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Determinants of fall armyworm (*Spodoptera frugiperda)* control strategies by maize-producing smallholder farmers in Mutasa District, Manicaland Province, Zimbabwe

Witness Sithole, Faustino Madzokere, Freddy Ruzhani, Newettie Jambo and Rutendo Nyamusamba

Agricultural Economics and Development, Manicaland State University of Applied Sciences, Mutare, Manicaland, Zimbabwe

ABSTRACT

Fall armyworm (FAW) outbreaks in Zimbabwe have exacerbated challenges for smallholder farmers, causing maize damage and yield losses. This study explores the various control strategies employed by smallholder farmers in Mutasa District to control pests and the factors influencing their selection. A sample of 158 randomly selected maize smallholder farmers was surveyed using a structured questionnaire, and the data were analysed using frequencies, means and Multivariate Probit Regression. Male farmers were less likely to use uprooting and disposal as a FAW control strategy while being a married farmer increased the probability of using handpicking by 34.9% compared to single farmers. Education level increased the probability of using pesticides by 26.4% but decreased the likelihood of using uprooting and disposal by 34.6%. Large families used labour-intensive techniques, while the distance from home reduced the probability of adopting early planting and intercropping strategies. Access to extension services increased the probability of using powdered soap by 29.3%. The study recommends an integrated strategy of FAW control that considers socioeconomic factors, promotes education, makes information accessible and supports sustainable FAW management techniques needed in the area.

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1. Introduction

Agriculture is critical to Zimbabwe's economy, providing a living for the majority of rural people. It continues to be a major source of income for the rural poor in Africa and Zimbabwe. Between 60% and 70% of the population is employed in agriculture, and 40% of all export revenues come from it (FAO, 2020a). Maize production, in particular, is critical to Zimbabwe's rural populations and directly affects the majority of food security at the household level. It is the most commonly produced crop in the country and a vital food source for both rural and urban inhabitants. The crop accounts for over 60% of Zimbabwe's overall crop production area (Mutambara, 2015). Due to the importance of maize in many Zimbabweans' diets, the crop is seen as having strategic national importance in terms of nutrition and food security.

Smallholder farmers generally face several challenges when undertaking their farming operations. Recent serious Fall armyworm (FAW) *(Spodoptera frugiperda)* outbreaks in Zimbabwe have added to the multiplicity of challenges for smallholder farmers, who are already strained in terms of resources. The pest was first recorded during the cropping season of 2016 to 2017, and it has remained a menace, inflicting a substantial decrease in yields and major damage to maize products (FAO, 2020b). The losses from FAW are severe, posing substantial negative implications for food security and livelihoods. There are significant yield losses due to the FAW larvae feeding on the leaves and reproductive organs of maize plants. According to Prasanna et al. (2018), FAW is one of the most destructive crop pests, generating losses of economic significance to cereals since it can survive on more than 80 different crop varieties. The availability of financial

CONTACT Faustino Madzokere fmadzokere69@gmail.com Agricultural Economics and Development, Manicaland State University of Applied Sciences, Mutare, Manicaland, Zimbabwe

resources and farmers' knowledge, which affect the adoption of efficient crop protection methods, are the two most crucial aspects that affect the ability to control FAW effectively (Kansiime et al., 2019). Farmers with more income were more likely to have the capacity to invest in FAW control, while farmers with good knowledge of FAW were more disposed towards implementing FAW control methods.

Tambo et al. (2020a), citing Rwomushana et al. (2018), indicated that the FAW could lower maize yields in Zimbabwe by 264,000 tonnes annually, leading to a US$83 million economic loss. Because the FAW is polyphagous and transboundary, it reproduces quickly, has a short life cycle, and quickly migrates to attack new locations (Matova et al., 2020). Therefore, control of this pest is highly challenging, threatening food security in Zimbabwe. The smallholder maize producers, who lack resources and may find it difficult to acquire adequate pest-control agents, are greatly impacted by FAW.

As smallholder farmers struggle to manage this pest with limited resources, they employ a variety of low-cost practices to mitigate crop losses caused by this pest. However, the different control methods employed by smallholder farmers in the Mutasa District and the variables influencing their decisions are poorly understood. Various FAW control measures implemented by smallholder farmers have been identified in previous studies, including the use of biopesticides, crop rotation, timely planning, use of ash, removing infected plants, uproot and disposal, use of improved varieties, and powdered soap and hand-picking of FAW larvae and eggs (Ansah et al., 2024; Chimweta et al., 2020; Kassie et al., 2020; Mutyambai et al., 2022; Tambo et al., 2020a; Tambo et al., 2020b). To lessen the detrimental effects of FAW, Tambo et al. (2020a) found that smallholder farmers in Africa employ a variety of cultural, physical, chemical and local options, with synthetic pesticides being the most often utilized method. In the same study, both access to subsidized farm inputs and information from extension agents were reported as the main drivers of pesticide use. Kassie et al. (2020) reported that Southern Ethiopia saw a rise in the use of pesticides against FAW. According to Chimweta et al. (2020), farmers experimented with 28 various combinations of pesticides, ash, and washing powder to reduce FAW infestation in the Zambezi Valley in northern Zimbabwe.

Compared to monoculture systems with irrigation and no weeding, mixed cropping systems with rain-fed production and frequent weeding had less FAW infestations and damage. In a study done in Eastern Zimbabwe, Baudron et al. (2019) discovered that frequent weeding operations and little to no tillage dramatically reduced FAW damage. However, intercropping of pumpkins, which is common in Zimbabwe, was found to significantly enhance FAW damage. Kasoma et al. (2021) found that smallholder farmers' coping mechanisms for FAW control included the use of chemical pesticides, cultural and landscape management approaches, and the crushing of FAW larvae. In Uganda, intercropping maize with leguminous crops significantly reduced FAW compared to maize monocropping, particularly during the early stages of the maize's growth (Hailu et al., 2018). Matova et al. (2020) mentioned pesticides, cultural practices, natural enemies, host-plant resistance, Integrated Pest Management (IPM) and plant breeding techniques as potential methods of FAW management methods.

Previous studies have found conflicting results on the factors influencing the farmer's choice of control strategies. Several studies have associated choice of FAW management techniques by smallholder farmers with socioeconomic characteristics such as gender, age, education, off-farm income, amount of agricultural extension training and family size (Ansah et al., 2024; Asare-Nuamah, 2021; Balasha, 2019; Murithi et al., 2020; Shiferaw et al., 2014). Other studies have found factors including credit constraints, plot size, social networks, spouse education, labour availability, and market access to have an impact on the farmer's decision to select a FAW control strategy (Korir et al., 2015; Teklewold et al., 2013).

This study focuses on the characteristics of the local farming community to provide valuable insights for targeted FAW control interventions. The research fills a gap in the existing literature by examining the determinants of these strategies among smallholder farmers, recognizing their unique socio-economic context and limited resources. It aids in understanding indigenous knowledge systems related to FAW control and hence helps in policy formulation for effective FAW control for smallholder farmers.

2. Materials and methods

2.1. Study area

The study was carried out in the Mutasa district of Manicaland Province, Zimbabwe. It is one of the seven districts in the Manicaland province and is located between 18° 34′ 59.99" S and 32° 44′ 59.99" E.

The yearly rainfall ranges between 450 and 1000 mm while minimum and maximum average temperatures are 13 and 25 degrees Celsius, respectively. Agriculture is the main activity in the Mutasa District, and most villagers engage in semi-commercial production.

2.2. Sampling procedure

Mutasa district has a total of 52,371 households constituting the sample population (ZIMSTAT, 2022). A multistage sampling design was adopted for this study. In the first stage, two wards were selected randomly in the Mutasa District to be part of the data collection areas. In the second stage, 158 maize farmers, consisting of 79 farmers from each selected ward, were randomly selected to participate in the study. Ethics clearance was obtained from the Manicaland State University of Applied Sciences Ethics Clearance Board. Informed consent was sought through a signed informed consent statement from each and every participant in the study. Data were collected by the principal investigator and one trained enumerator from January to February 2023. A structured questionnaire was utilized as the data collection tool. The questionnaire sought information on the socioeconomic factors of households, the challenges farmers encounter in FAW control, and the FAW control strategies utilized by small-scale farmers.

2.3. Data analysis

Frequencies and means were calculated to compare the socioeconomic characteristics of households and the FAW control strategies utilised by small-scale farmers. Multivariate Probit (MVP) model was employed to estimate the relationship between various socioeconomic factors and the FAW control approaches used by farmers. The MVP model is relevant to this study because it can address the relationship between several explanatory variables and the categorical dependent variable (FAW control methods used by small-scale farmers). The MVP model accounts for the simultaneous correlation between the different FAW control approaches and the subsequent correlation between error terms (Mittal & Mehar, 2016). Therefore, the MVP model was selected to analyse the variables affecting farmers' decisions regarding their FAW control strategies. The broad description of the MVP model is as presented in Equation 1:

$$y^*_{im} = \beta_{im} X_{im} + \varepsilon_{im} \tag{1}$$

Where:

y^*_{im} shows the latent variable of the probability of a FAW control strategy (m) being chosen. (the strategies considered in this study include early planting, improved varieties, powdered soap, uprooting and disposal, handpicking, intercropping and pesticides), *Xim* is a vector of characteristics or independent variables explaining the farmer's choice (these are provided in Table 1 and include age, gender, education, marital status, household size, farm size, extension contact, etc.), β_{im} indicates the parameters to be estimated in the study, e_{im} represents a vector of error terms.

The independent variables in the model are listed in Table 1.

Table 1. Description variables assessed in the study.

Variables	Measurement/category
Age of the household head	Years
Gender of household head	0. Female, 1. Male
Marital status of household head	1. Single, 2. Married, 3. Divorced, 4. Widowed
The highest level of education attained by the household head	1. None, 2. Primary, 3. Secondary, 4. Tertiary
Members of households who participate in maize production	Number
Farm size	Ha
Distance from home to the field	Km
Availability of stores of agricultural inputs in the area	0. No, 1. Yes
Extension access over the past season	0. No, 1. Yes
Distance from the farm to the closest neighbouring farm	Km

3. Results and discussion

3.1. Socioeconomic characteristics of respondents

Table 2 shows the socioeconomic characteristics of the 158 respondents who made up this study's sample.

Of the 158 sampled households, 61% were male-headed, while 39% were female-headed. Only 5% of household heads were single, while the majority of household heads (72%) were married. Widows and divorcees were next in line, each with 11% and 12% of the total. Their ages ranged from 25 to 87, averaging 48 years. Most of the household heads attained secondary education (34%) followed by tertiary (31%), no formal education (20%) and primary (15%). Almost all the respondents (92%) had access to extension advice during the previous maize growing season, while only 8% had no access. This shows that extension support has significantly improved in Zimbabwe, which is in line with the findings of Makate & Makate (2019) in a study conducted in Mashonaland East, Zimbabwe. This result is consistent with previous research on FAW control done in Ghana (Ansah et al., 2024). Regarding FAW control, access to extension expertise is essential because farmers receive guidance on the best control methods.

Family labour was estimated at an average of four members per household, ranging from one to nine. Labour availability is essential in FAW control as some of the strategies used by farmers to control this pest, such as hand-picking FAW larvae and FAW eggs, require a lot of labour. The impact of having a nearby store of agricultural inputs on selecting the FAW control strategies was another significant variable of interest for this study. In this regard, 47% of the respondents had access to a local store of agricultural inputs, compared to 53% who did not. The average distance from home to the field was 1.94 km, while the average distance from one farm to the next neighbouring farm was 0.48 km. The distance from home to the field is important, as some FAW control strategies require closeness to the home for constant monitoring and scouting.

3.2. FAW control strategies

The study identified seven predominant control strategies for managing FAW from previous studies (Table 3). These strategies were equally prevalent among small-scale maize farmers of the Mutasa District. These control strategies included early planting, improved varieties, powdered soap, uprooting and disposing of infected plants, handpicking FAW larvae and eggs, intercropping, and pesticide use (Table 3).

Table 2. Socioeconomic characteristics of the respondents.

Categorical variable	Frequency	Percent
Gender		
Female	61	38.61
Male	97	61.39
Marital status		
Single	8	5.06
Married	114	72.15
Divorced	17	10.76
Widowed	19	12.03
Level of education		
No formal education	32	20.25
Primary	49	31.01
Secondary	53	33.54
Tertiary	24	15.19
Access to extension advice		
No	12	7.59
Yes	146	92.41
Access to local store of agricultural inputs		
No	84	53.16
Yes	74	46.84

Continuous variables	Mean	SD	Min	Max
Age (years)	48.39	14.34	25	87
Members participating in maize production	4	1.87	1	9
Farm size (Ha)	3.79	3.71	0.06	12
Distance from home to field (km)	1.94	1.77	1	9
Distance of farm to neighbouring farm (km)	0.48	0.62	0.004	2

Table 3. FAW control strategies used by the respondents.

Control strategies	Frequency	Percentages (%)
Early planting		
No	21	13.29
Yes	137	86.71
Improved varieties		
No	33	20.89
Yes	125	79.11
Powdered soap		
No	131	82.91
Yes	27	17.09
Uprooting and disposal		
No	81	51.27
Yes	77	48.73
Handpicking		
No	83	52.53
Yes	75	47.47
Intercropping		
No	28	17.72
Yes	130	82.28
Pesticides		
No	19	12.03
Yes	139	87.97

Eighty-seven percent (87%) of the respondents used early planting as a strategy to control FAW, 82% used intercropping, 79% used improved varieties, 49% used uprooting and disposal of the infected plants, 47% used handpicking of FAW larvae and eggs as a control strategy, with only a few farmers using powdered soap (17%) for FAW control. Except for intercropping, the results presented above are consistent with findings made by Ansah et al. (2024) in Ghana.

Pesticide application was the most popular method of FAW control, with 88% of farmers resorting to chemical control strategies, possibly due to the strategies' proven effectiveness in managing FAW. However, due to this method being costly, and the possibility of pests developing resistance to some pesticides, farmers resorted to combining pesticide use with mechanical and cultural control techniques (Ansah et al. 2024; Asante et al., 2023). Pesticides commonly used for FAW control in Zimbabwe include; Methamidophos Diazinon, Lambda-Cyhalothrin, Carbaryl 85% wettable powder, Fenkill Fenvalerate and Acetamipridas (Chimweta et al., 2020). Several studies (Day et al., 2017; Gui et al., 2022; Matova et al., 2020; Phambala et al., 2020) have examined pesticide resistance in FAW control.

Rwomushana et al. (2018) found out that farmers in Ghana and Zambia had great success rates (91.2% and 97.0%, respectively) in using biopesticides, early planting and insecticides. On the other hand, strategies such as burning infected crops, uprooting infected crops and weeding them were reported as ineffective. Low success rates were also observed for the manual removal of egg masses and caterpillars in both Zambia (61.9%) and Ghana (76%).

Despite the extensive usage of pesticides, Kumela et al. (2019) noted issues to do with effectiveness in Ethiopia (46%) and Kenya (60%). However, due to a lack of empirical evidence to indicate the development of FAW resistance in African nations, Rwomushana et al. (2018) suggested that these observations may be due to adulteration, poor application or counterfeit items rather than evolved resistance. Resistance management techniques should be put into practice to stop the development of resistance.

3.3. Factors affecting the selection of FAW control strategies

We performed the multicollinearity test using the variance inflation factor (VIF), and the results showed no linearity problems among the variables. The results of the VIF test are presented in Table 4. According to the findings, various factors influence the selection of FAW control measures (Table 4). Gender, age, marital status and level of education of the household head as well as participation in farming by other members of the household, farm size, distance from the household to the farm, presence of a store of agricultural inputs in the locality and use of agricultural extension services were the key variables influencing the choice of FAW control strategies in Mutasa District (Table 4).

According to the findings (Table 4), male farmers were less likely to select uprooting and disposal as a FAW control approach than female farmers. Compared to females, being a male farmer was associated

Table 4. Factors affecting the choice of FAW control strategies.

Variable	Early planting	Improved varieties	Powdered soap	Uproot and disposal	Handpicking	Intercropping	Pesticide	VIF
Gender of household head	0.0332	0.1211	−0.0362	−0.3764***	−0.0765	0.0853	0.0430	1.25
Age	−0.0007	−0.0030	0.0008	0.0031	0.0053	0.0038	−0.0047*	1.83
Marital status								1.25
Married	−0.1335	0.4075***	−0.6306***	0.2030	0.2993*	−0.1854	−0.1317	
Divorced	−0.0690	0.5538***	−0.5385***	−0.0581	0.1074	−0.1824	−0.0456	
Widowed	0.0694	0.2936*	−0.5998***	−0.0299	−0.3029	−0.0307	0.0611	
Level of education								1.21
Primary	0.1049	0.2866***	0.1484	−0.2969**	0.0112	0.0262	0.2341**	
Secondary	0.0892	0.2570***	0.1733**	−0.1638	0.0468	0.0454	0.0881	
Tertiary	0.0744	0.2867***	−0.1283	−0.0060	0.1180	−0.1418	0.1148	
Household members participating in maize production	−0.0082	−0.0657**	0.0892***	−0.0259	−0.0345	0.0298	−0.0161	2.76
Farm size	−0.0092	0.0296**	−0.0181	0.0096	0.0338**	−0.0238*	0.0049	2.44
Distance from homes to fields	−0.0254*	0.0302*	0.0096	0.0335	0.0799***	−0.0347**	−0.0055	1.07
Availability of local agricultural inputs shops	−0.1025	0.0308	−0.1405**	0.1301	0.2390***	−0.0404	−0.0597	1.33
Received agro extension services	−0.1508	−0.0857	0.2566**	0.1994	0.0848	0.1238	0.1600	1.10
Distance from farm to a neighbouring farm	−0.0314	−0.0129	0.0048	0.0569	0.0350	0.0429	−0.0581	1.06
Constant	1.2314	0.4361	0.1930	0.2716	−0.3151	0.6818	−1.0404	
Mean VIF								1.53

***, ** and * indicate significance at 1%, 5% and 10%, respectively.

with a decrease in the probability of using the approach of uprooting and disposal by 45.7% relative to the probability of not selecting any other FAW control approach. Studies in developing countries have found that women are involved in all farming activities, particularly physically demanding tasks (Mensah & Fosu-Mensah, 2020; Patil & Babus, 2018; Van der Meulen Rodgers et al., 2024). A study by Kansiime et al. (2019) observed that female farmers in Zambia tended to employ cultural and mechanical management strategies, such as uprooting and discarding the infected plants, whereas male farmers tended to apply insecticides more frequently. It has been reported that women tend to choose mechanical control strategies since they typically lack financial resources and make up the majority of the labour force in the fields (Matova et al., 2020). Conversely, Ansah et al. (2024) in Ghana discovered that male household heads mainly used uprooting and disposal of the infected plants than female household heads. Rwomushana et al. (2018) discovered that households with female heads in Ghana employed agronomic practices more frequently. These agronomic practices included handpicking FAW eggs and caterpillars, along with hand-weeding, uprooting the infected plants, early planting and weeding. In Zambia, households with male heads tended to handpick larval and egg masses, whereas households with female heads favoured early planting and sand application, among other cultural management techniques (Rwomushana et al., 2018).

According to the findings, farmers were less likely to manage FAW using pesticides as their age increased. An increase in the farmer's age by one year was associated with a decrease in the probability of selecting pesticides as a control strategy by 0.47% relative to the probability of not choosing any other control strategy. Kansiime et al. (2019) noted that old farmers favoured cultural practices over young farmers who favoured chemical control of FAW. In their research, Kansiime et al. (2019) discovered that old farmers were more likely to use cultural techniques and a combination of cultural and insecticides or biological products than young farmers. This response was attributed to the propensity of young people to prefer choices that yield fast outcomes. This was further corroborated by Teklewold et al. (2013) and Ansah et al. (2024), who observed that young farmers are more open to attempting innovations than older farmers. They also discovered in their studies that old people were less likely to choose improved varieties or powdered soap to control FAW but more likely to choose early planting. According to Kumela et al. (2019), farmers who employed two or more approaches were likely to combine pesticides as their primary method with handpicking or other cultural control techniques. However, Tambo et al. (2019) and Balasha (2019) found that neither the age nor the gender of household heads significantly affected their adoption decisions.

Table 4 shows a positive relationship between being married and choosing the handpicking method. Compared to single farmers, being married was associated with an increase in the probability of

selecting the handpicking approach by 34.9% in relation to the probability of not choosing other management approaches. Farmers who were married tended to prefer the handpicking approach of managing FAW compared to those who were single, probably because the handpicking technique requires a lot of labour and would not be appealing to a single farmer, as the majority of smallholder farmers depend on family labour. Married or divorced farmers were more likely to select improved varieties but less likely to select powdered soap as a FAW control strategy. Compared to single farmers, being married or divorced was associated with an increase in the probability of selecting improved varieties as a management strategy by 50.3% or 74%, respectively, relative to the probability of not choosing other FAW management approaches. This finding occurred probably because married or divorced farmers may have better financial circumstances and are able to acquire improved varieties.

On the other hand, compared to single farmers, being married or divorced was associated with a decrease in the probability of using powdered soap as a management strategy by 87.9% or 71.3%, respectively, relative to the probability of not selecting any other FAW management strategy. This finding might be because single farmers often lack resources, unlike married farmers, which justifies their preference for the powdered soap technique of managing FAW.

Findings indicated a positive relationship between selecting seed as a FAW control measure and acquiring primary, secondary, and tertiary education. Compared to farmers without formal education, having primary education, secondary education or tertiary education was associated with an increase in the probability of choosing improved varieties by 33.2%, 29.3% or 33.2%, respectively, in relation to the probability of not choosing any other management strategy. This might be because education exposes farmers to innovations and current agricultural practices, influencing them to select improved varieties as a preventative measure against FAW (Korir et al., 2015; Shiferaw et al., 2014). Moreover, farmers who completed primary education were more likely to choose pesticides as a FAW control strategy but less likely to choose uprooting and disposal of the infected plants. Compared to farmers with no formal education, being educated up to the primary level was associated with an increase of 26.4% in the probability of using pesticides to manage FAW compared to the probability of not selecting any other management strategy. On the other hand, having primary education, compared to not having a formal education, decreased the probability of selecting uprooting and disposal of the infected plants by 34.6%, relative to the probability of not choosing other control strategies. The above findings align with those of Tambo et al. (2020a), who found a strong association between education and implementing FAW management strategies. This is mostly because education expands farmers' access to information and enhances their ability to analyse information regarding pest management options quickly and accurately. Education plays a crucial role in pest management decisions (Abdollahzadeh et al., 2016; Damalas et al., 2024)

Households with more family labour were less likely to choose improved varieties and more likely to choose powdered soap as a FAW control strategy. An increase in family labour by one member is associated with a 0.82% decrease in the probability of using improved varieties and a 9.33% increase in the probability of selecting powdered soap as a management strategy compared to the probability of not choosing any other approach. Ansah et al. (2024) discovered that household size positively influenced the decision to use improved varieties and powdered soap as FAW management measures. This would make sense because both techniques require increased labour, which can mostly be supplied by family members. Due to their reliance on inexpensive and easily accessible labour, large families may turn to labour-intensive FAW management techniques such as handpicking (Akeme et al., 2021).

Improved varieties were chosen as a FAW control strategy by households with larger farms than intercropping. An increase in farm size by a hectare led to a 3% increase in the probability of selecting seed varieties and a 2.41% decrease in the probability of using intercropping as a FAW management strategy in relation to the probability of not choosing other strategies. Large farm sizes may indicate greater wealth, which would increase farmers' willingness to use agricultural technologies like improved varieties (Korir et al., 2015; Tambo et al., 2019). Farmers with large landholdings found intercropping less appealing, probably because this practice reduces the usefulness of mechanical weeding and herbicides. Unexpectedly, families with large farms were more likely to select handpicking as a FAW management strategy. Increasing farm size by one hectare was associated with a 3.44% increase in the probability of using the handpicking control strategy relative to the probability of not choosing any other strategy.

Handpicking is feasible for farmers with small land, especially during scouting and field monitoring, but this method is unworkable for farmers with large farms (Tambo et al., 2020a). In this study, due to the labour-intensive nature of the large farms, the handpicking strategy is probably utilized during crop monitoring and scouting rather than as a field-wide control. This conclusion may be further explained by the larger and more organized farms focusing on management techniques like scouting as key management operations.

Farmers whose fields were far from residential areas were more likely to use improved varieties and manually remove FAW larvae but were less likely to plant early or use intercropping as FAW management strategies. An increase in the distance between the field and the residential area by one unit was associated with an increase in the probability of selecting improved varieties by 3.1% and handpicking as a control strategy by 8.32%, relative to the probability of not adopting any other strategy. Farmers who work in fields far from their homesteads are more likely to be dedicated farmers who use improved varieties and adhere to all necessary management procedures, such as scouting. During such scouting, handpicking of larvae is utilized to manage FAW for a crop established using improved maize varieties that are more tolerant to FAW attacks.

On the other hand, a negative relationship was found between the farm's distance from home and choosing strategies such as early planting and intercropping. An increase in the distance between the field and the homestead by one unit was associated with a 2.57% decrease in the probability of adopting the early planting approach and a 3.53% decrease in the probability of using the intercropping approach in relation to the probability of not choosing any other management strategy. When farmers stay far from their fields, they might not prefer early planting because early crops typically need to be protected from cattle and allowed to roam free throughout the winter and early cropping season. In contrast, Ansah et al. (2024) findings showed that farmers were more likely to choose early maize planting and handpicking as FAW management techniques the more distant their dwelling is from their fields.

Table 4 also indicates that farmers living closer to a store of agricultural inputs were less likely to choose powdered soap but prefer handpicking as a FAW management method. Having a store of agricultural inputs in the locality was associated with a decrease in the probability of choosing powdered soap as a control strategy by 15.1% and an increase in the probability of selecting the handpicking strategy by 27%, relative to the probability of not choosing any other strategy. Previous research reported that the existence of stores of agricultural inputs significantly decreased the possibility of farmers utilizing powdered soap as a FAW control method (Ansah et al., 2024).

The findings indicated a positive relationship between having access to extension services and choosing powdered soap as a FAW control strategy. Compared to those without access, having access to extension services was associated with a 29.3% increase in the probability of choosing powdered soap as a control strategy relative to the probability of not choosing any other approach. Extension services help farmers become open to change and adopt new solutions. Farmers with access to extension services are more likely to pursue alternative FAW control strategies. Information is essential for adopting agricultural technologies and farm households' ability to respond to pressures (Balasha, 2019; Tambo et al., 2019).

4. Conclusions and policy recommendations

Smallholder farmers use a diverse combination of options to reduce the negative impacts of FAW in the Mutasa District, with significant gender differences in the preferences of FAW control methods. Therefore, while promoting cultural ways of FAW management, policymakers and developmental organizations should focus on women, and when promoting interventions that are not cultural, they should focus on men. Young farmers preferred using pesticides and other practical FAW management strategies. This behaviour presents an opportunity for agrochemical companies to target these young farmers. The choice of a FAW control strategy was also influenced by marital status, with married farmers, who likely have more stable financial situations, showing a high tendency to choose improved varieties. Conversely, developmental organizations should include widows and less financially stable farmers when developing interventions and beneficiaries for their initiatives.

The adoption of technologies is influenced by education. Therefore, researchers and business people should focus on educating farmers when introducing new technologies like pesticides and improved varieties. For farmers that operate on a larger scale, policymakers should encourage contract farming so that they can have access to inputs like improved varieties and pesticides. Additionally, farmers will have access to the best FAW control strategies available on the market when they have easy access to local stores of agricultural inputs. Therefore, policymakers must provide incentives for agricultural input vendors to move closer to the farmers. Moreover, suppliers of agricultural inputs should receive training to capacitate them to advise their clients because they affect farmers' decisions. Farmers may also benefit from extension services since they pay attention to extension agents, so it is necessary to provide them with accurate information on how to control FAW effectively.

While our study is limited by a considerably lower sample size, our findings highlight the need for continuous research and investment in sustainable FAW management approaches that consider the socio-economic and environmental factors affecting smallholder farmers' selection of control methods. Future studies should also concentrate on the efficiency of the various FAW control measures employed by smallholder farmers.

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Author contributions

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About the authors

Witness Sithole is an agricultural economics graduate student at Manicaland State University of Applied Sciences' Department of Agricultural Economics and Development. He is interested in agricultural extension and development economics.

Faustino Madzokere teaches at Manicaland State University of Applied Sciences in the Department of Agricultural Economics and Development. His areas of interest include developmental economics, farm business management, and agricultural extension.

Freddy Ruzhani is a lecturer in the Department of Agricultural Economics and Development at Manicaland State University of Applied Sciences. His areas of interest include food security, climate change, livelihood enhancement, perception dynamics in agriculture, smallholder farmer development, and welfare economics.

Newettie Jambo is a lecturer at Manicaland State University of Applied Sciences in the Department of Agricultural Economics and Development. His research interests include behavioral economics, rural development, and the welfare and livelihood development of smallholder farmers.

Rutendo Nyamusamba is a lecturer in the Department of Agricultural Economics and Development at Manicaland State University of Applied Sciences. Her areas of research interest include ecology and management, weed biology, sustainable farming, and pest control.

ORCID

Freddy Ruzhani http://orcid.org/0000-0003-1345-2113

Data availability

Data is available upon reasonable request

References

Abdollahzadeh, G., Sharifzadeh, M. S., & Damalas, C. A. (2016). Motivations for adopting biological control among Iranian rice farmers. *Crop Protection*, *80*, 42–50. https://doi.org/10.1016/j.cropro.2015.10.021

Akeme, C. N., Ngosong, C., Sumbele, S. A., Aslan, A., Tening, A. S., Krah, C. Y., Kamanga, B. M., Denih, A., & Nambangia, O. J. (2021). Different controlling methods of fall armyworm (*Spodoptera frugiperda*) in maize farms of small-scale producers in Cameroon. *IOP Conference Series: Earth and Environmental Science*, *911*(1), 012053. https://doi.org/10.1088/1755-1315/911/1/012053

Ansah, I. G., Tampaa, F., & Tetteh, B. K. (2024). Farmers' control strategies against fall armyworm and determinants of implementation in two districts of the Upper West Region of Ghana. *International Journal of Pest Management*, *70*(4), 570–584. https://doi.org/10.1080/09670874.2021.2015008

Asante, I. K., Inkoom, E. W., Ocran, J. K., Kyeremateng, E., Sabari, G., & Odamtten, F. T. (2023). Intention of smallholder maize farmers to adopt integrated pest management practices for fall armyworm control in the Upper East region of Ghana. *International Journal of Pest Management*, *1*(18), 1–18. Retrieved from https://doi.org/10.1080/09670874.2023.2190627

Asare-Nuamah. P. (2021). Smallholder farmers' adaptation strategies for the management of fall armyworm (*Spodoptera frugiperda*) in rural Ghana. *International Journal of Pest Management*, 68(1), 8–18. https://doi.org/10.1080/09670874.2023.2190627

Balasha, A. M. (2019). Drivers of adoption of integrated pest management among small-scale vegetable farmers in Lubumbashi, DR Congo. *American Journal of Rural Development*, *7*(2), 53–59.

Baudron, F., Zaman-Allah, M. A., Chaipa, I., Chari, N., & Chinwada, P. (2019). Understanding the factors influencing fall armyworm (*Spodoptera frugiperda* JE Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in Eastern Zimbabwe. *Crop Protection*, *120*, 141–150. https://doi.org/10.1016/j.cropro.2019.01.028

Chimweta, M., Nyakudya, I. W., Jimu, L., & Bray Mashingaidze, A. (2020). Fall armyworm [*Spodoptera frugiperda* (JE Smith)] damage in maize: Management options for flood-recession cropping smallholder farmers. *International Journal of Pest Management*, *66*(2), 142–154. https://doi.org/10.1080/09670874.2019.1577514

Damalas, C. A., Koutroubas, S. D., & Abdollahzadeh, G. (2024). Farmers' willingness to use lower risk pesticides forpest control: Barriers and facilitators in northern Greece. *EnvironmentalChallenges*, *14*, 100871. https://doi.org/10.1016/j.envc.2024.100871

Day, R., Abrahams, P., Bateman, M., Beale, Tim., Clottey, V., Cock, M., Colmenarez, Y., Corniani, N., Early, R., Godwin, J., Gomez, J., Moreno, P. G., Murphy, S. T., Oppong-Mensah, B., Phiri, N., Pratt, C., Silvestri, S., & Witt, A. (2017). Fall Armyworm: Impacts and Implications for Africa. *Outlooks on Pest Management*, *28*(5), 196–201. https://doi.org/10.1564/v28_oct_02

FAO. (2020a). Zimbabwe at a glance. Available online at: http://www.fao.org/zimbabwe/fao-in-zimbabwe/zimbabwe-at-a-glance/en/. [Accessed on 15 February 2023].

FAO. (2020b). Forecasting threats to the food chain affecting food security in countries and regions *Food Chain Crisis Early Warning Bulletin No. 34, January–March 2020.* Rome.

Gui, F., Lan, T., Zhao, Y., Guo, W., Dong, Y., Fang, D., Liu, H., Li, H., Wang, H., Hao, R., Cheng, X., Li, Y., Yang, P., Sahu, S. K., Chen, Y., Cheng, L., He, S., Liu, P., Fan, G., … Kang, L. (2022). Genomic and transcriptomic analysis unveils population evolution and development of pesticide resistance in fall armyworm *Spodoptera frugiperda*. *Protein & Cell*, *13*(7), 513–531. https://doi.org/10.1007/s13238-020-00795-7

Hailu, G., Niassy, S., Zeyaur, K. R., Ochatum, N., & Subramanian, S. (2018). Maize–legume intercropping and push–pull for management of fall armyworm, stemborers, and striga in Uganda. *Agronomy Journal*, *110*(6), 2513–2522. https://doi.org/10.2134/agronj2018.02.0110

Kansiime, M. K., Mugambi, I., Rwomushana, I., Nunda, W., Lamontagne-Godwin, J., Rware, H., Phiri, N. A., Chipabika, G., Ndlovu, M., & Day, R. (2019). Farmer perception of fall armyworm (*Spodoptera frugiperda* J.E. Smith) and farm-level management practices in Zambia. *Pest Management Science*, *75*(10), 2840–2850. https://doi.org/10.1002/ps.5504

Kasoma, C., Shimelis, H., Laing, D. M., Shayanowako, A., & Mathew, I. (2021). Outbreaks of the fall armyworm (*Spodoptera frugiperda*), and maize production constraints in Zambia with special emphasis on coping strategies. *Sustainability*, *13*(19), 10771. https://doi.org/10.3390/su131910771

Kassie, M., Wossen, T., De Groote, H., Tefera, T., Sevgan, S., & Balew, S. (2020). Economic impacts of fall armyworm and its management strategies: Evidence from southern Ethiopia. *European Review of Agricultural Economics*, *47*(4), 1473–1501. https://doi.org/10.1093/erae/jbz048

Korir, J. K., Affognon, H. D., Ritho, C. N., Kingori, W. S., Irungu, P., Mohamed, S. A., & Ekesi, S. (2015). Grower adoption of an integrated pest management package for management of mango-infesting fruit flies (*Diptera: Tephritidae*) in Embu, Kenya. *International Journal of Tropical Insect Science*, *35*(02), 80–89. https://doi.org/10.1017/S1742758415000077

Kumela, T., Simiyu, J., Sisay, B., Likhayo, P., Mendesil, E., Gohole, L., & Tefera, T. (2019). Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. *International Journal of Pest Management*, *65*(1), 1–9. https://doi.org/10.1080/09670874.2017.1423129

Makate, C., & Makate, M. (2019). Interceding role of institutional extension services on the livelihood impacts of drought tolerant maize technology adoption in Zimbabwe. *Technology in Society*, *56*, 126–133. https://doi.org/10.1016/j.techsoc.2018.09.011

Matova, P. M., Kamutando, C. N., Magorokosho, C., Kutywayo, D., Gutsa, F., & Labuschagne, M. (2020). Fall-armyworm invasion, control practices and resistance breeding in Sub-Saharan Africa. *Crop Science*, *60*(6), 2951–2970. https://doi.org/10.1002/csc2.20317

Mensah, M., & Fosu-Mensah, B. Y. (2020). Agriculture and gender roles in the semi-arid region of Ghana. *West African Journal of Applied Ecology*, *28*(1), 144–157.

Mittal, S., & Mehar, M. (2016). Socio-economic factors affecting adoption of modern information and communication technology by farmers in India: Analysis using multivariate probit model. *The Journal of Agricultural Education and Extension*, *22*(2), 199–212. https://doi.org/10.1080/1389224X.2014.997255

Mutambara, J. (2015). Maize marketing and pricing in Zimbabwe. USAID. Available online at: https://pdf.usaid.gov/pdf_docs/PA00M75W.pdf. [Accessed on 18 February 2023].

Mutyambai, D. M., Niassy, S., Calatayud, P. A., & Subramanian, S. (2022). Agronomic factors influencing fall armyworm (*Spodoptera frugiperda*) infestation and damage and its co-occurrence with stemborers in maize cropping systems in Kenya. *Insects*, *13*(3), 266. https://doi.org/10.3390/insects13030266

Patil, B., & Babus, V. S. (2018). Role of women in agriculture. *International Journal of Applied Research*, *4*(12), 109–114.

Phambala, K., Tembo, Y., Kasambala, T., Kabambe, V. H., Stevenson, P. C., & Belmain, S. R. (2020). Bioactivity of common pesticidal plants on fall armyworm larvae (*Spodoptera frugiperda*). *Plants*, *9*(1), 112. https://doi.org/10.3390/plants9010112

Prasanna, B. M., Huesing, J. E., Eddy, R., & Peschke, V. M. (2018). *Fall armyworm in Africa: A guide for integrated pest management*. 1st ed. CIMMYT. https://repository.cimmyt.org/server/api/core/bitstreams/5f933e59-ad3a-4643-a91e-377f9d913370/content

Rwomushana, I., Bateman, M., Beale, T., Beseh, P., Cameron, K., Chiluba, M., Clottey, V., Davis, T., Day, R., Early, R., Godwin, J., Gonzalez-Moreno, P., Kansiime, M., Kenis, M., Makale, F., Mugambi, I., Murphy, S., Nunda, W., Phiri, N., Pratt, C., & Tambo, J. (2018). Fall armyworm: Impacts and implications for Africa Evidence Note Update. 2018. CAB International. https://www.invasive-species.org/wp-content/uploads/sites/2/2019/02/FAW-Evidence-Note-October-2018.pdf

Shiferaw, B., Kassie, M., Jaleta, M., & Yirga, C. (2014). Adoption of improved wheat varieties and impacts on household food security in Ethiopia. *Food Policy*, *44*, 272–284. https://doi.org/10.1016/j.foodpol.2013.09.012

Tambo, J. A., Kansiime, M. K., Mugambi, I., Rwomushana, I., Kenis, M., Day, R. K., & Lamontagne-Godwin, J. (2020a). Understanding smallholders' responses to fall armyworm (*Spodoptera frugiperda*) invasion: Evidence from five African countries. *The Science of the Total Environment*, *740*, 140015. https://doi.org/10.1016/j.scitotenv.2020.140015

Tambo, J. A., Day, R. K., Lamontagne-Godwin, J., Silvestri, S., Beseh, P. K., Oppong-Mensah, B., Phiri, N. A., & Matimelo, M. (2020b). Tackling fall armyworm (*Spodoptera frugiperda*) outbreak in Africa: An analysis of farmers' control actions. *International Journal of Pest Management*, *66*(4), 298–310. https://doi.org/10.1080/09670874.2019.1646942

Tambo, J. A., Aliamo, C., Davis, T., Mugambi, I., Romney, D., Onyango, D. O., Kansiime, M., Alokit, C., & Byantwale, S. T. (2019). The impact of ICT-enabled extension campaign on farmers' knowledge and management of fall armyworm in Uganda. *PloS One*, *14*(8), e0220844. https://doi.org/10.1371/journal.pone.0220844

Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of Agricultural Economics*, *64*(3), 597–623. https://doi.org/10.1111/1477-9552.12011

Van der Meulen Rodgers, Y., Nipun Tanjeem, N., & Menon, N. (2024). The agricultural sector and women's work in Asia. In *Spatial Spillovers: Viewpoints from Asia*. (pp. 89–115). Springer Nature Singapore.

ZimStat. (2022). (2022). from *2022 Population and Housing Census Preliminary Report on Population Figures*. Harare: Central Statistical Office. Retrieved September 12, https://www.zimstat.co.zw