Assessment of factors influencing farmers' perceptions of desert locust control strategies in Kenya

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Abstract

The destructive nature of desert locust invasion in terms of reduced food security and loss of agricultural incomes necessitates effective control strategies. While there exist both formal and indigenous control methods, effective control requires the combined efforts of all stakeholders. The adoption of integrated control depends on farmers' perceptions and acceptance of key control aspects. However, it remains unclear as to which factors influence farmers' perceptions of desert locust control. This study assessed the effects of socio-economic and institutional factors on farmers' perception of desert locust control. The study applied principal component analysis (PCA) to develop perception indices that were subsequently used in multiple regression analysis of data collected from a sample of 391 farmers in Isiolo and Meru Counties in Kenya. Descriptive results indicated that formal control (spraying) was effective though negatively affected both human and livestock health while indigenous control methods were effective only to a certain extent. The regression analysis results showed that years of formal schooling, group membership, access to extension services, awareness of desert locust information, land tenure ownership, number of shocks experienced, tarmac road distance, and location had significant effects on farmers' perceptions of desert locust control. The study recommends targeted training of pest management staff at the county level to improve early warning and institute mitigation measures to limit agricultural losses. The national and county governments should invest in infrastructural development and involve farmers as key stakeholders as these measures would improve farmers' participation in desert locust control programs.

Keywords: Desert locust control, Kenya, perceptions, principal component analysis.

1. Introduction

Pest management in agricultural production is important as it helps reduce both crop and livestock-related losses. While native pests cause significant crop losses, the emergence of invasive pests calls for the need to develop sustainable pest control methods (Ratto *et al* 2022). According to Eschen *et al*. (2021), the production losses and control costs related to invasive pests are estimated at USD 65.58 billion. One of the most destructive invasive migratory pests in East Africa is the desert locust (*Schistocerca gregaria*). A swarm covering one square kilometre consisting of approximately 80 million adult desert locusts consumes the same amount of food taken by 35,000 people in a day (FAO 2020a). The desert locust invasion between 2019 and 2020 in Ethiopia, Somalia and Kenya increased the vulnerability of nearly 12 million people who were already experiencing acute food insecurity due to severe drought (FAO 2020b). According to FAO (2020c), over 350,000 metric tonnes of cereal were lost following the desert locust invasion in Ethiopia. In Kenya, the desert locust invasion resulted in losses of approximately 31,000 hectares of cropland and 580,000 hectares of pastureland (FAO 2020d). The World Bank (2020) noted that desert locust invasion-related losses and damages amounted to about USD 8.5 billion in the East Africa region and Yemen. These findings highlight the threat posed by desert locust invasions to food security and agricultural incomes.

Following the desert locust invasion in Kenya between 2019 and 2020, the government through the Ministry of Agriculture, Livestock and Fisheries (MoALF) together with other partners including FAO and the Desert Locust Control Organization for Eastern Africa (DLCO-EA) carried out surveillance, aerial and ground spraying of affected areas (MoALF 2020). The control process faced a myriad of challenges including limited funding, lack of chemicals and limited trained personnel. These challenges coupled with the rapid spread of desert locust swarms affected vast areas of crops and pasture thus, affecting food security and incomes for farmers. Farmers applied different indigenous methods to help avert further losses. These methods included physically chasing the locusts with twigs/leaves, making noises, lighting fires, trampling and use of pesticides (FAO 2020d).

The use of chemical pesticides in controlling desert locusts is associated with environmental damage through contamination of vegetation, water, soil, and non-target species, and harmful effects on human and animal health (Githae & Kuria 2021; Pandey *et al.* 2021). These concerns have led to calls to adopt alternative control methods. Specifically, researchers and environmentalists have proposed increased use of biological control methods, particularly the use of bio-pesticides, predatory insects and use of plant extracts as alternatives to chemical pesticides (Pandey *et al.* 2021). Following the potential success of integrated pest management (IPM) in the control of other migratory pests, Githae & Kuria (2021) noted that the development of integrated desert locust management (IDLM) strategies to control desert locusts would help limit the negative impacts of chemical use on households and the environment.

The success of policy interventions, in this case, IDLM, requires the inclusion of farmers. It is often assumed that farmers purely make decisions from an economic perspective. However, besides economic literature, the inclusion of socio-psychological constructs can help

understand behaviour that influences farmers' perceptions thus aiding towards implementation of effective policy measures. Following Okello *et al.* (2021), this study defines perception as the cognitive interpretation and understanding of desert locust invasion and control. Several studies have taken this into account and examined farmers' perceptions of pest control methods (see, for instance, Ali *et al.* 2020; Khumalo *et al.* 2020). For example, Ali *et al.* (2020) observed that knowledge of the effects of pesticides influences positive perceptions concerning the use of pesticide-protective equipment. Musungu *et al.* (2021) examined farmers' perceptions on whether pest control methods are complementary or substitutes; but the study was limited to tsetse control in the coastal region of Kenya.

To date, there is limited empirical research on farmers' perceptions of desert locust control. Emana (2002) reported that households held positive perceptions about the effectiveness of chemical spraying of desert locusts and negative perceptions concerning the timeliness of spraying. Unlike Emana (2002), the current study aims to contribute to the emerging body of literature on IPM by including indigenous control methods and assessing factors influencing farmers' perceptions of desert locust control. The findings from this study can be used to inform policies and interventions aimed at promoting environmentally sustainable ways of managing desert locust invasion, thus, helping in reducing food insecurity and income losses. Moreover, the findings of the study will help strengthen the existing Emergency Locust Response Program (MoALF 2022) with a special focus on greater stakeholder involvement in desert locust control.

This paper specifically addresses the theme of the 7th African Conference of Agricultural Economists of *building resilient agri-food systems* through provision of critical insights for enhanced desert locust control.

2. Methodology

2.1 Empirical framework

This study applies multiple linear regression to assess the factors influencing farmers' perception of desert locust control in Kenya. The dependent variables of the regression are the perception indices derived from Principal Component Analysis (PCA) while the independent variables are a set of socio-economic and institutional characteristics. The ordinary least squares (OLS) is used since the dependent variable (perception indices) is continuous (Greene 2003). Before estimating the OLS model, diagnostic tests were carried out to ascertain the appropriateness of the model. Variance inflation factor (VIF) analysis and the Breusch-pagan test were used to test for the presence of multicollinearity and heteroscedasticity, respectively (Misango *et al.* 2022).

The study estimated five multiple regression equations. The dependent variables of the five equations are perception indices derived from the PCA method. The indices comprise four individual indices derived from the factor scores of four perception components and a composite index of the individual components. Following Distefano *et al.* (2009), the composite index was generated using the weighted sum scores criterion (Okello *et al.* 2021), and contextualized in the study as follows:

$$P_m = \sum_{m=1}^{n} c_n \ (d_{mn} - d_n)/s_n \quad (1)$$

where P_m is the perception index for the *m*th farmer, c_n is the weight or factor loading of the *n*th perception statement, d_{mn} is the response of the *m*th farmer for the *n*th perception statement, d_n and s_n are the mean and standard deviation of the *n*th perception statement, respectively. The multiple regression model was specified as:

$$P_m = \beta_0 + \beta_1 X_i + \beta_2 X_j + \ldots \beta_k X_k + \mu \quad (2)$$

where P_m is the *mth* factor score, X_i,….. X_k are explanatory variables, β_0 is the intercept term, $\beta_1 \ldots \beta_k$ are coefficients, and μ is the error term or disturbance. The explanatory variables are informed by previous pest management studies (Stallman & James Jr 2015; Abtew *et al.* 2016; Allahyari *et al.* 2017; Khumalo *et al.* 2020; Weyori 2021; Misango *et al.* 2022). These variables include age, education, group membership, farming experience, land acreage, tropical livestock units (TLU), tarmac distance and mobile phone ownership. Considering desert locusts consume vegetation and crop cover of a large area, the study goes beyond previous studies to explore the effect of land tenure ownership and the number of shocks experienced on farmers' perceptions of desert locust control.

2.2 Data sources and sampling procedure

This study was carried out in two counties that were affected by desert locust invasions between 2019 and 2020 (FAO 2020d; MoALF 2020). Isiolo County is mainly an arid zone where pastoralism is the main source of livelihood (County government of Isiolo 2018). Meru County is characterized by upper highlands to lower midlands; livelihood practices include mixed crop-livestock and pure crop farming (County government of Meru 2018). Initially, focus group discussions were carried out to gain a better understanding of farmers' views concerning the desert locust invasion and control measures implemented. The insights were used to develop perception statements and adjust the survey tool. Thereafter, a multistage sampling technique was used to identify households for the survey. In the first stage, two counties (Isiolo and Meru) affected by desert locusts were purposively selected. In the second stage, Garbatulla and North Imenti sub-counties were selected from Isiolo and Meru counties, respectively. In the third stage, simple random sampling was used to select households from Kinna North (Garbatulla) and Nyaki East (Imenti North) wards. The sample size was determined following Cochran (1977) as shown below:

$$n = \frac{t^2 * (p)(q)}{d^2} \quad (3)$$

where n is the sample size, *t* is the desired confidence level (1.96), *(p)(q)* is the estimated proportion of the population that has the attribute in question/estimation of variance (0.5) and *d* is the margin of error (.05).

$$n = \frac{1.96^2 * (0.5)(1-0.5)}{0.05^2} = 384 \quad (4)$$

In order to account for incomplete questionnaires and non-response, the sample size was increased slightly to 400, that is 200 for each county. The sample size is close to the those used in previous pest management studies, for instance, Weyori (2021) and Muriithi *et al*. (2020), who used a sample of 482 and 371 households, respectively. A semi-structured questionnaire

consisting of perception statements, and socio-economic and institutional characteristics were used to collect data. The questionnaires were administered by trained enumerators through face-to-face interviews in May 2022. After data entry and cleaning, 9 questionnaires were dropped from the analysis due to incomplete data, leaving 391 questionnaires. Data were analysed using Excel, SPSS version 26, and Stata version 14.

3. Results and discussions

3.1 Socio-economic characteristics of households

Table 1 presents the socio-economic characteristics of sampled households in Isiolo and Meru Counties. From the pooled sample, over two-thirds of the respondents were male; with a higher proportion in Isiolo compared to Meru. This shows that more males mainly participate in studies related to pest management; though it is slightly lower compared to the 85% reported by Tambo *et al.* (2019). Group membership was higher in Meru compared to Isiolo. This could be attributed to the vibrancy of farmer groups in the marketing of agricultural commodities in sedentary societies compared to nomadic systems. Access to extension services was low, though significantly higher in Meru (46%) compared to Isiolo (24%); the disparities can be attributed to marginalization of arid lands on infrastructure development and institutional support services delivery over decades (Sala *et al.* 2020). About half of the households had access to desert locust information; with a higher proportion in Meru compared to Isiolo. The finding compares well with the 48% reported in REACH (2020). Over two-thirds of the respondents owned a mobile phone, implying improved network access. More than half of the respondents in Meru own private land with title deeds. This compares well with the 65% ownership of title deeds reported in the Meru County Integrated Development Plan [CIDP] (County government of Meru 2018). The average age of respondents was 44 in the pooled sample; though higher in Meru compared to Isiolo. The finding implies that middle-aged farmers are mainly involved in agricultural production.

From the pooled sample, the majority of the respondents had primary education as the highest level of formal education; the average years of formal schooling was 8 years (Table 1). The average age of farming experience was 13 years; with a higher average in Meru compared to Isiolo. The finding implies that the majority of the households start farming in adulthood. This is consistent with Allahyari *et al.* (2017) who observed that farmers who participate in pest management surveys have at least ten years of farming experience. The average tropical livestock unit was 12, though higher in Isiolo, signifying the importance of the livestock sector (County government of Isiolo 2018). On average, households in Isiolo experienced 4 different shocks over the past five years. The major shocks noted were drought, livestock diseases, conflicts and the COVID-19 pandemic. Exposure to these shocks constrains agricultural production thus negatively affecting the livelihood systems of households (Sala *et al.* 2020). On average the distance to the nearest tarmacked road was 6km; with the distance being longer in Isiolo compared to Meru.

Table 1: Socio-economic and institutional characteristics of households

Characteristics	Isiolo (n=196)	Meru (n=195)	Pooled sample (n=391)	Significant difference
Gender of the respondent (% male)	84.7	64.1	74.4	0.000***
Group membership (% yes)	27.0	79.0	52.9	0.000***
Access to extension services (% yes)	23.5	46.1	34.8	0.000***
Awareness of desert locust information (% yes)	38.8	67.1	52.9	0.000***
Mobile phone ownership (% yes)	74.0	76.9	75.4	0.499
Land tenure system (% of respondents)				
Private with title deeds	15.3	58.5	36.8	0.000***
Private with allotment letters	41.3	36.4	38.9	
Communal	43.3	5.1	24.3	
Age (years)	41(13.2)	48(13.1)	44(13.6)	0.000***
Years of formal schooling	7 (5.5)	9 (2.9)	8 (4.5)	0.000***
Farming experience (years)	12 (9.0)	15 (7.3)	13 (8.3)	0.001**
Tropical livestock units (TLUs)	21 (31.1)	2 (2.0)	12 (24.1)	0.000***
Shocks experienced (number)	4 (1.5)	3 (1.1)	4 (2.0)	0.000***
Distance to the nearest tarmac road (kilometres)	7 (4.9)	5 (3.2)	6 (4.2)	0.000***

Note: *** and ** denote statistically significant differences at 1% and 5%, respectively.
Source: Survey Data (2022).

3.2 Farmers' perceptions of desert locust control methods

Figure 1 shows farmers' perceptions of the formal control methods implemented by the government and other agencies. About a third of households in Isiolo and Meru counties observed that formal control methods were very effective, while nearly a quarter of farmers in both counties noted that the formal control methods were effective. This is in line with a report by FAO (2020d) which noted that spraying was the most effective control method. About 40% of households in Isiolo and 20% in Meru reported that chemical spraying affected livestock health. This could be explained by the observation that livestock are grazed on sprayed areas. More households in Meru (16%) compared to Isiolo (3%) developed health complications following the spraying of desert locusts. This is slightly lower compared to the 23% reported in FAO (2020d). Households also reported that spraying had affected other animals, mainly bees. This finding conforms with Githae & Kuria (2021) who observed that the use of pesticides reduces desert locust numbers but also harms other non-target organisms.

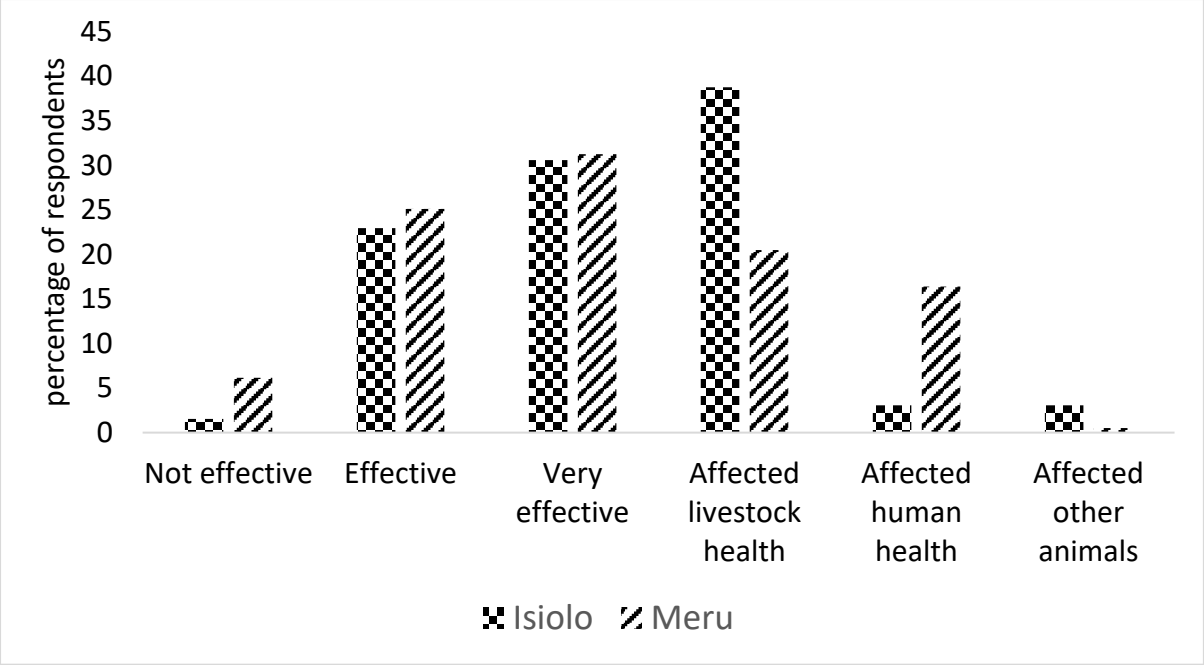

Figure 1: Perceptions on formal control measures
Source: Survey Data (2022).

Table 2 describes the indigenous control methods applied and perceptions of their effectiveness. Physically chasing locusts using twigs combined with making noises was the main method used by 84% of households; with the percentage being higher in Isiolo compared to Meru. Significantly more households in Meru used fire, burying with soil, and trampling of locusts compared to Isiolo in controlling desert locusts. Pandey *et al.* (2021) also reported that farmers used indigenous control methods to limit the effects of a desert locust invasion. A higher proportion of households in Isiolo avoided areas infested by desert locusts compared to Meru. The majority of the households in Isiolo being pastoralists encountered desert locusts, and thus had to search for other grazing areas.

From the pooled sample, less than a third of the households perceived indigenous control methods as being effective. This is consistent with Showler *et al.* (2022) that the application of indigenous control methods in desert locust control was ineffective in Pakistan. A higher proportion of households in Meru compared to Isiolo perceived burying with soil and trampling as being effective. Nearly a third of households in Isiolo perceived avoiding infested areas as an effective control method. Households in Isiolo moved in search of pasture that had not been invaded by desert locusts.

Table 2: Indigenous control methods and perceptions

Control methods	Isiolo (n=196)	Meru (n=195)	Pooled (n=391)	Statistically significant difference
Chasing/Making noises (% applied method)	90	78	84	0.001***
Effectiveness (1 = effective)	25	21	23	0.389
Use of fire/burning (% applied method)	48	65	56	0.001***
Effectiveness (1 = effective)	45	35	39	0.137
Burying with soil (% applied method)	14	29	21	0.000***
Effectiveness (1 = effective)	4	33	23	0.004**
Trampling/sweeping (% applied method)	15	40	28	0.000***
Effectiveness (1 = effective)	13	32	26	0.052*
Avoiding infested areas (% applied method)	30	11	21	0.000***
Effectiveness (1 = effective)	31	28	30	0.825
Spraying (% applied method)	11	14	13	0.434
Effectiveness (1 = effective)	15	26	21	0.373

Note: ***, ** and * denote statistically significant difference at 1%, 5% and 10%, respectively.
Source: Survey Data (2022).

3.3 Principal components of farmers' perceptions of desert locust control and associated loadings

Table 3 presents the results of the retained principal components and their associated loadings from each of the 15 perception statements. The Kaiser–Meyer–Olkin (KMO) test of sampling adequacy was 0.693 which falls within the recommended range of 0.5 to 1. Bartlett's test of sphericity was significant at the 1% level, indicating that items loading in each group had a significant relationship. Additionally, all Cronbach alpha values were greater than 0.6, indicating strong internal consistency (Taber 2018). The retained factors cumulatively explained 71% of the variation. The first component labelled "comprehensiveness" explained 22% of the cumulative variance. This component consisted of five items related to the role played by mandated agencies in desert locust control. These statements included: recovery assistance, timeliness of spraying, the effectiveness of spraying, information on not grazing on sprayed areas, and protection of households from possible side effects of spraying. The second component labelled "knowledge" accounted for 19% of the cumulative variation and recorded four statements with factor loadings above the 0.5 threshold. This component loaded statements explaining the threat of desert locusts, the effects on agricultural productivity, and information about the invasion and possible mitigation measures.

Three statements loaded on the third component labelled "acceptability", which explained 15% of the cumulative variation (Table 3). The statement on the use of indigenous control methods in desert locust control had the highest factor loading (0.919). Farmers agreed with the statements, "Majority of the community members were involved in desert locust management" and "Combining different control methods improve desert locust management". The adoption of IPM enhances desert locust control with limited negative effects on the environment and

livelihoods (Githae & Kuria 2021; Pandey *et al.* 2021). The fourth component labelled “ineffectiveness" loaded statements concerning the challenges of using indigenous and formal control methods, accounting for 15% of the cumulative variation. Households typically agreed that indigenous control methods were time-consuming and laborious. Additionally, households indicated that livestock health was affected following grazing in sprayed areas. This is plausible, as chemicals used in desert locust control have detrimental effects on livestock health (Githae & Kuria 2021).

Table 3: Loadings of perception statements after varimax rotation

Perception statements	Rotated components			
	Comprehensiveness	Knowledge	Acceptability	Ineffectiveness
Desert locust invasion/attack is a much more serious threat compared to other shocks		0.894		
Desert locust invasion/attack significantly reduced agricultural income		0.880		
Information concerning desert locust invasion was readily available		0.801		
I am better informed on how to respond to future desert locust invasions/attacks		0.752		
There was recovery assistance following the desert locust invasion	0.750			
Use of indigenous control methods helped reduce the effect of desert locust invasion/attack			0.919	
Majority of the community members were involved in desert locust control management			0.859	
Use of indigenous control methods requires more time than could be used for other activities				0.918
Use of indigenous control methods requires labour that may not be available				0.871
Spraying of desert locusts was carried out at the appropriate time	0.888			
Spraying was done at the right place targeting locusts	0.830			
During the spraying period, farmers were advised not to graze livestock in sprayed areas	0.779			
During spraying, care was taken to protect households from the chemicals	0.771			
Livestock fell sick or developed complications after feeding on areas that were sprayed				0.797
Combining different control methods improves desert locust management			0.831	
Eigenvalues	3.269	2.804	2.300	2.276
Variance explained (%)	21.79	18.69	15.34	15.17
Cumulative variance explained (%)	21.79	40.48	55.820	70.990
Cronbach's alpha	0.863	0.841	0.842	0.828

Notes: Cronbach's alpha = 0.718; Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy = 0.693; Bartlett's test of sphericity: Chi-square (df) = 2974.57 (105).
Source: Survey Data (2022).

3.4 Factors influencing farmers' perceptions of desert locust control

This section describes the socio-economic and institutional factors influencing farmers' perception of desert locust control. Initially, model diagnostics were carried out to ascertain the absence of correlation among factor scores and to justify the use of individual linear regressions (Table 4). Table 4 shows the rejection of the null hypothesis of the presence of correlation, thus, justifying the analysis of five individual regressions. The mean VIF score was 1.41, implying no multicollinearity among explanatory variables (Gujarati & Porter 2009). The Breusch-pagan test fails to reject the null hypothesis of homoscedasticity (Chi2 (1) = 0.13 Prob>Chi2 = 0.722) suggesting no heteroscedasticity. The adjusted R-squared, which measures the goodness of fit, was low (6% to 18%). According to Greene (2003), it is not unusual to observe low values for the goodness of fitness in analysis involving cross-sectional data and behavioural studies.

Table 4: Model diagnostics of the MANOVA for multiple linear regression

Model diagnostic		**Statistic**		***F*-value**
Wilks' lambda		0.788***		5.95
Pillai's trace		0.222***		5.67
Lawley-Hotelling trace		0.258***		6.14
Roy's largest root		0.202***		19.52
Observations		391		
Residual		386		
*** denotes statistical significance at the 1% level.				

Source: Survey Data (2022).

Table 5 presents the results of the factors influencing farmers' perceptions of different components of desert locust control. Farmers who had access to extension services and were aware of desert locust information were more likely to perceive that desert locust control was comprehensive. This implies that farmers held favourable perceptions about the role played by the government and other agencies in desert locust control and offering post-recovery assistance (food assistance, cash transfers, crop and pasture seeds). Extension services are a critical source of information in terms of creating awareness about pest management. Group membership had a negative and significant effect on the first principal component of comprehensiveness. This was unexpected, as social networks are a key avenue for accessing information and thus improve perceptions (Mbugua & Nzuma 2020). However, the finding contradicts Stallman & James Jr (2015) who noted that membership in a group enhances positive perceptions about pest management. The negative effect of group membership might be explained by lack of focus of the existing groups on issues specific to desert locust control.

Awareness of desert locust information positively and significantly influenced farmers' perceptions of the second principal component of knowledge. Farmers who were aware were likely to be more knowledgeable about desert locust management. This finding is in line with Allahyari *et al.* (2017) who observed that awareness improves farmers' knowledge about

integrated fruit fly management. Farmers owning private were likely to perceive the knowledge component as a crucial aspect in desert locust management. This is possible because access to private land incentivizes farmers to engage in agricultural production and control of any negative aspects such as desert locust invasion (Pitoro 2017). Thus, farmers held favourable perceptions about statements relating to the threat posed by desert locust invasion and preparedness for future invasions. This is in line with Sala *et al.* (2020) who noted that secure land ownership enables one to derive benefits, such as agricultural income. An individual owning private land would institute measures to limit any externalities that reduce agricultural income. The number of shocks experienced positively influenced farmers' perceptions of the knowledge component. The exposure to shocks over time means that farmers experience huge losses, and with the desert locust shock, thus, farmers are highly likely to perceive information on control as being very important. Also, lengthened exposure to shocks pushes individuals to invest in resilience building measures to avert future losses; following the old age adage that necessity is the mother of invention.

Contrary to expectations, group membership and mobile phone ownership indicated a negative and significant effect on the second principal component of knowledge. Members in groups held negative perceptions about statements concerning the threat posed by desert locusts and resulting agricultural income losses. A plausible reason is that group members were able to assist each other through various shocks, in this case, desert locust invasion. Mobile phone ownership reduced the likelihood of farmers having positive perceptions about the knowledge component. A plausible reason is that information on desert locust control was received from other sources such as community members. This corroborates the finding of a report by REACH (2020) which observed that the main sources of information on desert locusts were community members, radio/television and family members.

Access to extension services and location positively influenced farmers' perceptions of the third component of acceptability. Based on the statement loadings, farmers perceived that combining desert locust control methods were acceptable. The finding is consistent with Weyori (2021) who observed that providing information on the adverse effects of pest invasion improves the intention to adopt integrated pest management. Farmers located in Meru compared to those in Isiolo were more likely to accept and use desert locust control methods. A possible explanation is that crop farmers were likely to combine efforts towards using various control methods to avert losses related to desert locust invasion. Distance to the nearest tarmac had a negative effect on the component of acceptability. A plausible reason for this finding is that inaccessibility to infested areas limits control interventions by control organisations. Consistent with Showler (2019), poor infrastructural development impedes desert locust control efforts.

Table 5: Factors influencing farmers' perceptions of desert locust control

Explanatory variables	Regression parameter estimates				
	Composite index (pooled sample)	**Comprehensiveness**	**Knowledge**	**Acceptability**	**Ineffectiveness**
Age (years)	-0.028 (0.025)	-0.005 (0.005)	0.006 (0.005)	-0.005 (0.005)	-0.008 (0.005)
Years of formal schooling	-0.11 (0.064) *	0.007 (0.012)	-0.02 (0.012)	-0.015 (0.012)	-0.017 (0.012)
Group membership (1 = yes; 0 = no)	-1.604 (0.606) ***	-0.403 (0.116) ***	-0.225 (0.118) *	0.035 (0.114)	0.074 (0.117)
Farming experience (years)	0.001 (0.038)	0.000 (0.007)	-0.004 (0.007)	0.003 (0.007)	0.004 (0.007)
Tropical livestock units (TLUs)	-0.008 (0.012)	-0.001 (0.002)	-0.001 (0.002)	-0.001 (0.002)	0.001 (0.002)
Access to extension services (1 = yes; 0 = no)	2.092 (0.586) ***	0.419 (0.112) ***	0.064 (0.114)	0.327 (0.110) ***	-0.024 (0.113)
Awareness of desert locust information (1 = yes; 0 = no)	1.532 (0.574) ***	0.287 (0.109) ***	0.263 (0.112) **	-0.198 (0.108) *	0.157 (0.111)
Mobile phone ownership (1 = yes: 0 = no)	-0.434 (0.611)	0.143 (0.117)	-0.257 (0.119) **	0.005 (0.115)	-0.050 (0.118)
Land tenure system (1 = private; 0 = communal)	2.937 (0.683) ***	0.148 (0.130)	0.325 (0.133) **	0.189 (0.128)	0.447 (0.132) ***
Shocks experienced (in the last 5 years)	0.497 (0.197) **	0.025 (0.038)	0.085 (0.038) **	0.030 (0.037)	0.023 (0.038)
Distance to the tarmac road (kilometres)	-0.118 (0.063) *	-0.012 (0.012)	-0.004 (0.012)	-0.026 (0.012) **	0.002 (0.012)
Location (1 = Meru; 0 = Isiolo)	1.509 (0.777) *	-0.127 (0.148)	-0.165 (0.151)	0.560 (0.146) ***	0.328 (0.150) **
Constant	-2.216 (1.54)	-0.087 (0.294)	-0.340 (0.300)	-0.067 (0.289)	-0.242 (0.298)
Number of observations	391				
F-test	0.000	0.000	0.000	0.000	0.000
R-squared	0.181	0.115	0.086	0.144	0.097
Adjusted R-squared	0.155	0.087	0.057	0.117	0.068
Mean-variance inflation factor (VIF)	1.41				
Breusch-pagan test	Chi2 (1) = 0.13 Prob>Chi2 = 0.722				

Note: ***, **, and * denote statistically significant differences at 1%, 5%, and 10%, respectively. Standard errors are in parentheses.

Source: Survey Data (2022).

Land tenure system and location positively and significantly influenced farmers' perceptions of the fourth principal component of ineffectiveness. Farmers who owned private land were more likely to perceive desert locust control as ineffective compared to those on communal land. A plausible reason is that desert locusts invaded crops on private land and farmers had to implement various control measures. However, farmers found these methods to be time-consuming and laborious. This corroborates the finding by Showler *et al.* (2022), which showed that indigenous control methods are ineffective in controlling large desert locust populations. Furthermore, the chemical residue on pasture affected livestock health leading to reduced productivity. As noted by Githae & Kuria (2021), while chemical pesticides are effective, spray residues are detrimental to environmental safety, and human and livestock health. Farmers in Meru were more likely to perceive desert locust control methods as ineffective compared to those in Isiolo. The possible explanation for this is that slightly more farmers in Meru compared to Isiolo applied different desert locust control methods, the majority of whom acknowledged that these methods were ineffective in protecting crops and pasture.

Finally, from the composite index (pooled sample), access to extension services, awareness of desert locust information, the land tenure system, number of shocks experienced, and location positively influenced farmers' perceptions of desert locust control. Conversely, years of formal schooling, group membership, and distance to the nearest tarmacked road negatively influenced farmers' perception of desert locust control.

4. Conclusion

This study assessed the factors influencing farmers' perception of desert locust control in Kenya. Generally, the findings of the study showed that farmers in Meru had better access to institutional support services such as extension, desert locust information, groups, secure land tenure and road network compared to farmers in Isiolo. The majority of the farmers perceived that formal control; mainly chemical spraying was very effective in reducing desert locust invasion. However, they had concerns, particularly about the detrimental effects on human and livestock health. This was confirmed by the lower ranking of statements related to chemical spraying. The rational use of effective but less harmful chemicals in future interventions would help alleviate negative impacts on the environment and health.

The study used PCA analysis to generate four indices and a composite index. The four indices resulting from factor loading were labelled as comprehensiveness, knowledge, acceptability, and ineffectiveness. Access to extension services and awareness of desert locust information positively influenced farmers' perceptions of desert locust control, however, access remains low. There is a need to train extension officers involved in pest management at the county level on aspects like surveillance and appropriate control measures. Extension officers should also be trained on communicating early warning information through channels like face-to-face interactions, radio, and short message services (SMS) on mobile phones. This information covering early warning and possible mitigation measures should be simple to understand and comprehend to enable farmers to take necessary actions. Such interventions would help improve perceptions leading to greater participation of farmers in desert locust control programs.

The findings also revealed the importance of private tenure systems in enhancing positive perceptions about desert locust control. This suggests the need for county governments to expedite formal land registration processes to improve the productive use of land. This will enhance farmers' adoption of effective desert locust control methods. While indigenous control methods are effective only to a certain extent, formal control methods, mainly spraying have negative effects on the environment and health. The development of an integrated desert locust management (IDLM) strategy that combines the rational use of chemicals, biological methods, and indigenous control methods would be effective against desert locusts. The national government through pest management agencies, non-governmental organizations, and county agricultural departments should collaborate to develop an IDLM strategy that combines surveillance, analysis of the cost, effectiveness, and efficiency of both chemical and biological control options, and implementation of approved methods coupled with robust monitoring systems. Farmers should also be involved as key stakeholders as this will enhance positive perceptions, thus, greater involvement in desert locust control programs.

However, group membership was associated with negative perceptions concerning desert locust control. Future desert locust control programs should target individual farmers who are not involved in groups and are likely to be vulnerable to reduced food security and loss of agricultural incomes following desert locust invasions. Such programs should focus on implementing effective control measures and post-invasion recovery assistance. Post-recovery assistance can be in the form of unconditional cash assistance, distribution of relief food, farm crop seeds, pasture, and livestock feeds as well as veterinary services. Farmer groups in areas prone to desert locust invasion should also be sensitized to prioritize the search for information on desert locust control methods as one of their main agenda. Lastly, distance to the tarmac road reduced the likelihood of farmers having favourable perceptions towards desert locust control. National and county governments should coordinate infrastructural development programs, especially in the interior less accessible regions as this will enable swift response to desert locust invasion in terms of surveillance and control. In the short to medium term periods, improved access to affordable non-motorized means of transport that can be used in areas with rugged terrain should be prioritized by the county governments and development partners in the desert locust prone areas.

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Conflict of interest declaration

None.

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