Participatory modelling across Kenyan villages facilitates insights into the complexity of human–elephant interactions

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Abstract Negative human–wildlife interactions are a growing problem, particularly for people living near protected areas and wildlife refuges. In Kenya, African savannah elephants *Loxodonta africana* threaten food security for subsistence farmers by crop foraging, which can jeopardize conservation efforts if farmers retaliate against elephants. To inform conservation and management, this study had three objectives: (1) to evaluate stakeholder participatory models of human–elephant conflict; (2) to note any novel or under-represented variables in the models; and (3) to determine if there were indicators for assessing the success of mitigation programmes using a biocultural approach. We conducted participatory modelling sessions in six villages in rural Kenya using fuzzy cognitive mapping (n = 206 participants). Farmers created group visual models with variables related to conflict with elephants. A total of 14 variables were common across all six villages, with the two highest centrality scores (a measure of importance to overall dynamics) associated with income and feelings of security. Most variables fell into two categories: environmental interactions, and policy and management. Multiple variables such as road infrastructure (drivers) and soil compaction (consequences) were identified as aspects of conflicts that are under-reported or absent in scientific literature, as well as potential socio-cultural indicators. The participatory method used is a tool for gaining more refined insights into interactions with elephants, with implications for other complex conservation issues or wildlife interactions. A more holistic view of the impacts of human–elephant interactions as demonstrated here can lead to sustainable, co-developed programmes that benefit both farmer livelihoods and elephant conservation.

Keywords Bioculture, conservation planning, human–elephant conflict, human–wildlife interactions, mental models, rural sociology, social-ecological systems, systems thinking

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Introduction

Negative interactions between humans and elephants are a prominent problem across areas of Asia and Africa (Hoare, 2000; Desai & Riddle, 2015; Shaffer et al., 2019). Positive elephant interactions drive tourism in many countries, but negative ones, also known as human–elephant conflicts, are among the greatest threats to the species along with illegal killing (including ivory poaching) and habitat loss (Goswami et al., 2014; Boult et al., 2019; LaDue et al., 2021; IUCN, 2023). Crop foraging, also termed crop raiding, is the main type of negative interaction, whereby elephants alter their natural foraging routines to include cultivated crops (Osborn, 2004; Davies et al., 2011; Hill, 2018). Elephants may also destroy and/or consume food or water stores, especially in times of drought (Hoare, 2000; Karidozo et al., 2016). Crop foraging can also result in destruction of property, and can cause injury or death of people and/or elephants when farmers attempt to prevent elephant incursions (Zarestky & Ruyle, 2016; Schlossberg et al., 2020).

Although mitigation of such conflicts is a primary focus for many agencies, socio-economic disparities hinder these efforts (Dickman, 2010; Virtanen et al., 2020; Raphela & Pillay, 2021), particularly in areas where local or Indigenous people have been displaced, or impacts of colonialist policies persist (Kamau & Sluyter, 2018). For instance, farmers seeking to mitigate crop foraging can be constrained by lack of knowledge about deterrent methods or limited access to financial or material resources (Shaffer et al., 2019; O'Connell-Rodwell et al., 2000; Snyder & Rentsch, 2020; Von Hagen et al., 2024). Notably, rural communities that border protected areas often bear the brunt of these conflicts (Mcleod et al., 2015; Jordan et al., 2020). Numerous approaches to mitigating human–elephant conflicts have been evaluated, such as fencing deterrents or compensation programmes, but none have emerged as ubiquitous solutions (Blackwell et al., 2016; van de Water & Matteson, 2018).

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One reason why conservation organizations managing negative human–elephant interactions are challenged is that they may not fully understand the extent of the conflict, how local communities conceptualize the problem, or how it varies dependent on local context (Waylen et al., 2010; Kansky & Knight, 2014). To overcome these challenges, practitioners are increasingly using participatory processes with stakeholders that can provide unique insights into local ecological knowledge when offered with free, prior and informed consent (UN, 2007; Buchholtz et al., 2020; König et al., 2021; Jessen et al., 2022). Participatory modelling using fuzzy cognitive mapping is an approach that aids in creating a shared knowledge space as stakeholders share parts of their mental models (Biggs et al., 2011; Gray et al., 2012). Mental models are the individual cognitive constructs of how someone views the world or a specific issue (Johnson-Laird, 1986) and can be used in systems thinking. Developing individual or shared mental models has helped demonstrate marked differences between the knowledge and perceptions of stakeholders and wildlife managers regarding an ecological system, and has facilitated the creation of potential solutions to environmental challenges (Moon et al., 2019; LaMere et al., 2020). However, the technique has rarely been used to evaluate the multi-dimensional relationships present in human–wildlife conflicts (but see Mosimane et al., 2014; Nyaki et al., 2014).

Here we adopt a biocultural approach to understanding human–elephant conflict. Biocultural approaches to conservation emphasize cultural perspectives of local people, recognizing how ecological and human health are interconnected (Gavin et al., 2015; Sterling et al., 2017). Evaluating programme effectiveness is an important part of creating long-term solutions, and a biocultural approach can help identify locally relevant and qualitative indicators (Dacks et al., 2019; DeRoy et al., 2019). In the case of negative interactions with elephants, understanding how farmers conceptualize the connections, interactions and causes of the conflict can lead to co-creation of solutions. However, these aspects are generally little understood, leaving the causes and consequences of some interactions unaddressed (Gavin et al., 2015; Bridgewater & Rotherham, 2019).

Community views on negative human–elephant interactions need to be incorporated to advance current management strategies (IUCN, 2023). Our overarching goal was to develop a systems view (a holistic examination of the interplay of different components of a system) of human–elephant conflicts amongst rural communities in the Tsavo Ecosystem of Kenya, to inform policy and management. To address this goal, our objectives were to evaluate stakeholder participatory models to understand how farmers conceptualize conflict, determine if locally novel or underrepresented system components were present, and evaluate if there were indicators that would be useful in assessing mitigation programmes. We expected that variables unfamiliar to conservation practitioners would emerge from the mental models based on the expertise of local ecosystem actors.

Study area

The Kasigau Wildlife Corridor of Kenya lies between Tsavo East and West National Parks in south-eastern Kenya in the Greater Tsavo Ecosystem and contains 14 community-owned ranches. The region is home to the country's largest and growing population of c. 15,000 African savannah elephants *Loxodonta africana* (Waweru et al., 2021). The elephants use the wildlife corridor to transit between the parks. Rukinga Wildlife Sanctuary, operated by Wildlife Works, is one of the largest Reducing Emissions from Deforestation and Degradation (REDD+) carbon offset projects, and part of the corridor's 14 ranches. This area is home to almost 120,000 people, and the high number of villages, farms and nomadic pastoralists create many opportunities for human–wildlife interactions. Community outreach by Wildlife Works has been prevalent in this area, making it ideal for engagement. Most areas outside the Sanctuary are smallholder farms, with maize being the predominant crop. Almost half of the villagers in this area use basic deterrents such as guarding crops, lighting fires or scaring crop-foraging wildlife away with loud noises. Few farmers use more modern and effective deterrents such as electric, beehive, metal or chili fences (Von Hagen et al., 2023). We selected six communities surrounding Rukinga Wildlife Sanctuary as the focus of the study: Itinyi and Kombomboro (combined because of their small population size and geographical proximity, hereafter referred to as Itinyi), Bungule, Miasenyi, Kisimenyi, Buguta and Makwasinyi (Fig. 1). The key criteria for selecting these villages were adjacency to the Sanctuary and that they were predominantly comprised of farming households experiencing crop foraging by elephants.

Methods

We conducted participatory modelling sessions in conjunction with social surveys (Von Hagen et al., 2023) in the six villages. We hired and trained a local facilitator to conduct the sessions. Chiefs, elders and the facilitator together identified 30–35 farmers from each village to participate in the survey sessions, selecting people who were known to frequently experience interactions with elephants. Approximately half of the participants were men and half women, as women are at least equally responsible for farming duties in the area. We then reduced this cohort to 12–15 participants per village, which is the optimal number for modelling sessions (Phillips & Phillips, 1993; Nyaki et al., 2014). To maintain sample independence, only one person per household participated, resulting in a total sample size of 77 villagers (39 men, 38 women; Supplementary

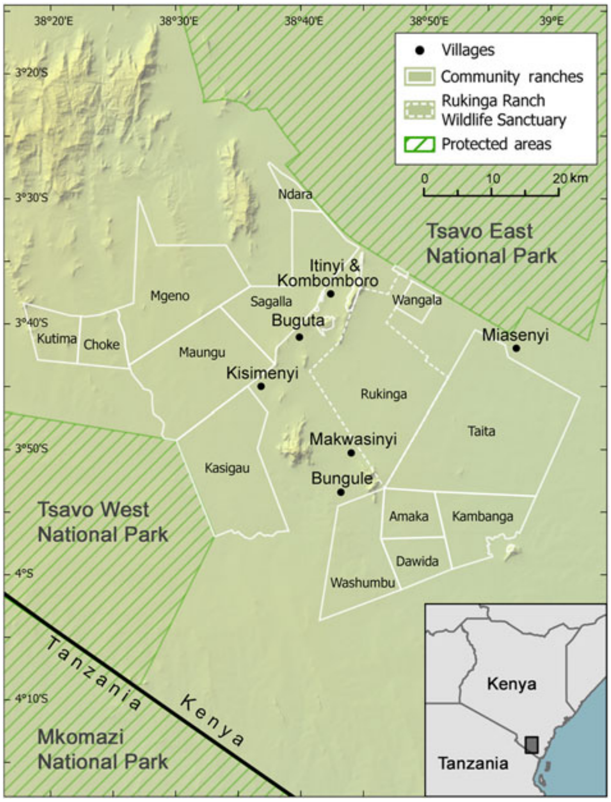

Fig. 1 The Kasigau Wildlife Corridor, Kenya, shown with the 14 community ranches and the locations of the six villages participating in this study.

Table 1). One session per village was conducted on a Friday or Saturday during 21 November–22 December 2020.

On days of the sessions, the trilingual facilitator initiated the participatory sessions in Swahili by introducing the concepts of the research and model building, and clarifying terms that would be used (such as crop raiding/foraging, human–elephant conflict and deterrents) to assure construct validity. Using coloured markers and large sheets of paper, the issue of human–elephant conflict was listed in the centre of the paper and participants were asked to determine system components or variables that affected conflict, with lines drawn to connect these variables. Participants were allowed to add variables through group discussion until they felt they had included all key aspects. The facilitator was encouraged not to prompt with specific variables, only suggesting topics for consideration if the participants appeared stuck or confused with the models. The 'fuzzy' portion of the model construction was to quantify on a scale of 1 (lowest impact) to 10 (highest impact) how the two variables related to each other. Negative (−) and positive (+) influences were demarcated on the chart in different colours, red for decreasing, blue for increasing. Normally this process is done on a valence scale of −1 to +1 with decimal intervals (Özesmi & Özesmi, 2004), but for simplicity we used −10 to +10. For each step, the participants from each village agreed on a consensus, and the facilitator encouraged every participant to contribute their views.

We used *Mental Modeler 1.0* (Gray et al., 2013, 2017) to convert the hand drawn models to fuzzy cognitive maps for each village (Fig. 2, Supplementary Figs 1–5), with the variables randomly placed on the models. The software determined the number of variables in each model including the number of connections (indicating the degrees of interactions; Özesmi & Özesmi, 2004), transmitter variables (the drivers that affect other variables but are not affected by them), receiver variables (items that only receive impacts and do not affect other components), and ordinary components (variables that are both receivers and transmitters). The software calculated centrality scores, a measure of importance to the overall system dynamics, which is determined by the number of edges or connections for each variable in the system. We also calculated complexity to determine the level of complex systems thinking according to previous studies, and density to compare the number of connections in a particular model to all possible connections (Eden, 1992; Özesmi & Özesmi, 2004). To assess if variables were novel or underrepresented, we referred to our collective knowledge of and existing literature on human–elephant interactions.

During input of the village models, we noticed complexity seemed to increase with successive sessions. Thus, we evaluated if changes were occurring linearly by plotting the density metric over time and the number of variables, connections, drivers and ordinary components, and tested these with a linear regression. The positive correlation coefficient values for variables ($P = 0.002$), connections ($P < 0.001$), drivers ($P = 0.006$), and ordinary components ($P = 0.007$) ranged from 0.93 to 0.98, and the density had a negative correlation coefficient of −0.98 ($P < 0.001$). We therefore concluded that the likely reason for this significant increase in variables and complexity was that the facilitator improved their skills over time, resulting in the models becoming more complex.

To address and compensate statistically for this facilitator adaptation and potential bias, we created a qualitative aggregation method across villages (Fig. 3; Vasslides & Jensen, 2016; Misthos et al., 2017) by establishing four locally relevant categories to group each variable from the respective village models: economic, environmental interactions, social, and policy and management. To better visualize the categories into which each variable fell, we assigned a different colour to each category, resulting in a cognitive colour spectrum (Cholewicki et al., 2019; Supplementary Fig. 6). We calculated the percentage of variables within each category for each village and compared the means of each category with ANOVA, and used a Tukey's post hoc honest significant difference test for multiple comparison.

The lead author (LVH) developed a single co-created model of human–elephant conflict (Fig. 4) based on input

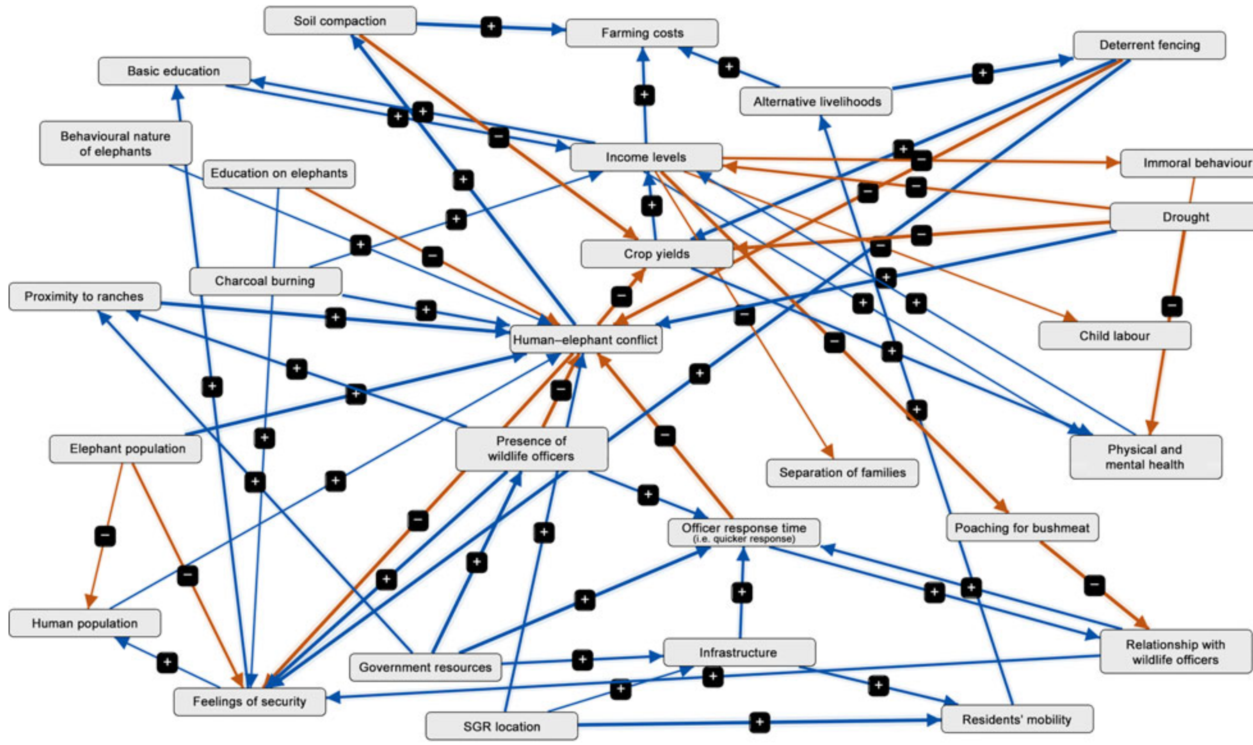

FIG. 2 A fuzzy cognitive map of variables related to human–elephant conflict. The map was created with *Mental Modeler* software from a participatory session in the village of Bungule in the Kasigau Wildlife Corridor, Kenya. Variables are linked together through connecting lines (edges) with the strength of association represented by the thickness of the lines. To read the model, take any variable with an arrow originating from it and with an increase of said variable it will have either a positive and increasing (a plus (+) sign) or negative and decreasing (minus (–) sign) causal influence on the variable it is connected to. SGR, Standard Gauge Railway.

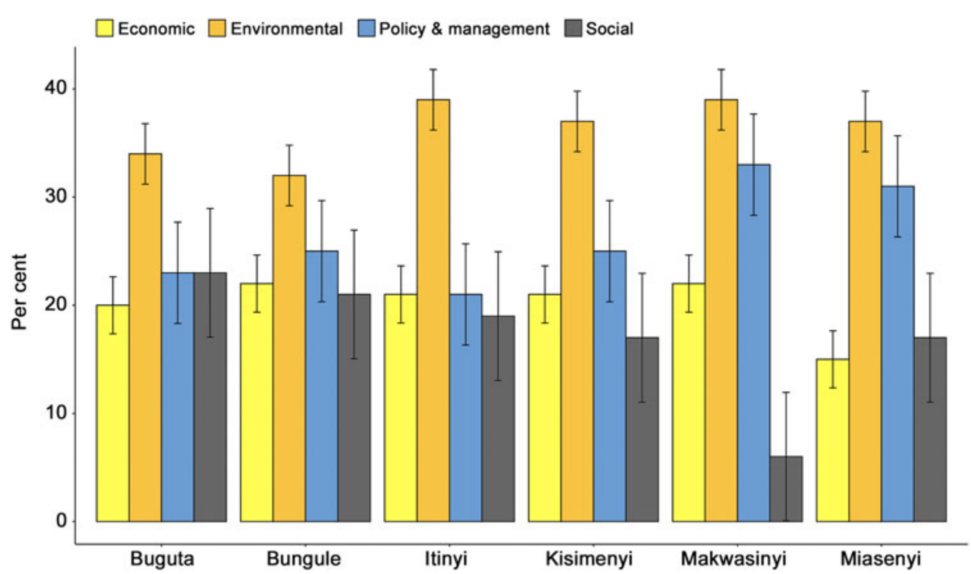

FIG. 3 A qualitative aggregation of model variables in four categories from participatory sessions with six villages in the Kasigau Wildlife Corridor surrounding the issue of human–elephant conflict. Error bars show the standard deviation.

from the six village models, literature references on wildlife conflict, knowledge of the local system from a conservation practitioner's perspective and input from farmers during the sessions (Supplementary Table 2). We conducted all statistical analyses in *R 4.0.2* (R Core Team, 2020) with an alpha value of 0.05.

Results

To achieve our goal of developing a systems view of human–elephant conflict, we first evaluated stakeholder participatory models. To demonstrate how the fuzzy cognitive maps are visually interpreted, we use the variable

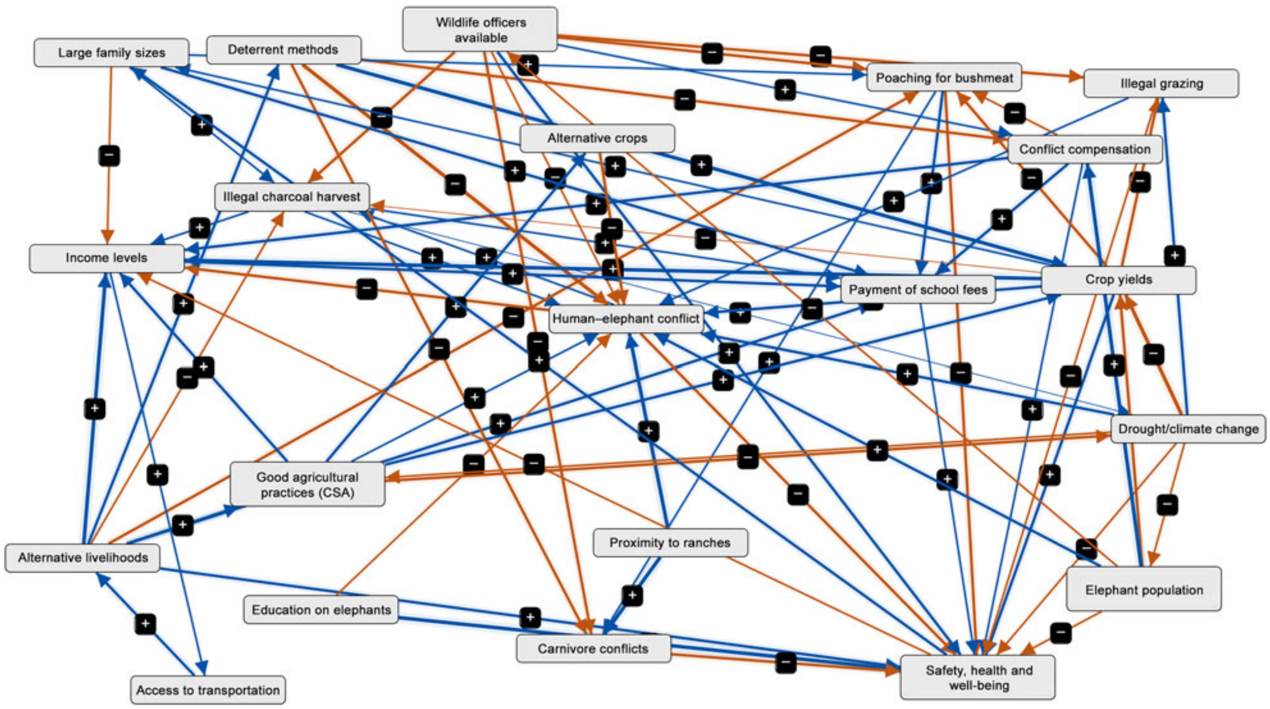

FIG. 4 A fuzzy cognitve map of variables related to human–elephant conflict based on the authors' knowledge of the local context, expertise of local villagers, and literature. Variables are linked together through connecting lines (edges) with the strength of association represented by the thickness of the lines. To read the model, take any variable with an arrow originating from it and with an increase of said variable it will have either a positive and increasing (a plus (+) sign) or negative and decreasing (a minus (–) sign) causal influence on the variable it is connected to. CSA, climate smart agriculture.

elephant population as an example in Fig. 2: the arrow originating from this variable to human–elephant conflict has a positive sign, meaning that a higher elephant population had an increasing effect or influence on human–elephant conflict. The thicker line means it has more influence than other variables with thin connections. An example of a negative influence is the relationship of education on elephants and human–elephant conflict, meaning that more education about elephants decreases the impact of human–elephant conflict. Of the six study villages, Bungule had the highest complexity score (a potential indicator of complex systems thinking) and Miasenyi had the highest number of overall variables, connections, driver variables and ordinary variables, and the lowest density (Table 1). In the qualitative aggregation for the four categories of variables (economic, environmental interactions, social, and policy and management), environmental interactions emerged as the leading source of grouped variables, followed by policy and management (Fig. 3, Supplementary Fig. 6). These four variable categories differed significantly ($F_{3,20} = 23.86$, $P < 0.001$), and post hoc analysis revealed significant differences between environmental–economic

TABLE 1 Summary metrics of mental model components related to human–elephant conflict taken from participatory model sessions from six villages in the Kasigau Wildlife Corridor, Kenya, as part of fuzzy cognitive map construction.

Order	Village	Number of variables	Connections[1]	Drivers[2]	Ordinary[3]	Density[4]	Complexity score
V1	Makwasinyi	18	28	6	10	0.09	0.33
V2	Kisimenyi	24	46	4	17	0.08	0.75
V3	Bungule	28	57	7	18	0.08	0.43
V4	Buguta	30	59	9	18	0.07	0.33
V5	Itinyi	43	84	14	24	0.05	0.36
V6	Miasenyi	52	103	15	31	0.04	0.33
	Co-model	21	73	2	19	0.17	0.00

[1]How many times variables were linked (degree of interaction with other variables).
[2]Variables that affect interactions or variables but are not affected by other variables.
[3]The number of concepts that influence and are influenced by other variables.
[4]The number of connections compared to all possible connections.

TABLE 2 Fuzzy cognitive map centrality scores (a measure of importance to overall dynamics, calculated by the number of connections to each variable) from six villages in the Kasigau Wildlife Corridor, Kenya, and the top 14 variables related to human–elephant conflicts that were common across all villages.

	Centrality scores							
Variable	Buguta	Bungule	Itinyi	Kisimenyi	Makwasinyi	Miasenyi	*Total*	Rank
Human–elephant conflict	11.40	11.20	13.80	9.90	8.90	17.45	72.65	1
Income levels	6.20	6.40	8.03	6.20	1.80	8.90	37.53	2
Feelings of security	5.10	5.40	4.70	4.60	3.30	6.90	30.00	3
Deterrent fencing	3.20	4.00	5.70	3.40	3.80	5.50	25.60	4
Crop yields	4.30	5.40	3.90	3.84	3.70	4.00	25.14	5
Officer response time	4.00	4.60	2.70	3.00	3.00	3.40	20.70	6
Relationship with wildlife officers	2.40	2.90	4.20	3.70	2.30	3.60	19.10	7
Drought	2.60	3.40	3.60	2.20	2.70	4.50	19.00	8
Government resources	3.40	3.30	1.18	2.50	2.38	3.40	16.16	9
Proximity to ranches/boundary issues	2.50	2.20	1.10	3.40	2.70	2.10	14.00	10
Infrastructure	2.90	2.30	1.28	1.50	1.98	2.20	12.16	11
Alternative livelihoods	1.50	2.10	3.09	1.50	1.50	1.10	10.79	12
Resident mobility	1.70	2.10	1.10	1.50	1.30	2.30	10.00	13
Elephant population	1.70	1.80	1.50	1.00	0.80	1.70	8.50	14

($P < 0.001$, 95% CI = 9.31, 23.03), environmental–policy and management ($P < 0.001$, 95% CI = −16.86, −3.14), environmental–social ($P < 0.001$, 95% CI = −26.03, −12.31), and social–policy and management ($P < 0.01$, 95% CI = −16.03, −2.31).

Participating farmers shared similar perceptions of conflict, as 14 variables were consistent across all models including the key variable human–elephant conflict. Income level held the highest centrality score, followed by feelings of security (Table 2). The co-created, local model shared many of the same variables as the individual village models (Fig. 4). However, variables not prevalent in the village models were present in the co-created model that were known concerns from local conservation agencies and NGOs, and this model also had more reciprocal relationships.

To address our second objective of determining if novel system components were present, we identified variables representative of novel or underrepresented drivers and consequences of elephant conflicts. *Fire setting* occurs when farmers light fires to remove dead vegetation, often post-drought, on their land. However, these fires are not closely managed and can confuse or alarm elephants, causing some elephants to retreat away from farms but others to go further into farmlands. The variable *rearing culture of elephants* originates from some farmers' beliefs that conservation agencies that rehabilitate and release elephants into Tsavo are making them less wild, causing them to enter farming areas with little fear of humans. *Protection from God* is indicative of a strong religious and sociocultural belief in that the more one gives to God (in the form of devotion, time or money), the more protection is received from crop foraging elephants. *Infrastructure* referred to some rural roads that can become unnavigable, especially during the rainy season, resulting in wildlife officials being unable to reach farmers complaining of elephant presence.

The variable *soil compaction* is one of several consequences that create economic challenges for farmers. Farmers stated that when elephants frequent the same areas of land, they compact the soil, resulting in the added cost of renting equipment to plough their fields. The *immoral behaviours* variable reflected farmers' beliefs that when income levels were low, drug and alcohol abuse, pre-marital relations, theft and crime all increased because people became idle or depressed. The parallels between these social behaviours and the negative impacts of human–elephant conflict have yet to be highlighted. However, other issues besides crop foraging can contribute to some of these behaviours, further illustrating the system's complexity. Finally, *child labour* results when a family has limited funds because of crop damage/loss and must take their children out of school to earn income or stay home and support the family with farming tasks.

For the third objective, using a biocultural approach to assess if indicators for measuring the success of mitigation programmes were present, we identified variables related to elephant conflicts that could be adapted as indicators. *Early marriages and pregnancies* and *motherhood deliveries* may result when incomes decrease and girls or young women (typically aged 15–22 years) marry earlier than expected as they feel a need to be provided for and secure. Thus, when harvest and incomes are good, marriage and pregnancy are delayed until desired. However, these variables can also be affected by other hardships. *Separation of families* was also noted as a negative consequence: when crop yields are low, male household members may have to leave home to find work elsewhere.

The *Standard Gauge Railway* emerged in some models as a novel local variable. Construction of the railway, which began in 2014, has been controversial because it reduced pathways available for wildlife to cross one of the main highways bisecting Tsavo East National Park (Okita-Ouma et al., 2016). Some villagers believe proximity to railroad underpasses increases or redirects elephants' access to farms. All variables by village and category are included in Supplementary Fig. 6.

Discussion

By evaluating the participatory models constructed during our sessions with local farmers, we clearly distinguished how farmers conceptualized human–elephant interactions across the villages. Many complex interactions between variables were displayed in the models, showing that local expertise is invaluable for gaining insights into conservation issues (Vogel et al., 2022). Several variables stood out as underrepresented drivers and consequences of human–elephant conflicts, such as soil compaction by frequent elephant visits, and the lack of reliable road infrastructure, leading to wildlife officers being unable to reach some farms. Some variables were novel to this ecosystem, such as the local railroad altering wildlife movements; our new insights on this issue can be used to address concerns of local villagers and develop specific management plans. Using a biocultural approach, we found that certain variables could potentially be adapted as indicators to gauge mitigation programme success with respect to socio-cultural aspects, such as feeling more secure, reduced early marriages, or families remaining intact instead of men leaving home to find work. By using more cultural approaches in lieu of the standard socio-economic indicators to assess programme success (Dacks et al., 2019), we can ensure that human culture, health and well-being are considered when addressing conservation issues. Our success in gaining intimate knowledge of this system indicates the potential for this methodology to be used with other stakeholders across a broad range of conservation issues.

With income levels being the dominant variable across the villages (aside from human–elephant conflict), it is clear that the economic impacts from crop foraging are a key driver of conflict in this community. In particular, when income levels are reduced, individuals have fewer resources available to address challenges such as drought or medical emergencies (Twomlow et al., 2008; Mcleod et al., 2015). Feelings of security emerged as an important variable, which corroborates results from other surveys showing the majority of villagers live in fear of elephants (Von Hagen, 2024) and earlier research that showed impacts of crop foraging are not only economic (McShane et al., 2011; Barua et al., 2013; Mmbaga et al., 2017). These findings collectively point to human–elephant conflict as a multidimensional issue jeopardizing the ability of farmers to thrive across social, cultural and economic levels.

Environmental interactions were the dominant category in the models across all villages, demonstrating the connectedness of this socio-ecological system. The policy and management category was the second most prevalent type of variable, and participants voiced their concerns about the way these conflicts are managed. For the co-created local model, several issues prominent in this system were not highlighted by farmers such as the payment of school fees and illegal grazing (farmers are not allowed to graze their cattle in the Sanctuary). School fee payment and other intermittent events such as illness in the household can also drive an increase in other harmful activities such as charcoal production and bushmeat poaching (Zulu & Richardson, 2013; Nyaki et al., 2014). Thus, village models and those incorporating practitioner experiences had key differences. These types of differences can be an indicator of different priorities between ecosystem actors and various wildlife authorities and point to the need for further open dialogue about what is truly important to local communities.

Underrepresented and novel local drivers again demonstrated the utility of our methodology in exposing local concerns related to specific conservation issues and priorities for communication by wildlife officials. For example, *soil compaction* was an unexpected consequence of crop foraging by elephants, which demonstrated the importance of incorporating the knowledge of local people. One study evaluating the impacts of African elephant presence on soil found positive effects of moderate elephant presence but that soil moisture, infiltration rates, nitrogen mineralization and nitrification all decreased with increased elephant presence (Maponga et al., 2022). These negative effects of soil compaction from heavy elephant presence appear to be an issue already known to some local farmers. The variable *farming spirit* (how determined a farmer was to continue with their profession, despite losses incurred by elephants) could be adapted as a biocultural indicator as it relates to a sense of place and cultural identity, and it is sensitive to environmental impacts (DeRoy et al., 2019).

Despite the novel and informative insights gained, there were limitations to this study. Firstly, there was the facilitator adaptation as the sessions progressed, as noted above. To avoid such issues and reduce bias for future project managers, we recommend training and practice sessions for facilitators prior to commencing the actual study. Secondly, although all participants were encouraged to share their opinions, differences in personalities or social intimidation may have caused some farmers to refrain from fully expressing themselves.

This study revealed several management implications for agencies working with farmers to mitigate the impacts of human–elephant conflicts, which can be applied to other wildlife conflicts. The first is the establishment of multidimensional indicators that capture both the ecological and social-cultural impacts of human–elephant interactions (Sterling et al., 2017) to measure programme efficacy in local communities. Secondly, our findings suggest implementation of programmes that provide information for farmers and assistance with mitigation efforts. They also point to the need for additional research to assess the impact of social variables on human–wildlife interactions. Thus, implementing community-based programmes to increase community resilience can benefit both farmers and wildlife conservation. Our study demonstrated that working with stakeholders to gain insights into complex conservation issues such as human–elephant conflict is important for creating customized mitigation programmes that prioritize the livelihoods and health of people while simultaneously preserving ecosystem health.

Author contributions Study design: LVH, SAG, BAS, MG, CAL; fieldwork: LVH, HIK; data analysis: LVH, HIK, SAG, CAL; writing: LVH, SAG, BAS, MG, CAL.

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Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards. The survey and study design were reviewed and 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. This project operated under the PIC/MAT agreement between Kenya Wildlife Service and Wildlife Works, and with approval from NACOSTI, Kenya's science agency (license no. NACOSTI/P/20/2292).

Data availability Data related to this project, except for identifying information related to participants, are available from the corresponding author upon request.

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