. In our study, the average age of farmers in all counties were 55 years and the mean age for farmers in Trans-Nzoia, Homabay and Siaya were 57, 46 and 58 years, respectively (Table 1) suggesting minimal age differences across counties. Nevertheless, there was a tendency for older farmers, presumably with access to more land, having a higher propensity to test their preferred vegetables in the PPT. This may be associated with management of risk among farmers where limited land often leads to farmer commitment on more developed technologies.

Farmer level of education is a major factor that influences technology adoption where farmers with higher levels of education readily adopt technologies even when technological complexity may be a barrier for others. Since the PPT is considered knowledge-intensive, it is plausible that farmers` level of education could have adoption and preferences. In our study the farmers` level of education was variable with 50% having attained primary level of education, 26% at secondary level, 14% at tertiary level whilst the remaining 10% had no access to formal education.

Profitability and climatic compatibility are key drivers of smallholder farmer vegetable crop preferences. In our study, farmers were individually asked to choose their most preferred vegetable, which they would wish to integrate into the PPT. Our results showed that kale were overall the most preferred vegetable (47%) chosen by farmers across the three counties (Fig 2.). The second most preferred vegetable was black nightshade with an overall score of 30%. Cowpea was third at 15%, followed by onion and tomato at 6% and 2%, respectively. These choices underly the importance of participatory appraisal by farmers given the clear differences in preferences among the crops of choice.

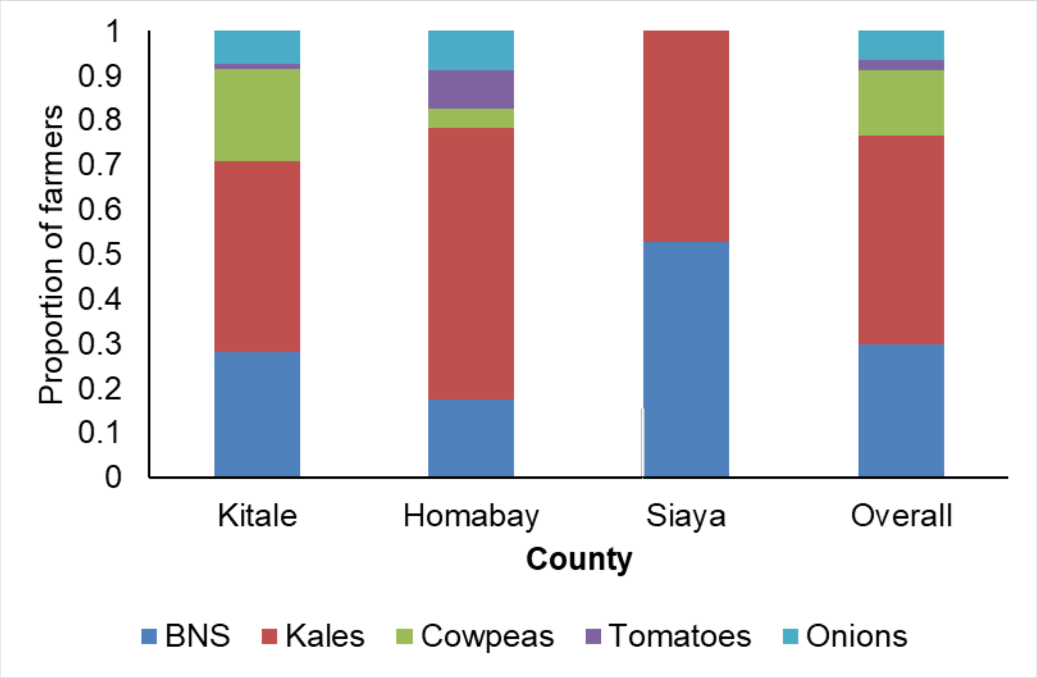

Figure 2: Farmers' preferred vegetables for integration within the push pull technology in western Kenya

Influence of crop attributes on farmer preferences

Under the consumer theory, we can derive discrete choice experiments (DCEs) to obtain attributes influencing farmers in the choice of a given product [32]. This is because same farmers can choose a particular vegetable, experience the same constraints, and realise the same benefits but vegetable traits may differently affect their utility functions [33]. In this study, we regarded the vegetable type as a product over specific agronomic traits as comparisons were made across different crop types. Instead, farmers ranked the crops not on only agronomic performance but based on potential benefits. For example, kales were most preferred vegetable majorly because farmers associated it with improved food and nutritional security, in addition to profitability. Black nightshade and cowpea were preferred by farmers mostly because of their nutritional value whilst onion and tomato were largely preferred because of their profitability (Figure 3). Interestingly, there was a gender bias in reasons for preferences of lucrative crops such as onion as male farmers selection was based on potential income whilst females considered nutrition. Similarly, male farmers considered cowpea for market purposes whilst females considered because of nutritional purposes. There was however consensus in the case of black nightshade where both males and females preferred it for both nutrition and commercial value.

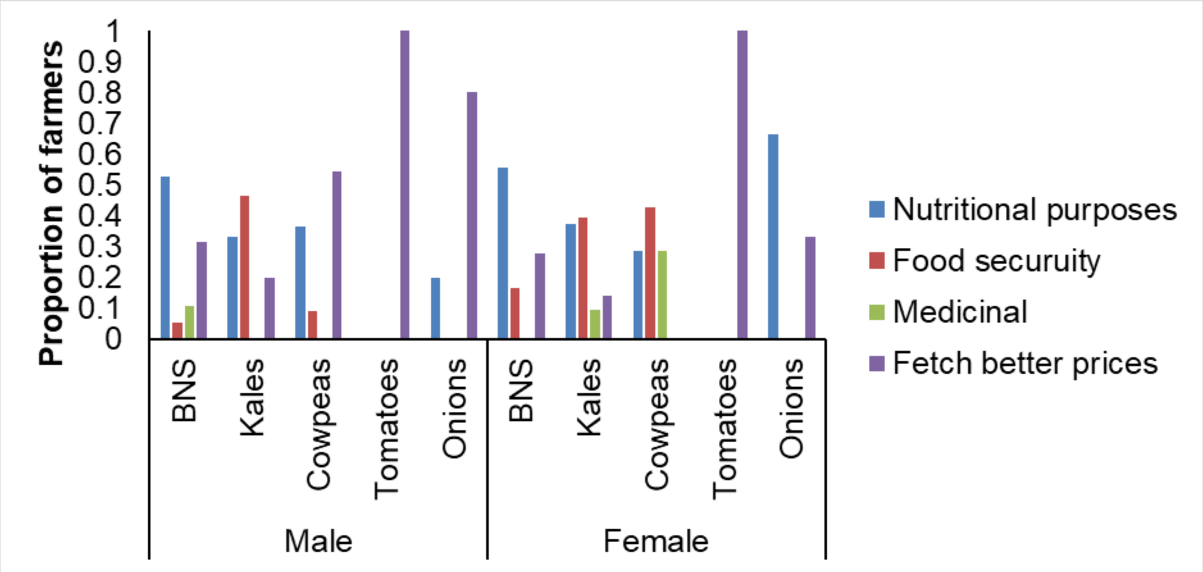

Figure 3: Chief crop attributes influencing farmer choices of selected vegetables for integration within the push pull technology

Econometric dynamics of farmer preferences

To allow for modelling of different vegetables based on a household`s choice, we employed the Multinomial Logistic Regression Model (MLRM). In this regard, the model was used to determine factors influencing farmers' choice of preference for vegetable where kales were considered as the base category since they were the most preferred (Table 2). Explanatory variables related to farmers' characteristics were used to specify the estimated models. The (MLRM) was highly significant and suitable for the analysis as indicated by likelihood ratio test (χ^2 (32) = 323.93, Pseudo R^2 = 0.637, Prob > χ^2 = 0.000), suggesting strong explanatory power of the model. The socioeconomic characteristics that significantly affected smallholder farmers' choice of vegetables included gender of the farmer, education level of the farmer, farming experience of the farmer, and farmers experience in mixed cereal-vegetable intercropping (Table 2). The results indicate that the gender of the farmer was significantly associated with the probability of selecting black nightshade and cowpea at 10% and 1% significance levels respectively and positively and significantly associated with the probability of choosing onion at 5% significant level. Male farmers were less likely to either prefer black nightshade or cowpea relative to choosing kale, but probably chose onion compared to their female counterparts. This implies that male farmers probably have more access to capital and resources that increases their chances of engaging in capital-intensive agricultural production systems than female farmers. This result is consistent with study conducted by Murage *et al.* [19] that insufficient access to agricultural productive resources by female farmers in SSA hinders their adoption on labour-intensive agricultural technologies agricultural growth.

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When gender disaggregated, age of the farmer was found to influence farmers' probability of choosing black nightshade with regards to kales at 1% significant level, and negatively influencing the choice of tomato to kale at 1% significant level. This means that relatively older farmers prefer growing black nightshade vegetable in their PPT than integrating kales whereas younger farmers preferred integrating tomato into their PPT plots than growing kales. Thus, young farmers were willing to take capital and labour-intensive vegetables into their PPT plots if they were of high market value. Indeed, there was a decrease in the preference of tomatoes as age increased in both males and females (Table 3). Previous studies have argued that younger farmers were likely to be more innovative and dynamic and were more interested in learning activities such as training thereby increasing their awareness and uptake of new agricultural technologies [34, 35]. A study by Eshetu [36] also posited that increase in farmers' age raises their vulnerability to poverty due to lack of mobility.

The farmers` level of education is an important factor which also determines their preferences and choice of vegetables. In our study, pooled results showed that farmers` level of education positively and significantly influenced the choices. However, when gender disaggregated education level of male farmers was significant for black nightshade and tomato. In other words, male farmers with higher level of education were more likely to choose or prefer black nightshade and tomato in relation to kale as the base category. This can be attributed to the fact that growing tomato and black nightshade can result in higher profits per unit area compared to growing kale. This result is in line with other studies which have shown that male farmers put more preferences in vegetable commercialization, while their female counterparts produce vegetable majorly for food and nutrition security purposes. However, as reported earlier, our results revealed that very few farmers chose tomato and onion as their most preferred vegetables not only because of their labour and capital intensiveness but also tomato's susceptibility to diseases mostly blight. Given that the push pull technology is knowledge intensive, it can also be argued that its diffusion and adoption will also depend on the demographic of education and literacy apart from vegetable choices. Nevertheless, any knowledge and understanding of new technology will not only depend on formal education since access to information through efficient and effective pathways of dissemination and training and may improve the uptake rate [37, 38].

In our study, farming experience of the subject farmers was regarded as years of independently farming as a household. Our results show that farming experience

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on the choice of vegetable preference was negative for black nightshade but positive for tomato and were both significant at 1% significance level. One-year increase in farming experience had a likelihood of decreasing preference of black nightshade by 1.3% and increasing farmers' preference for tomato by 0.5%. Increased farmer experience resulted in a lesser likelihood of uptake of black nightshade farming and the more the likelihood of tomato farming, relative to kale farming. This can be explained by the fact that advanced farmer experience endows capacity to manage high value enterprises. However, Ainembabazi and Mugisha, [39] have also argued that farmers gradually adopt a new technology until a certain time and limit where dis-adoption may even occur, ostensibly due to unmet expectations. Furthermore, Saqib *et al.* [40] argued that experiences farmers may benefit from long built relationships and strategic placement within the value chain where access to e.g. markets and credit facilities from banks cooperatives confers competitive advantage. It is therefore plausible that farmers who can have access to credit facilities may improve the adoption of capital-intensive vegetables for integration within PPT since capital can be a limiting factor.

Farmers' experience in intercropping vegetable with cereal was negatively associated with preference to black nightshade and cowpea relative to preferring kale at 1% and 10% significant levels, respectively. In other words, farmers who had intercropped cereal with vegetable were more likely to choose kale as their most preferred vegetable to integrate in PPT plot than the two vegetables. Marginal effects result shows that if farmers' experience in intercropping vegetable with other cereal crops increases by one year, the likelihood of farmers' preference for black nightshade and cowpea was 20.2% and 7.7% less likely. This is possibly because cereal crops have long been grown mixed with most of the African indigenous vegetables and farmers allowing for easier integration within the PPT.

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

Our study focused on identifying farmers' preference for vegetables for integration PPT and the socioeconomic and institutional drivers of the preferences. Both indigenous (black nightshade and cowpea) and exotic (kales, onion, and tomato) vegetables emerged as the most preferred vegetables for integration in push-pull plots, underscoring the diverse priorities and preferences of different farmers across the counties. Gender and education level were key determinants of farmer` preferences and priorities underlining the need for gender disaggregation and education during participatory agricultural technology development. We conclude that preference surveys need to be preceded by adequate training and awareness to allow for balanced responses that inform viable technology development.

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Conflict of Interest

Authors declare no conflict of interest.

Table 1: Descriptive statistics for farmers' demographic and socioeconomic characteristics that influence choice of vegetables for adoption in western Kenya

	Overall Sample	Respondents' counties				
Socioeconomic characteristics	**n = 124**	**Kitale**	**Homabay**	**Siaya**	**F-Statistics**	**X^2**
Gender of the main farmer (%)						
Male	42	42	70	11		14.92***
Female	58	59	30	90		
Education level of main farmer (%)						
None	8.9	2.4	8.7	36.8		30.09***
Primary	50	53.7	39.1	47.4		
Secondary	25.8	28	34.8	5.3		
Tertiary/College	14.5	15.9	13	10.5		
University and above	0.8	0	4.3	0		
Farmers' main source of income (%)						
Crop farming	69.4	69.5	73.9	63.2		8.94
Livestock Keeping	12.9	12.2	13	15.8		
Aquaculture and apiculture	1.6	2.4	0	0		
Casual labour on other farms	3.2	2.4	4.3	5.3		
Casual labour non farms	0.8	1.2	0	0		
Self-employed off farm	9.7	9.8	8.7	10.5		
Remittances	1.6	2.4	0	0		
Food aid	0.8	0	0	5.3		
Age of the main farmer	55.05(1.141)	57.1(1.188)	45.61(3.061)	57.63(3.067)	8.796***	
Farming experience of the farmer	19.04(1.193)	17.29(1.238)	14.57(2.323)	32(3.783)	13.255***	

***, denotes significant at 1% level. Figures in the parenthesis are the standard errors associated with the means for the continuous variables

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Table 2: Multinomial Logistic Regression model on farmers' choice of vegetables for integration within the push-pull technology

	BNS		Cowpeas		Tomato		Onion	
Variables	**Coef.**	**dy/dx**	**Coef.**	**dy/dx**	**Coef.**	**dy/dx**	**Coef.**	**dy/dx**
County/Site	0.818**	0.239**	-2.751*	-0.296*	0.997	0.021	-0.884	-0.031
	(0.383)	(0.067)	(1.519)	(0.136)	(1.037)	(0.019)	(1.455)	(0.074)
Gender of the main farmer	-0.920*	-0.054*	-1.924***	-0.139***	2.314	-0.025	1.529**	0.042**
	(0.526)	(0.080)	(0.767)	(0.065)	(1.460)	(0.025)	(0.652)	(0.037)
Age of the farmer	0.078***	0.016***	-0.038	-0.005	-0.418***	-0.007***	0.002	0.000
	(0.027)	(0.004)	(0.037)	(0.003)	(0.094)	(0.003)	(0.056)	(0.003)
Education Level of main farmer	0.623**	0.091**	0.007	0.029	2.884*	0.042*	0.107	-0.009
	(0.276)	(0.043)	(0.429)	(0.040)	(1.185)	(0.025)	(0.411)	(0.021)
Main source of income	-0.031	-0.066	0.130	0.066	-19.238***	-0.295***	0.084	0.025
	(0.100)	(0.059)	(0.155)	(0.039)	(1.942)	(0.151)	(0.164)	(0.015)
Farming experience of the farmer	-0.078***	-0.013***	-0.001	-0.003	0.301***	0.005***	-0.087	-0.004
	(0.026)	(0.004)	(0.032)	(0.003)	(0.085)	(0.003)	(0.055)	(0.003)
Experience vegetable with cereals	-1.580***	-0.202***	-1.390*	-0.077*	-1.413	-0.011	-0.677	-0.011
	(0.574)	(0.090)	(0.829)	(0.076)	(2.266)	(0.034)	(0.829)	(0.045)
Experience vegetable into PPT plot	1.465	0.214	0.538	0.003	-2.621	-0.049	1.314	0.043
	(0.751)	(0.113)	(0.764)	(0.071)	(1.509)	(0.032)	(1.247)	(0.070)
Constant	-5.275**		7.652*		30.294		0.897	
	(2.645)		(4.299)		(5.263)		(5.817)	
Base /reference category	Kales							
Number of observations	124							
Wald Chi^2(32)	323.93							
Prob > Chi^2	0							
Pseudo R^2	0.6366							
Log-likelihood	-121.157							

*, **, ***Represent 10, 5 and 1% levels of significance, respectively

Table 3: Gender disaggregated results of farmers' preference of vegetables for integration within the push pull technology using the Multinomial Logistic Regression model

	BNS		Cowpeas		Tomatoes		Onions	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
County/Site	1.088**	0.927	-1.609*	-1.926	-1.004	1.631	-23.139	25.438
	(0.471)	(0.881)	(1.074)	(1.02)	(0.910)	(0.455)	(1.26)	(2.348)
Age of the farmer	0.046	0.127***	-0.129	0.083**	-0.418*	-0.368**	-3.918	0.109
	(0.038)	(0.044)	(0.081)	(0.034)	(0.245)	(0.165)	(0.17)	(0.067)
Education Level of main farmer	0.389	1.228**	-0.118	0.488	0.646	3.711***	-14.182	0.604
	(0.397)	(0.608)	(0.979)	(0.6)	(0.684)	(1.103)	(0.78)	(0.819)
Main source of income	-0.110	0.225	0.291	0.311	-16.815***	-16.751***	5.860	-0.262
	(0.156)	(0.176)	(0.258)	(0.21)	(4.148)	(1.783)	(0.32)	(0.253)
Farming experience of the farmer	-0.076***	-0.072	0.022	-0.031	0.253	0.295**	1.775	-0.105**
	(0.031)	(0.057)	(0.057)	(0.04)	(0.184)	(0.148)	(0.13)	(0.061)
Experience vegetable with cereals	1.478**	1.742*	1.941	2.291**	12.265***	2.114	26.453	0.199
	(0.718)	(1.006)	(1.510)	(1)	(3.010)	(1.471)	(1.55)	(1.574)
Experience vegetable into PPT plot	-1.538	-1.675	0.075	-2.139	17.687***	-15.123***	-61.476	-0.282
	(1.261)	(1.769)	(1.032)	(1)	(1.801)	(2.422)	(2.94)	(2.508)
Constant	-5.332**	-10.168***	4.582	7.289***	0.100	13.960***	153.177	-6.786
	(2.677)	(3.1610	(6.184)	(2)	(14.818)	(4.939)	(7.40)	(5.198)

*, **, ***Represent 10, 5 and 1% levels of significance respectively and standard errors are in parenthesis. Kale is the categorised base variable

REFERENCES

1. **FAO.** Growing Greener Cities in Africa: First Status Report on Urban and Peri-urban Horticulture in Africa. United Nations Food and Agriculture Organization, Rome. 2012. https://www.fao.org/3/i3002e/i3002e.pdf *Accessed May 2021.*

2. **Oyinbo O, Chamberlin J, Vanlauwe B, Vranken L, Kamara Y A, Craufurd P and M Maertens** Farmers' preferences for high-input agriculture supported by site-specific extension services: Evidence from a choice experiment in Nigeria. *Agricultural Systems.* 2019; **173:** 12-26. https://doi.org/10.1016/j.agsy.2019.02.003

3. **Sheahan M and CB Barrett** Food loss and waste in Sub-Saharan Africa. *Food Policy.* 2017; **70(1):** 1-12. https://doi.org/10.1016/j.foodpol.2017.03.012

4. **Vidogbéna F, Adégbidi A, Tossou R, Assogba-Komlan F, Ngouajio M, Martin T and KK Zander** Control of vegetable pests in Benin–Farmers' preferences for eco-friendly nets as an alternative to insecticides. *Journal of Environmental Management.* 2015; **147:** 95-107. https://doi.org/10.1016/j.jenvman.2014.09.010

5. **De Bon H, Huat J, Parrot L, Sinzogan A, Martin T, Mal_ezieux E and JF Vayssi_eres** Pesticide risks from fruit and vegetable bio-aggressors management by small-farmers in sub-Saharan Africa. A review. *Agron. Sustain. Dev.* 2014; **34(4):** 723-736. https://doi.org/10.1007/s13593-014-0216-7

6. **Khan ZR, Midega CAO, Pittchar J, Murage AW, Birkett MA, Bruce TJ and JA Pickett** Achieving food security for one million sub-Saharan African poor through push–pull innovation by 2020. Phil. *Trans. R. Soc. B.* 2014; **369(1639):** 20120284. https://doi.org/10.1098/rstb.2012.0284

7. **Midega CA, Pittchar JO, Pickett JA, Hailu GW and ZR Khan** A climate-adapted push-pull system effectively controls fall armyworm, Spodoptera frugiperda (JE Smith), in maize in East Africa. *Crop Protection.* 2018; **105:** 10-15. https://doi.org/10.1016/j.cropro.2017.11.003

8. **Midega CA, Jonsson M, Khan ZR and B Ekbom** Effects of landscape complexity and habitat management on stemborer colonization, parasitism and damage to maize. *Agriculture, Ecosystems and Environment.* 2014; **188:** 289–293. https://doi.org/10.1016/j.agee.2014.02.028

9. **Pickett JA, Midega CA, Pittchar J and ZR Khan** Removing constraints to sustainable food production: new ways to exploit secondary metabolism from companion planting and GM. *Pest Management Science.* 2019; **75(9):** 2346-2352. https://doi.org/10.1002/ps.5508

10. **Cheruiyot D, Midega CA, Pittchar JO, Pickett JA and ZR Khan** Farmers' Perception and Evaluation of Brachiaria Grass (*Brachiaria spp.*) Genotypes for Smallholder Cereal-Livestock Production in East Africa. *Agriculture*. 2020; **10(7):** 268. https://doi.org/10.3390/agriculture10070268

11. **Chidawanyika F, Muriithi B, Niassy S, Ouya FO, Pittchar JO, Kassie M and ZR Khan** Sustainable intensification of vegetable production using the cereal 'push-pull technology': benefits and one health implications. *Environmental Sustainability*. 2023; **6:** 25–34. https://doi.org/10.1007/s42398-023-00260-1

12. **Lamichhane JR, Barzman M, Booij K, Boonekamp P, Desneux N, Huber L and A Messéan** Robust cropping systems to tackle pests under climate change. A review. *Agronomy for Sustainable Development.* 2015; **35(2):** 443-459. https://doi.org/10.1007/s13593-014-0275-9

13. **Mitchell S, Weersink A and B Erickson** Adoption of precision agriculture technologies in Ontario crop production. *Canadian Journal of Plant Science.* 2018; **98(6):** 1384-1388. https://doi.org/10.1139/cjps-2017-0342

14. **Vermeulen SJ, Aggarwal PK, Ainslie A, Angelone C, Campbell BM, Challinor AJ and E Wollenberg** Options for support to agriculture and food security under climate change. *Environmental Science & Policy.* 2012; **15(1):** 136-144. https://doi.org/10.1016/j.envsci.2011.09.003

15. **Leigh A, Ricker-gilbert J and RJGM Florax** How does population density influence agricultural intensification and productivity ? Evidence from Ethiopia. *Journal of Food Policy.* 2014; **48:** 1-11. https://doi.org/10.1016/j.foodpol.2014.03.004

16. **Altieri MA and CI Nicholls** Agroecology scaling up for food sovereignty and resiliency. In *Sustainable agriculture reviews* (pp. 1-29). Springer, Dordrecht. 2012. https://doi.org/10.1007/978-94-007-5449-2_1

17. **Kiesel C, Dannenberg P, Hulke C, Kairu J, Diez JR and A Sandhage-Hofmann** An argument for place-based policies: The importance of local agro-economic, political and environmental conditions for agricultural policies exemplified by the Zambezi region, Namibia. *Environmental Science & Policy*. 2022; **129:** 137-149. https://doi.org/10.1016/j.envsci.2021.12.012

18. **Takahashi K, Muraoka R and K Otsuka** Technology adoption, impact, and extension in developing countries' agriculture: A review of the recent literature. *Agricultural Economics.* 2020; **51(1):** 31-45. https://doi.org/10.1111/agec.12539

19. **Murage AW, Pittchar JO, Midega CAO, Onyango CO and ZR Khan** Gender specific perceptions and adoption of the climate-smart push–pull technology in eastern Africa. *Crop Protection.* 2015; **76:** 83-91. https://doi.org/10.1016/j.cropro.2015.06.014

20. **Muriithi BW, Menale K, Diiro G and G Muricho** Does gender matter in the adoption of push-pull pest management and other sustainable agricultural practices? Evidence from Western Kenya. *Food Sec.* 2018; **10(2):** 253–272. https://doi.org/10.1007/s12571-018-0783-6

21. **Kassie M, Stage J, Diiro G, Muriithi B, Muricho G, Ledermann ST and Z Khan** Push–pull farming system in Kenya: Implications for economic and social welfare. *Land Use Policy.* 2018; **77:** 186-198. https://doi.org/10.1016/j.landusepol.2018.05.041

22. **Murage AW, Midega CAO, Pittchar JO and ZR Khan** Potential uptake determinants of climate-smart push-pull technology in drier agro-ecological zones of eastern Africa. 2013 (No. 309-2016-5245).

23. **Ouya FO, Murage AW, Pittchar JO, Chidawanyika F, Pickett JA and ZR Khan** Impacts of climate-resilient push–pull technology on farmers' income in selected counties in Kenya and Tanzania: propensity score matching approach. *Agriculture and Food Security.* 2023; **12:** 15 https://doi.org/10.1186/s40066-023-00418-4

24. **Dhehibi B, Rudiger U, Moyo HP and MZ Dhraief** Agricultural technology transfer preferences of smallholder farmers in Tunisia's arid regions. *Sustainability.* 2020; **12(1):** 421. https://doi.org/10.3390/su12010421

25. **Bukchin S and D Kerret** Character strengths and sustainable technology adoption by smallholder farmers. *Heliyon.* 2020; **6(8):** e04694. https://doi.org/10.1016/j.heliyon.2020.e04694

26. **Ojiem JO, De Ridder N, Vanlauwe B and KE Giller** Socio-ecological niche: a conceptual framework for integration of legumes in smallholder farming systems. *International Journal of Agric Sust.* 2006; **4(1):** 79-93. https://doi.org/10.1080/14735903.2006.9686011

27. **Srisopaporn S, Jourdain D, Perret SR and G Shivakoti** Adoption and continued participation in a public Good Agricultural Practices program: The case of rice farmers in the Central Plains of Thailand. *Technological Forecasting and Social Change.* 2015; **96:** 242-253. https://doi.org/10.1016/j.techfore.2015.03.016

28. **Teshome A, de Graaff J and M Kassie** Household-Level Determinants of Soil and Water Conservation Adoption Phases: Evidence from North-Western Ethiopian Highlands. *Environmental Management.* 2016; **57:** 620–636. https://doi.org/10.1007/s00267-015-0635-5

29. **Government of Kenya.** Economic review of agriculture (EAR). Central Planning and Project Monitoring Unit, Ministry of Agriculture, Livestock and Fisheries, Nairobi. 2015. https://academia-ke.org/library/download/malf-economic-review-of-agriculture-2015/?wpdmdl=7465&refresh=6278d812749dd1652086802 *Accessed June 2021.*

30. **Gujarati DN** Basic Econometrics. (4 ed.) Singapura: McGraw-Hill. 2003. 623.

31. **Greene WH** Econometric analysis. 71e. Stern School of Business, New York University. 2012. 721-723.

32. **Silberg TR, Richardson RB and MC Lopez** Maize farmer preferences for intercropping systems to reduce Striga in Malawi. *Food Security.* 2020; **12(2):** 269-283. https://doi.org/10.1007/s12571-020-01013-2

33. **Useche P, Barham BL and JD Foltz** Trait-based adoption models using ex-ante and ex-post approaches. *American Journal of Agricultural Economics.* 2013; **95(2):** 332-338. https://doi.org/10.1093/ajae/aas044

34. **Ouya F, Ayuya OI and IM Kariuki** Effects of agricultural intensification practices on smallholder farmers' livelihood outcomes in Kenyan hotspots of Climate Change. *East African Journal of Science, Technology, and Innovation*. 2020; **2(1):** 1-23. https://doi.org/10.37425/eajsti.v2i1.110

35. **Yahaya I, Pokharel KP, Alidu A and FA Yamoah** Sustainable agricultural intensification practices and rural food security: the case of North Western Ghana. *British Food Journal.* 2017; **120(2):** 468-482. https://doi.org/10.1108/BFJ-01-2017-0021

36. **Eshetu F and A Guye** Determinants of Households Vulnerability to Food Insecurity: Evidence from Southern Ethiopia. *Journal of Land and Rural Studies*. 2021; **9(1):** 35-61. https://doi.org/10.1177/2321024920967843

37. **Amudavi DM, Khan ZR, Wanyama JM, Midega CAO, Pittchar J, Hassanali A and JA Pickett** Evaluation of farmers' field days as a dissemination tool for push–pull technology in Western Kenya. *Crop Protection.* 2009; **28(3):** 225–235. https://doi.org/10.1016/j.cropro.2008.10.008

38. **Murage AW, Obare G, Chianu J, Amudavi DM, Pickett J and ZR Khan** Duration analysis of technology adoption effects of dissemination pathways: a case of 'push–pull'technology for control of striga weeds and stemborers in Western Kenya. *Crop Protection.* 2011; **30(5):** 531-538. https://doi.org/10.1016/j.cropro.2010.11.009

39. **Ainembabazi JH and J Mugisha** The role of farming experience on the adoption of agricultural technologies: Evidence from smallholder farmers in Uganda. *Journal of Development Studies.* 2014; **50(5):** 666-679. https://doi.org/10.1080/00220388.2013.874556

40. **Saqib SE, Kuwornu JK, Panezia S and U Ali** Factors determining subsistence farmers' access to agricultural credit in flood-prone areas of Pakistan. *Kasetsart Journal of Social Sciences.* 2018; **39(2):** 262-268. https://doi.org/10.1016/j.kjss.2017.06.001