Lack of crucial information exacerbates barriers to mitigating human–elephant conflicts in rural Kenya

Lynn Von Hagen*[1], Bruce A. Schulte[2], Todd D. Steury[1], Kelly Dunning[1,3], Mwangi Githiru[4], Sarah Zohdy[1] and Christopher A. Lepczyk[1]

Abstract Crop foraging by African savannah elephants *Loxodonta africana* negatively affects farmer livelihoods and support for conservation, yet affordable, sustainable and practical solutions remain elusive. To inform conservation priorities, our goal was to assess the hitherto little explored relationships between farmers' views on agricultural damage and the socio-economic factors limiting their use of elephant deterrents. We tested our hypotheses associated with the demographic categories of age, education level, years spent farming, gender, exposure to information on deterrent methods, farm size, village and relevant combinations of these factors by surveying 206 respondents across six villages in rural Kenya and analysing the resulting data using an information theoretic approach. Respondents were almost four times more likely to use deterrents if exposed to the relevant information, and almost five times more likely to do so if they had secondary education as opposed to none. Farmers with a higher level of education were five times more likely to have received information on deterrents compared to those with no formal education. Participants who had not received information on deterrents were almost three times more likely to believe that they could implement deterrent methods. Respondents who stated that they could not implement deterrents overwhelmingly cited a lack of financial resources as the reason. Overall, we found that crucial information on reducing elephant crop foraging is not reaching the relevant stakeholders, and socio-economic factors such as education and exposure to information appear to limit uptake of protective measures. These insights are important for developing mitigation strategies and supporting the livelihoods of people affected by negative human–elephant interactions, and thus for effective elephant conservation. Our findings also have broader applications for practitioners seeking to understand barriers stakeholders face in their efforts to mitigate negative interactions with wildlife.

*Corresponding author, lvonhagen@comcast.net
[1]College of Forestry, Wildlife and Environment, Auburn University, Auburn, Alabama, USA
[2]Western Kentucky University, Bowling Green, Kentucky, USA
[3]Current address: Haub School of Environment and Natural Resources, University of Wyoming, Laramie, Wyoming, USA
[4]Wildlife Works, Nairobi, Kenya

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Introduction

Interactions between people and wildlife are increasing globally as a result of continued habitat loss and conversion of natural areas to agriculture (Young et al., 2010; Redpath et al., 2015; König et al., 2020), leading to competition between wildlife and people over resources, including habitable space (Madden, 2004; Seoraj-Pillai & Pillay, 2017). Negative interactions or conflicts are particularly frequent in regions where rural communities live near protected areas or important wildlife features such as movement corridors (Western et al., 2015; Mc Guinness, 2016; Pozo et al., 2020). One of the most common types of negative interaction involves agricultural damage (Hill, 2000; Naughton-Treves & Treves, 2005; McKee et al., 2021), whereby wildlife enters cultivated lands and consumes or damages crops as part of modified foraging strategies (Owen-Smith et al., 2010). Often termed crop raiding or crop foraging, this behaviour has been observed in a wide range of species (Krijger et al., 2017; Seoraj-Pillai & Pillay, 2017; Gross et al., 2018; Hill, 2018). However, in areas where wild elephants range, they are generally perceived as the primary cause of crop damage (Sukumar, 1990; Osborn, 2004; Mackenzie & Ahabyona, 2012).

The negative impacts of elephants and other wildlife can threaten the food security of affected communities and weaken support for conservation (Raphela & Pillay, 2021; Salerno et al., 2021). Crop foraging incidents not only result in loss of livelihood for farmers but also affect human health and well-being as farmers may experience lost opportunity costs, fear and stress whilst protecting their farms (Barua et al., 2013). Negative human–elephant interactions are also a threat to conservation as some farmers retaliate against wildlife perceived as pests (Distefano, 2005; Treves et al., 2009; Davies et al., 2011). Farmers repeatedly experiencing crop foraging may become frustrated with wildlife authorities if they feel that the importance of their livelihoods is not being considered, potentially reducing their tolerance for coexisting with wildlife (Naughton-Treves & Treves, 2005; Kansky & Knight, 2014).

Traditional methods to deter elephants include patrolling, guarding (Killion et al., 2020), lighting fires, erecting fences constructed from locally available materials (Kassilly et al., 2008; Osipova et al., 2018) and using devices to scare elephants (Gilsdorf et al., 2002). However, these often achieve only limited success as elephants can habituate to sounds or the presence of humans, and learn to overcome fences (Hoare, 2012; Mumby & Plotnik, 2018; Gross, 2019). Information on deterrent methods is often provided by NGOs or wildlife agencies, which usually operate with limited funding and resources (Folke et al., 2005; Noga et al., 2016; Galvin et al., 2018). Additionally, such traditional approaches often require human presence to deter elephants, which can be dangerous for farmers.

Modern deterrents can be more difficult to implement because the required materials are often not available locally and/or are expensive to purchase (Vogel et al., 2022). However, methods using electric fencing, chili (Parker & Osborn, 2006; Hedges & Gunaryadi, 2010; Chang'a et al., 2016), beehives (King, 2010), solar lights (Adams et al., 2020) and metal fencing (Von Hagen et al., 2021) may achieve greater efficacy as they involve recurring negative stimuli. Furthermore, such methods require no human presence when elephants are present, making them safer and freeing up farmers to fulfil their other duties. Successful designs for deterrents consider elephant physiology, behaviour and cognition (Mumby & Plotnik, 2018), and the socio-economic limitations of farmers, to create mitigation techniques that are also resistant to elephant habituation (Naughton-Treves & Treves, 2005; Dickman, 2010; Schulte, 2016).

The attitudes and behaviours of farmers towards elephants, conservation initiatives and the uptake and use of elephant deterrents have been examined in several regions in Africa (Graham & Ochieng, 2008; Noga et al., 2015; Vogel et al., 2022). However, the socio-economic factors that determine whether or not farmers decide to implement deterrents have not been fully explored. Ageing tends to make people more risk averse (Okun & Siegler, 1976; Dohmen et al., 2011), yet decision-making is often affected by local culture and can be highly variable (Rieger & Mata, 2015). Thus, older farmers may be hesitant to try new techniques or crop types but have often accumulated significant local knowledge of elephant movements and behaviours (Buchholtz et al., 2020). Education levels are highly variable amongst rural farmers (Noga et al., 2015), and higher education levels can positively affect farmer productivity and the adoption of new farming techniques (Oduro-Ofori, 2014). Understanding the factors that affect farming decisions is important to improve elephant conservation and management efforts, and provide benefits to farmers.

Given the gaps in knowledge about farmer decision-making regarding deterrent implementation, the threats to livelihoods of rural farmers in Kenya and the need to conserve threatened African elephants, our goal was to examine the relationships between socio-economic factors and crop damage by elephants. We developed three a priori hypotheses: Firstly, we hypothesized that age, education, exposure to information on deterrents and farm size would be positively associated with deterrent usage by farmers and that most would use traditional methods (deterrent-use hypothesis). Secondly, we hypothesized that most rural farming households had not been exposed to information on mitigating the impacts of crop foraging but that, amongst those who had, education would be positively correlated with receipt of any such information, particularly on fencing (deterrent-exposure hypothesis). Thirdly, we hypothesized that most farmers who believed that they could not implement deterrents (even if they had the relevant knowledge) would be constrained by limited economic resources and that only education level would be positively correlated with farmers who believed that they could implement deterrents (economic-barriers hypothesis). The evaluation of these hypotheses will inform conservation planning strategies for agencies aiming to improve food security for farmers whilst conserving elephants.

Study area

The Kasigau Wildlife Corridor lies between Tsavo East and West National Parks in south-eastern Kenya (Fig. 1) and forms part of the Greater Tsavo Ecosystem. African savannah elephants *Loxodonta africana* are frequent crop foragers in this area, as are other herbivores such as the eland *Tragelaphus oryx*, and they are a source of conflict between community members and wildlife officials (Litoroh et al., 2012; Githiru et al., 2017). The region is home to the largest elephant population in Kenya, consisting of c. 15,000 individuals (Waweru et al., 2021), and many elephants use the Corridor to move between the two national parks (Omondi et al., 2008; Ngene et al., 2017). Rukinga Wildlife Sanctuary (Rukinga) is one of the community ranches in the Corridor and is operated by Wildlife Works. Villagers in these areas are mostly subsistence farmers, and their income is c. KSH 1,500 (USD 15) per person per month. In years with lower crop yields 39% of the population drops below this income level. The area is characterized by a biannual rainfall pattern of rainy and dry seasons, and has been suffering from ongoing periods of drought (Kasaine & Githiru, 2016).

We selected villages surrounding the Sanctuary to test our hypotheses, focusing on those that shared a boundary with the Sanctuary (where interactions occur often), were within 1 h drive of the centralized base in Rukinga (for

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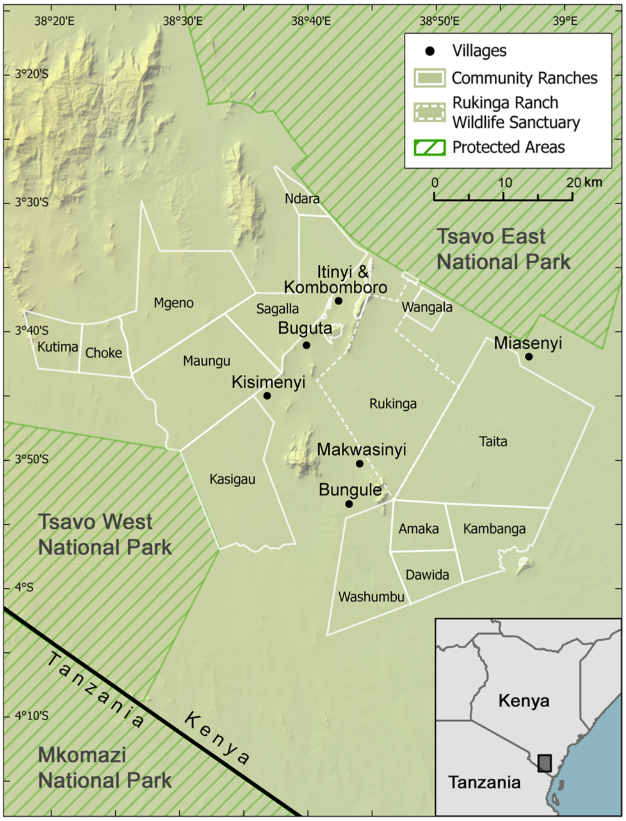

Fig. 1 The Kasigau Wildlife Corridor in Kenya, shown with its 14 community ranches and the locations of the six study villages.

ease of access) and comprised a majority of farming households experiencing frequent elephant interactions. Because of logistical and budgetary constraints we limited our selection to six villages: Itinyi and Kombomboro (combined because of population size and proximity, hereafter referred to as Itinyi), Bungule, Miasenyi, Kisimenyi, Buguta and Mwakwasinyi (Fig. 1).

Methods

We developed a questionnaire (Supplementary Material 1) with our local partners based on previous research with farmers experiencing elephant crop foraging (Hoffmeier-Karimi & Schulte, 2015), taking into account local knowledge and customs, and people's experience with and knowledge of encounters with elephants. The survey contained 64 questions, both semi-structured and open-ended, 19 of which formed the basis of this study. The relevant questions focused on the knowledge and use of deterrent methods and attitudes and behaviours towards elephants (Table 1). To further localize our efforts, we enlisted the help of Hellen Kiute, a facilitator from the community, to conduct the survey sessions. In 2020, with the support of local government officials, we selected as participants 30–35 farmers from each village who were most affected by

Table 1 Questions administered to farmers from six villages in the Kasigau Wildlife Corridor, near Rukinga Wildlife Sanctuary, Kenya (Fig. 1), related to crop foraging by African savannah elephants *Loxodonta africana*.

Question	Survey question (response type)
1	Do you use methods to prevent crop raiding by wildlife on your farm? (Yes/no)
2	If yes, what type of methods do you use? (Open-ended)
3	Have you ever received information on methods to prevent crop raiding? (Yes/no)
4	If yes, what type of information have you received on methods to prevent crop raiding? (Open-ended)
5	Have you ever received instructions on how to build deterrent fences? (Yes/no)
6	If yes, what types of deterrent(s)? (Open-ended)
7	If you were given information about ways to prevent crop raiding, how likely is it you would be able to invest in and build deterrent methods? (Definitely/possibly/I am unsure/definitely not)
8	If not, please tell us why you would not be able to purchase or construct deterrent methods. (Open-ended)
9	What do you feel is the main reason for your crop losses? (Open-ended)
10	Have you ever actively chased elephants from your farm? (Yes/no)
11	Have you ever harmed or attempted to harm elephants when they came to your farm (these answers will NOT be shared with authorities)? (All the time/never/once/regularly/several times)
12	How much do you fear elephants? (Very afraid/somewhat afraid/not at all afraid/unsure/a little bit afraid)
13	Have you ever received information on how to safely live with elephants? (Yes/no)
14	How many acres do you currently use for crop farming? (Open-ended)
15	How many years have you been farming? (Open-ended)
16	What year were you born? (Open-ended)
17	Village of origin? (Open-ended; this was verified for each survey)
18	Gender? (Male/female)
19	What is the highest level of education that you have achieved? (Open-ended)

elephant crop foraging (a total of 206 participants from the six villages; Supplementary Table 1). To avoid gender bias, we selected c. 50% male and c. 50% female participants. We surveyed only one member per household to maintain sample independence.

We invited individuals to participate in a meeting occurring in their respective village in September 2020. At the meeting the facilitator administered a paper survey and was available to answer any queries and aid those who might be illiterate (White et al., 2005), which was c. 15% of the participants (n = 31 across all villages). Participants completed the surveys independently of each other. To ensure construct validity, the facilitator orally defined the concepts of crop damage (i.e. the act of any animal entering a farm and consuming or trampling crops) and deterrents (i.e. any method used to prevent entry or frighten wildlife away from farms). These methods could involve both active deterrence such as yelling, waving a torch (flashlight) or patrolling, or passive methods such as any type of fencing. We subsequently transferred the data from the hardcopy surveys into a database for analysis.

We edited the data to create groupings for survey questions and to prepare the data for analysis (Supplementary Material 2), and we then selected models to evaluate our hypotheses (Table 2). We evaluated each variable of interest (age, education level, years farming, gender, exposure to deterrents, farm size and village) for collinearity with a robust variance inflation factor, and all factors were near 1.0, signifying no collinearity between these variables. We analysed the models using a generalized linear model that accounts for the non-normal distribution of response variables. We used a binomial distribution when creating logistic regression models. We compared our results using the Akaike information criterion corrected for small sample sizes (AICc) as a measure of fit. We also report adjusted pseudo-r^2 values, following a previously proposed approach (Zhang, 2017). We considered models with ΔAICc ≤ 2 (compared to the best model; Burnham & Anderson, 2002) to be competitive and evaluated them using the explanatory values of model weights and adjusted pseudo-r^2 values. Top models are reported, but these are not indicators of hypothesis support as we evaluated each model independently according to respective model metrics, effect sizes and sociological meaning. For each top model we report effect sizes with 95% confidence intervals (CI) of significant coefficients ($P < 0.150$; Arnold, 2010) to further describe the significance of our data. We conducted all analyses in *R 4.0.2* (R Core Team, 2020).

TABLE 2 A priori models used to test hypotheses related to the use of deterrents to prevent crop damage by elephants in the six study villages. Note that farm size is a quadratic term (area size; indicated by superscript 2), so the relationship is not linear as for the other terms.

Model	Description	Hypotheses[1]
1	Null	All
2	Constant + age	DU, EB
3	Constant + education level	All
4	Constant + years farming	DU, EB
5	Constant + gender	DU, EB
6	Constant + exposure	DU, EB
7	Constant + farm size^2	DU, EB
8	Constant + village	DU, EB
9	Constant + age + education level	DU, EB
10	Constant + age + exposure	DU
11	Constant + age + farm size^2	DU
12	Constant + education level + exposure	DU, EB
13	Constant + education level + farm size^2	DU, EB
14	Constant + exposure + farm size^2	DU
15	Constant + age + education level + exposure	DU, EB
16	Constant + age + exposure + farm size^2	DU
17	Constant + education level + exposure + farm size^2	DU, EB
18	Constant + age + education level + exposure + farm size^2	DU, EB
19	Constant + age + education level + years farming	DU, EB
20	Constant + age + education level + years farming + gender	DU, EB
21	Constant + age + education level + years farming + gender + exposure	DU, EB
22	Constant + age + education level + years farming + gender + exposure + farm size^2	DU, EB
23	Constant + age + education level + years farming + gender + exposure + farm size^2 + village	DU, EB
24	Constant + age + education level + years farming + gender + farm size^2 + village	DE

[1]DE, deterrent-exposure hypothesis; DU, deterrent-use hypothesis; EB, economic-barriers hypothesis.

Results

Of the 206 respondents that completed the survey, the number of participants per village ranged from 29 to 37. The ratio of female to male participants was 53:47, although this varied by village (Supplementary Table 1). Respondents ranged in age from 18 to 85 years, with a mean age of 46 ± SD 14 years and household size ranged from 2 to 34 with a mean of 8 ± SD 4. Most respondents (64%) had a primary education level, 22% had completed secondary education, 7% had completed tertiary education and the remaining 7% had no formal education. The main source of income for 92% of respondents was farming.

For the deterrent-use hypothesis, model 12 (education level + exposure to deterrents) best described which farmers used deterrents (Table 3). Individuals exposed to information about deterrents were 3.65 (95% CI: 1.65–8.63) times more likely to use deterrents ($P = 0.002$). Respondents with secondary levels of education were 4.64 (95% CI: 1.21–20.75) times more likely to use deterrents compared to those with no education ($P = 0.031$). We also found that individuals with primary education were 1.94 (95% CI: 0.55–7.87) times more likely to use deterrents compared to those with no education, but this was not significant ($P = 0.310$). Education level alone (model 3) was the best-fitting model for farmers who had received information on deterrents (deterrent-exposure hypothesis). We found that respondents with tertiary education were 5.00 (95% CI: 0.89–40.97) times more likely to have received information on deterrents compared to those with no education ($P = 0.087$). For information specifically on fencing

TABLE 3 The top five results from binomial generalized linear models for the deterrent-use hypothesis, evaluating which farmers from the six study villages were using deterrents, based on demographic variables (n = 189). Model descriptions and terms are presented in Table 2 and full model results are in Supplementary Table 4. For each model, the table shows the Akaike information criterion adjusted for small sample sizes (AICc), the difference in AICc from the best-performing model (ΔAICc), the adjusted pseudo-r^2 value, the Akaike weight (w_i), log-likelihood (LL) and the number of variables (k).

Model	Intercept	AICc	ΔAICc	Adjusted r^2	w_i	LL	k
12	−0.93	253.71	0.00	0.07	0.36	−121.69	5
15	−1.54	255.05	1.33	0.07	0.19	−121.29	6
6	−0.04	255.55	1.84	0.04	0.14	−125.74	2
17	−1.09	256.30	2.59	0.07	0.10	−120.84	7
10	−0.05	257.61	3.90	0.03	0.05	−125.74	3

(deterrent-exposure hypothesis), the null model (1) provided the best fit (Table 4). For the economic-barriers hypothesis, exposure to deterrents (model 6) was the best-fitting model for those who believed they could use deterrents (Table 5). However, individuals who had not received information on deterrents were 2.78 (95% CI: 1.01–7.63) times more likely to believe that they could implement deterrents than those who had received such information (P = 0.046).

For the survey question associated with the deterrent-use hypothesis, 54% of respondents used at least one form of deterrent to prevent crop foraging. Regarding the deterrent-exposure hypothesis, 22% of respondents had received information on deterrent methods and 10% had received information specifically on fences. The types of deterrent methods about which villagers had received information were primarily traditional fencing methods (Supplementary Table 2), and most individuals (87%) who used deterrents used traditional types (Supplementary Table 3). Regarding the economic-barriers hypothesis, only 40% of respondents believed that they could invest in deterrents, and all who said they could not make such an investment (123 respondents) cited economic constraints as the reason.

Elephants were cited as the main reason behind the crop losses by 84% of respondents; 74% had actively chased elephants from their farms but few (6%) had attempted to harm the animals. When asked how much they fear elephants, 55% of respondents said they were very afraid, 23% were somewhat or a little bit afraid, 15% were not afraid at all and 7% were unsure. Only 16% of respondents had received information on how to safely live with elephants.

Discussion

Over half of the participants in this study used some type of elephant deterrent, of which the majority were of traditional types. Education level and exposure to relevant information were the prevalent variables in the top models for the deterrent-use hypothesis. However, the adjusted pseudo-r^2 values for these models indicated that not much of the variation in responses was explained by the variables. Effect sizes were more descriptive of the relationship between variables and demographic categories as farmers were almost four times more likely to use deterrents if they had been exposed to information and if they had higher education levels. The deterrent-exposure hypotheses was supported in that higher education levels (model 3) were related to receipt of general information on deterrents, and those with tertiary education were more likely to have received such information but not specific information on deterrent fencing, for which the null model provided the best fit (model 1). Finally, the economic-barriers hypothesis was not supported in terms of education level having an effect, but instead exposure to deterrent information (model 6) was associated with whether farmers believed that they could implement such deterrents. Those who had not received

TABLE 4 Results of binomial generalized linear models for the deterrent-exposure hypothesis, a two-part hypothesis evaluating whether farmers from the six study villages had been exposed to information on any type of deterrent information and specifically on fencing deterrents, based on demographic variables (n = 189). Model descriptions and terms are presented in Tables 2 and 3.

Model	Intercept	AICc	ΔAICc	Adj. r^2	w_i	LL	k
Any type of deterrent							
3	−1.61	182.90	0.00	0.08	0.97	−87.34	4
24	−0.89	189.59	6.69	0.10	0.03	−80.75	13
1	−1.32	197.12	14.22	0.00	0.00	−97.55	1
Fencing deterrents							
1	−2.13	129.67	0.00	0.00	0.95	−63.82	1
3	−2.40	135.52	5.86	−0.01	0.05	−63.65	4
24	−4.29	148.42	18.75	−0.04	0.00	−60.17	13

TABLE 5 Top five results from binomial generalized linear models for the economic-barriers hypothesis evaluating demographic factors of farmers from the six study villages who said that they definitely could implement deterrents (n = 98). Model descriptions and terms are presented in Tables 2 and 3, and full results are in Supplementary Table 5.

Model	Intercept	AICc	ΔAICc	Adj. r^2	w_i	LL	k
6	1.12	119.24	0.00	0.03	0.39	−57.56	2
1	0.87	121.09	1.85	0.00	0.16	−59.52	1
12	2.12	122.29	3.05	0.02	0.09	−56.93	4
4	1.13	122.62	3.38	< 0.00	0.07	−59.25	2
2	1.20	122.98	3.75	−0.01	0.06	−59.43	2

information (no exposure) were almost three times more likely to believe that they could implement such deterrents. This may seem counterintuitive, but appears to show initial over-confidence on the part of the farmers and aligns with our additional results and previous studies showing that once farmers understand the expense and effort required to implement and maintain deterrents, they may view such implementation unfavourably or realise they cannot afford the relevant materials (Noga et al., 2015; Vogel et al., 2022). The prevalence and effect sizes of the variables of exposure and education across several models suggest that farmers receiving information and the variation in education appear to significantly affect usage and uptake behaviours. Why education level is important in this context is unclear, but it could be related to those with more education also having higher income levels, enabling them to afford deterrent materials.

Understanding local attitudes and contexts related to elephants and crop foraging is an important part of holistic approaches to addressing conflict. Respondents in the study area live in fear of elephants, and such fear can affect their health and well-being and incur lost opportunity costs (Barua et al., 2013; Mmbaga et al., 2017; Thondhlana et al., 2020). Another factor that could lead farmers to fear elephants was that most had never received information on how to safely live near elephants or interact with them. In addition, the majority of villagers blamed elephants for their crop losses despite significant drought having occurred and despite the presence of other pests (Karimi, 2009; Kasaine & Githiru, 2016). Fears and frustrations from crop losses could lead farmers to retaliate against elephants (Naughton-Treves & Treves, 2005; Treves & Santiago-Ávila, 2020), but only a small percentage of farmers stated they had attempted to harm elephants, although most respondents admitted to actively chasing elephants from their farms. This is a common way of deterring elephants (Fernando, 2015; Mariki et al., 2015; Montero-Botey et al., 2021), but it is also dangerous. Our findings show that negative interactions with elephants in this area represent a threat to human health and livelihoods and pose concerns for elephant conservation.

We demonstrated that exposure to relevant information plays an important role in the usage of deterrents, which has broad implications for conservation management. Most respondents had never received information on ways to prevent crop foraging, and most of the information they had received was on traditional measures; very few had received information specifically about different types of fencing (usually modern methods). Not only is information rarely reaching villagers but, when it does, it focuses on methods that are potentially less effective and more time-consuming (although perhaps more easily implemented in practice). Only 18% of respondents used modern methods such as deploying solar lights along fencing, planting chili peppers (an unpalatable crop; Osborn & Parker, 2003) or installing Kasaine metal strip fences (Von Hagen et al., 2021). This low uptake rate of modern deterrents demonstrates the need for outreach efforts that provide up-to-date information on such methods.

All respondents who believed that they could not implement deterrents cited a lack of financial resources as the reason, which is consistent with previous research (Vedeld et al., 2012; Seoraj-Pillai & Pillay, 2017). This is a key factor that is often overlooked in mitigation plans. Our findings in this community suggest that if the deterrent methods are too labour intensive or require too many resources, or if there is a lack of community cooperation, then they may fail even if they have been implemented successfully in other areas (Osborn & Parker, 2003; Sitati & Walpole, 2006; Graham & Ochieng, 2008). That financial constraints influence the deterrent usage of farmers has also been shown in recent research from Botswana (Vogel et al., 2022).

Other than exposure and education level, demographic variables had little explanatory power in the models, probably because of the respondent population being essentially homogeneous in their views. Some respondents may have provided answers they thought would be viewed favourably, potentially introducing social desirability bias (Chung & Monroe, 2003). Several respondents did not fully answer the questions, and some gave contradictory answers, indicating that some questions may have been unclear; we eliminated these responses from our analysis (Supplementary Material 2). Despite these limitations, our findings are relevant and applicable for agencies managing human–elephant interactions.

In our study area in the Kasigau Wildlife Corridor in Kenya, we found that vital information for reducing elephant crop foraging is not reaching local farmers and that multiple barriers exist regarding the uptake of deterrents. Our findings suggest several key management recommendations. Firstly, increased outreach efforts to farmers are needed to share knowledge on deterrent approaches, especially in remote areas. Secondly, community leaders are needed who can help encourage farming communities to incorporate existing deterrents or who can create and share sustainable solutions that are effective and practical within the local context. Thirdly, farmers need information on how to live safely near elephants, to decrease both the fear and the risk associated with elephant encounters. A combination of these efforts could increase local food security, tolerance of elephants and support for conservation programmes. Without additional educational and financial resources, elephant crop foraging is likely to persist. However, our study provides insights that could help practitioners address some previously little examined economic and social concerns of farmers related to the use of elephant deterrents.

Author contributions Study design: LVH, BAS, KD, MG, SZ, CAL; fieldwork: LVH; data analysis: LVH, TDS, KD, CAL; writing: LVH, BAS, MG, CAL.

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Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards. Survey and consent procedures were approved by Auburn University's Institutional Review Board panel (Protocol no. 20-440 EX 2009) and Strathmore University's Institutional Ethics Review Committee (Approval no. SU-IERC0877/20) in Kenya. The research was conducted under the umbrella of Wildlife Works' PIC/MAT agreement with Kenya Wildlife Service and with approval from NACOSTI (Kenya's science agency, License no. NACOSTI/P/20/2292).

Data availability Data are available in the Supplementary Material and on request from the corresponding author.

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