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RESEARCH ARTICLE

Understanding farmers' reasons behind mitigation decisions is key in supporting their coexistence with wildlife

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Abstract

1. Coexistence between wildlife and farmers can be challenging and can endanger the lives of both, prompting the provisioning of mitigation methods by governments and non-governmental organizations (NGOs). However, provision of materials, demonstration of the effectiveness of methods or willingness to uptake a method do not predict uptake of methods.
2. We used ethnographic decision models to understand how farmers' work through the decisions of uptake or non-uptake of methods to mitigate crop consumption by elephants, and how the government and NGOs can either enable or impede the ability of farmers to protect themselves and their crops.
3. While farmers were motivated to use methods if they received or could afford to buy materials and they believed in the effectiveness of the methods, they still did not use them if they considered a method to be dangerous, or issues with elephants not to be severe enough, or when the supply of materials or income was not sufficient. Methods were not even considered by farmers if they lacked awareness or knowledge of the method. Government departments and NGOs enabled farmers to mitigate elephant crop consumption by providing opportunities for cash income, and providing materials and knowledge. Yet, there was disparity between the materials farmers received and methods they wished to adopt.
4. One-off inputs of materials did not result in sustainable use of mitigation methods. We see an opportunity for governmental departments or NGOs to stimulate logistics (e.g. roads and retail) to increase availability of mitigation materials since this promoted farmer autonomy. We also highlight the importance of empowering farmers by facilitating within community sharing of mitigation ideas and increasing knowledge about the effectiveness of promising wildlife conscious farming, as despite promising farmer testimonies, only a few farmers used these techniques.

KEYWORDS
crop consumption, ethnographic decision model, human–elephant coexistence, wildlife conscious farming

1 | INTRODUCTION

Globally, subsistence farming and areas of conservation concern overlap, so the sustainability of these social–ecological systems depends on the ability to reconcile potentially conflicting land-use interests (Food and Agriculture Organization, 2019; Green et al., 2005; Naidoo & Iwamura, 2007). This means that large, wide-ranging species, like elephants (*Loxodonta africana* and *Elephas maximus*), must be able to coexist—share space and resources—with humans to thrive outside of protected areas (Bouché et al., 2011; Hoare & de Toit, 2010; O'Connell-Rodwell et al., 2000). However, the consumption and damaging of crops by wildlife challenges this coexistence by severely affecting farmers' livelihoods and safety (Mackenzie & Ahabyona, 2012) and contributes to threatened wildlife being at risk of being harassed or killed (Mariki et al., 2015).

Therefore, governments and non-governmental organizations (NGOs) encourage farmers to use mitigation methods to deter wildlife from agricultural lands (Fernando, 2008; Hoare, 2012; Parker et al., 2007). By doing so, these institutions aim to build on the work farmers are already doing to keep wildlife from fields, while also encouraging new behaviours, and motivating people to participate actively in mitigation. For elephants, this includes deterring them from fields by building fences and barriers, and changing what, where or when they farm (Sitati et al., 2005; Songhurst, McCulloch, & Coulson, 2015). Still, in areas with high elephant concentrations, like in northern Botswana, among farmers there is no widespread adoption of mitigation methods provided (Graham & Ochieng, 2008; Noga et al., 2015; Sitati & Walpole, 2006). This is despite a large body of evidence on the effectiveness of these mitigation methods (Fernando, 2008; Hoare, 2012).

The literature on agricultural decisions is vast, yet only a subgroup focuses on how farmers actually make decisions (Kim & Cameron, 2013). Economical perspectives often adhere to the assumption that rural decisions are ultimately financially motivated, while social psychological perspectives tend to focus on the importance of attitudes in driving agricultural behaviour (St John et al., 2010; Willock et al., 1999). However, the mismatch of intended conservation goals and outcome of conservation interventions can be the result of perceiving farmers' decisions as merely rationally economic decisions (Malawska et al., 2014; Milner-Gulland, 2012; St John et al., 2010), while farmers base their decisions on many factors (Azjen & Albarracín, 2007). Factors identified as influencing farmers' decision to uptake a method range from their socio-demographics, psychological makeup, characteristics of the farm household or farm business, to external factors, like wider social milieu, government policies, and information on and the characteristics of agricultural innovations (Edwards-Jones, 2006; Kim & Cameron, 2013; Malawska et al., 2014). Choosing an economic, social or psychological perspective to farmer decision-making will limit the focus on factors considered to drive adoption of agricultural methods to those areas where the expertise of the researcher lies (Edwards-Jones, 2006; Singh et al., 2016; St John et al., 2010; Willock et al., 1999). Therefore, research on farmer decision-making needs to be holistic, and inclusive of financial, socio-economical and psychological perspectives and go beyond boundaries of disciplines and theoretical frameworks (Singh et al., 2016).

Ethnographic decision models (EDMs) are useful in such a holistic perspective, as these models are not limited by the researchers' perspective and expertise. They take into account the fact that in real life, decisions are made with hierarchical levels of importance (Gladwin, 1983; Ryan & Bernard, 2006). EDMs aim to capture the context-specific hierarchical thinking by allowing respondents to identify the relevant conditions they associate with a method, and the order of hierarchy of criteria (Levine et al., 2015). This results in a hierarchical decision tree; each node is a criterion that a farmer takes into consideration, and different routes on the tree end up with different choice results (Gladwin, 1989b). EDMs have proven to be an insightful and effective tool to study the uptake and non-uptake of farming techniques (Bernard, 2006; Darnhofer et al., 1997, 2005; Gladwin, 1983; Ryan & Bernard, 2006). EDMs aim to capture as much as possible how behaviour evolves in real-world complexity, while still allowing for the testing of the predictability of these ethnographically identified behaviour influences. Thus, EDMs have the potential to be a bridge between valuable in-depth insights from ethnographic research, and the predicting power of quantitative modelling techniques, responding to the call to increase interdisciplinary approaches towards understanding decision-making in conservation science (Milner-Gulland, 2012).

Most of our knowledge on farmers' reasoning behind the uptake or non-uptake of mitigation methods to deter elephants from fields is based on anecdotal evidence (O'Connell-Rodwell et al., 2000; Sitati et al., 2005; Sitati & Walpole, 2006). When it comes to innovative mitigation methods, designed to target the heightened senses of an elephant, through sight, sound, touch and smell, such as chilli pepper and beehive fencing, farmers appear to not adopt a method when they felt they were disrespected or not consulted by those providing the method (Noga et al., 2015, 2017). However, we lack systematically collected evidence in the reasons behind the (non-) adoption of other methods. These include passive mitigation (e.g. fences), actively scaring elephants away (e.g. sounds) and the adaptation of agricultural decisions farmers make to reduce the likelihood of elephants entering the fields (Hockings & Humley, 2009; Parker et al., 2007). While active guarding is reported as more effective to deter elephant from fields than merely passive methods (Sitati & Walpole, 2006), most farmers employ different passive and active mitigation methods simultaneously as elephants easily habituate to these methods (Hoare, 2012).

Adapting land-use planning to allow access to space and resources by both people and wildlife, and making agricultural choices that are conscious to wildlife behaviour can be a strategy to address crop consumption issues more sustainably (Gunaryadi, Sugiyo, & Hedges, 2017; Hockings & Humley, 2009; Parker et al., 2007; Songhurst, McCulloch, & Coulson, 2015). Examples of these wildlife conscious farming methods are buffer regions around fields (Sitati et al., 2005), cleared vegetation (Osborn & Parker, 2002) and the use of alternative or buffer-crops that are unattractive to consume or move through (Gross et al., 2016, 2017; Hockings &

Humley, 2009). But also land-use planning strategies that consider critical wildlife habitat, such as setting aside specific regions or corridors for elephants to roam (Adams et al., 2016; Jachowski et al., 2013; Songhurst, McCulloch, & Coulson, 2015). Finally, the timing of planting could play a role in crop consumption for species that show seasonal movement patterns, such as elephants (Jackson et al., 2008), and ploughing early can allow farmers to harvest before the elephants arrive.

Successful demonstration of the effectiveness of elephant deterrent methods can increase willingness to invest in a method (Graham & Ochieng, 2008), but do not guarantee uptake by farmers (Sitati & Walpole, 2006). Even willingness to adopt agricultural methods is not a sufficient indicator for adoption (Baumgart-Getz et al., 2012). Therefore, we need a systematic approach to understand why farmers take up certain methods, and do not take up other methods, despite external support to do so. With this study, we want to introduce EDMs as a strategy to achieve this, by permitting respondents to identify the plurality of methods and uptake criteria they consider, and do so in their own terminology.

By applying EDMs we go beyond evaluating people's experiences, method uptake rates and analysing behavioural intentions, and identify hierarchy in decision-making, increasing our understanding in how people work through the process of mitigation method choices. This allows us to identify motivation and elimination criteria on which farmers base their (non-) adoption of these four classes of crop consumption mitigation methods (passive, active, innovative and 'wildlife conscious farming'), and the constraints they face in these choices. It also opens opportunities for predicting farmer behaviour and capturing the causal relationships between actual behaviour and criteria (Bernard, 2006; Gladwin, 1989b; Ryan & Bernard, 2006). Finally, we interpret farmers' decisions within the historical and political contexts and relations of power (Gupta, 2013), to identify the role of different agents in supporting or restricting farmers in the uptake of mitigation methods. We use the eastern panhandle of Botswana's Okavango Delta as our human–elephant conflict and coexistence case study.

2 | METHODS

2.1 | Study site

Botswana is home to 37% of the total African elephant population, which makes its elephant population the largest of all nations, with on average 1.28 elephants per km^2 (Chase et al., 2016). Over 80% of elephants roam outside of protected areas in Botswana, where they have a protected status (Thouless et al., 2016). One of these areas is the eastern panhandle of the Okavango Delta in northern Botswana, which is just over 8000 km^2 where around 18,000 elephants (Songhurst, Chase, & Coulson, 2015) and 16,000 people share the land (CSO, 2011). We focused our study on four of the 14 villages along the Okavango River, Beetsha, Eretsha, Gunotsoga and Seronga, which surround the largest elephant corridors in the area (Figure 1; Songhurst, McCulloch, & Coulson, 2015). The people living in these villages are from four main ethnic groups: the BaHaMbukushu, BaYei, BaSarwa and BaKgalagadi (Demotts et al., 2009; Hitchcock et al., 2011).

2.1.1 | Socio-ecological background of human–elephant coexistence in the study site

The soil in the area mainly consists of nutrient-poor Kalahari sands (Dougill & Thomas, 2004); nevertheless, most inhabitants of the area are mainly dependent on crop production for their subsistence, along with livestock farming and harvesting natural resources such as fish (Cassidy et al., 2011; Motsholapheko et al., 2011). Only a small proportion of farmers sell their harvest for cash income; and short-term, labour-intensive public works (*Ipelegeng*) are popular for temporary cash income, especially among young people (Gupta, 2013; Motsholapheko et al., 2011). The Okavango River with its annual flood, together with the annual rainfall periods in the region, play important roles in the subsistent livelihoods of people here. Homesteads and agricultural fields are concentrated near the stretch of the river and floodplains, where most natural resources are sought, and arable farming predominantly takes the form of dry land farming, or *molapo* farming, dependent on rainfall during a single sporadic and unpredictable rainy season (Motsholapheko et al., 2011; Songhurst, McCulloch, & Coulson, 2015).

The river and its floods are also vital in elephant feeding ecology, movements and social behaviour, and elephants show daily and annually reoccurring movement patterns towards and away from the Okavango River and agricultural fields (Jackson et al., 2008; Vogel et al., 2020). During those movements, they make use of heavily used elephant corridors that often pass near farmlands, and crop consumption occurs (Songhurst, Chase, & Coulson, 2015; Songhurst, McCulloch, & Coulson, 2015). During a survey across the study site ($n = 909$), 63% of farmers identified crop consumption by elephants as the biggest challenge to farming, and 77% of farmers identified elephants as the animal that caused them the worst problems, mainly due to their consumption of crops (Songhurst, 2017).

Besides crop losses, the increased overlap in elephants and human use of the area have resulted into physical conflicts, and deaths of both (Buchholtz et al., 2019; Schlossberg et al., 2019; Songhurst, 2017). This makes mitigation methods to deter elephants from agricultural fields a priority in both agricultural and conservation initiatives (Jackson et al., 2008; Noga et al., 2015; Songhurst, McCulloch, & Coulson, 2015). Both the Botswana government and NGOs have a history of involvement with farmers' agricultural methods and have provided them with wildlife conflict mitigation interventions, although the cultural appropriateness and effectiveness of some of these measures and policies are questionable (Cassidy et al., 2011; Jackson et al., 2008; Noga et al., 2017; Shinn, 2016).

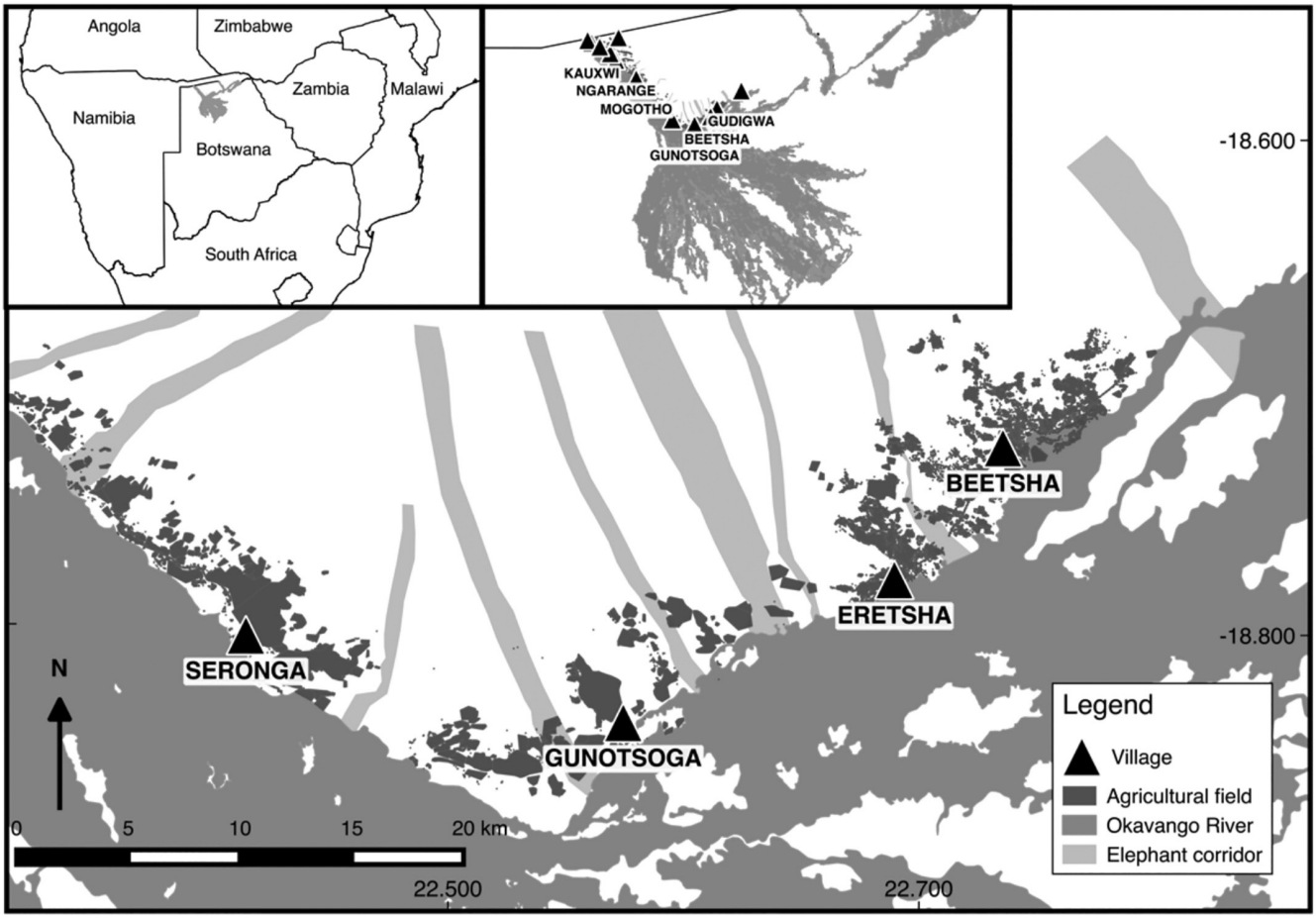

FIGURE 1 Map of the four villages of the northern panhandle of the Okavango Delta included in this study: Beetsha, Eretsha, Gunotsoga and Seronga.

2.1.2 | Political background of human–elephant coexistence in the study site

During British colonial rule, protected areas were created in the study site, forcefully removing people from their land, negatively impacting their livelihoods by restricting the use of land, wildlife resources and other natural resources (Mbaiwa, 2005). This caused local livelihood strategies of agriculture and cattle herding to conflict with national economic interests driving diamond mining and wildlife-based tourism (Demotts et al., 2009; DeMotts & Hoon, 2012; Magole & Magole, 2009). In post-independent Botswana, wildlife tourism remains important (Natural Resources and People, 2007), and previous appropriation of land and lack of involvement of rural communities continue to cause disagreements about land ownership and natural resource use (Demotts et al., 2009; DeMotts & Hoon, 2012; Kgomotso & Swatuk, 2006; Magole & Magole, 2009).

The Botswana government is a welfare state with national policies aimed at eliminating poverty (Magombeyi & Odhiambo, 2017; Seleka et al., 2007; Seleka & Lekobane, 2017). The government provides extensive agricultural support to local communities with subsidies and training (Gupta, 2013; Ministry of Agriculture Botswana, 2008a, 2008b), and over half (55%) of the people in northern Botswana claim to be solely depended on government support for their income, while over 70% of households receive agricultural inputs through government support systems (72.4%) and directly receive food support from the government (71.1%) (Gupta, 2013).

Since 2008, the agricultural support programme is called the Integrated Support Programme for Arable Agriculture Development (ISPAAD), offering subsistence farmers services and resources to cultivate their arable land plots: water sources, seeds, fencing, fertilizer, access to credit, diesel, pesticides and financial support for the farmers' labour costs for ploughing, planting and harrowing, which farmers can also use to borrow subsidized tools from the government (Ministry of Agriculture Botswana, 2008a, 2008b). The Department of Wildlife and National Parks (DWNP) also provides advise on which mitigation methods to use (Gupta, 2013), and delivers material assistance and training in the use of innovative mitigation methods (Noga et al., 2017). Still, poverty, unemployment and illiteracy are prevalent in the area (Noga et al., 2015; Statistics Botswana, 2016, 2018). See Supplementary Information I for a more detailed description of the political and historical context of human–elephant coexistence in northern Botswana.

2.2 | Data collection

2.2.1 | Ethics statement

This research project has been reviewed and approved by the Oxford University ethics committee. We received written permission to conduct the research by the Ministry of Environment Natural Resources Conservation and Tourism, Republic of Botswana, permit reference EWT 8/36/4 XXXIX (9) and oral permission of the Kgosi (chief) of each of the villages (Supplementary Information II). Before each interview, we discussed the oral consent form (Supplementary Information III) and we only proceeded upon informed consent.

2.2.2 | Positionality statement

The interviews were facilitated by the NGO Ecoexist, which seeks to reduce conflict and foster coexistence between elephants and people. Interviews were conducted by a Batswana male research collaborator from Eretsha village, who asked the questions and translated answers; by the first author, a European white female Ecoexist research fellow, trained in EDMs, who recorded the reported hierarchical criteria and performed model backtracking (see Section 2.2.3); and by one of four Batswana Ecoexist community officers from the village where the interviews took place (two women and two men). These entwinements between interviewers and the NGO Ecoexist, and the presence of a foreign female, could both be associated with pro-elephant sentiments and could have reduced the likelihood for people to feel free to express their concerns about elephant (conservation) in the area. Loyalty towards the NGO or dependency on the NGO could have also increased the willingness of people to participate in the study or created an incentive for people to express positive opinions on the NGO or (received) support by the NGO or their (perceived) partners, or for the interviewers to positively bias the translation, interpretation and recording of the answers regarding the NGO. On the other hand, expectations of future support from the NGO could have created an incentive to respond more negatively than people's actual experiences. Besides this, the author team conducting the analyses and writing this manuscript were white European and Northern-American researchers, of which three are directors of the NGO, which could reduce the likelihood of critical reflection and reporting of negative roles performed by the NGO. Therefore, the results from this study should not be interpreted without the context of mitigation method evaluations conducted independently of this NGO (MEWT & DWNP, 2016; Noga et al., 2015). For a more detailed reflexivity statement, and measures we used to try to mitigate risk of biases and cultural inappropriateness of the study, please see Supplementary Information II.

2.2.3 | Construction of EDMs

We conducted interviews and focus group discussions from January to April 2017. Because agricultural crops start to grow in January, and mature around April–May when most farmers harvest them (Songhurst, 2017), most farmers were attending to their fields during the research period. Therefore, we visited them in their fields or at their homesteads before or after going into the field. At the time we conducted the fieldwork, a prolonged dry season took place.

After receiving approval from the Dikgosi of each of the villages, we held a focus group discussion in each village in which we encouraged a dialogue around mitigation methods, their effectiveness and farmers negative and positive experiences with living with elephants. Subsequently, in each village, we held five in-depth open interviews regarding the reasons behind the (non-) use of mitigation methods. We purposely selected respondents to make sure that for each mitigation measure we included farmers who did and did not use the method (Gladwin, 1989a, Supplementary Information II). We held interviews in English, Setswana, Mbukushu or Siyei, depending on the preferences of the respondent. Further details, consent seeking forms and questions asked during the interviews are found in Supplementary Informations II–IV.

Based on the hierarchical order of the elements in the decision tree, we divided the decision criteria that farmers used to explain their (non-) adoption of mitigation measures into *elimination*, *motivation* and *constraint* criteria (Gladwin, 1989b). We used these reasons to create dichotomous questions that formed each of the nodes in the decision model and sorted the hierarchical order of importance based on the prevalence of criteria (Gladwin, 1989b). If backtracking a respondent's answers on the decision tree made the respondent end up with a different decision than they actually made, or end up with the correct choice, yet reached this point in the decision tree without including all of their conditions given, this was considered an '*error*' (Gladwin, 1989b). We continued examining the position of the adoption conditions in the decision tree until in at least 85% of the cases we correctly predicted the mitigation choice of our respondents along their route of reasoning. We piloted each of the draft decision trees in English and Setswana, to make sure the order of questions was logical and correct.

2.2.4 | Testing EDMs

In total, we tested 16 decision models, each on 81 farmers of which 64.9% were female. We selected a stratified random sample for each of the villages, a sample of 20–30 farmers per village (Bernard, 2006). We successfully predicted the decision when the decision tree questions showed the mitigation measure that the farmer later confirmed to apply in their field, and again checked for *errors*, in which case we marked the point at which a question resulted in the respondent starting to follow an incorrect path. Therefore, the sum of errors at a final point of the tree can be traced back to the previous nodes where errors started to occur in the answers. After conducting all the interviews, we calculated success rates of our predictions in percentages, and by making use of Klecka's tau. This is a measure predicting the power of our model compared to a prediction of mitigation measure merely by chance (Ryan & Bernard, 2006). EDMs are considered to accurately represent farmers' decisions criteria if the

models correctly predict decisions for at least 85% of the farmers (Gladwin, 1989b).

3 | RESULTS

3.1 | Mitigation measure uptake criteria

The EDMs we constructed to accurately predict over 85% of the answers and decision routes of our initial interviews, contained between one and eight hierarchical criteria. As in the initial interviews, some decisions appeared to be strongly related, we tried to combine them into one tree, as in the case of chilli burning and fences, and adapting the crop composition and type (Figure 3a). In the initial interviews and focus group discussions, farmers informed us about 16 different *passive*, *active*, *innovative* and *wildlife conscious farming* (or more commonly used in the area '*elephant aware farming*') mitigation measures they applied, Table 1. Women always used methods more often than men (mean ration women/men = 1.85), but men had a relative preference for dogs (ratio = 1.18), torches (ratio = 1.11) and tin cans (ratio = 1.28). The most commonly employed methods were shouting, drumming or clapping, fire and using a watch hut, for both men ($mean_{men}$ = 22.00, SD = 2.45) and women ($mean_{women}$ = 44.75, SD = 1.71). Both women and men also had a preference for using plastic (n_{women} = 28, n_{men} = 15) and early ploughing (n_{women} = 30, n_{men} = 14). There were no strong differences between villages in

TABLE 1 Passive, active, innovative and elephant aware farming mitigation methods mentioned in focus group discussions and construction phase of ethnographic decision models

Mitigation type	Mitigation method
Passive	Traditional fencing (wire fences and bush fences), the application of tin cans and plastic on these fences, or the use of electric fences and trenches
Active	Using a torch, shouting, drumming or clapping and the use of fire, dogs and a watch hut to guard at night
Innovative	Beehive fences, chilli pepper fences and chilli pepper burning
Elephant aware farming	Adapting the location of the field, the type of crop or composition of crops in the field and ploughing early

TABLE 2 Percentages of farmers that adopt or not adopt, for each of the mitigation measures, and the accuracy scores for the ethnographic decision models predicting this (non-) adoption

Method	Uptake (%)	Non-uptake (%)	Predictability (%) (Klecka's tau)
Traditional fence			
Wire fence	37 (*n* = 30)	4 (*n* = 3)	77 (0.69)
Bush fence	27 (*n* = 22)		
Both	32 (*n* = 26)		
Tin cans	22 (*n* = 18)	78 (*n* = 63)	99 (0.98)
Electric fence	6 (*n* = 5)	94 (*n* = 76)	100 (1)
Plastic	55 (*n* = 45)	45 (*n* = 36)	84 (0.68)
Trenches	0	100 (*n* = 81)	100 (1)
Torch	23 (*n* = 19)	77 (*n* = 62)	86 (0.73)
Dog	35 (*n* = 28)	65 (*n* = 53)	94 (0.88)
Fire	85 (*n* = 69)	15 (*n* = 12)	93 (0.85)
Drumming/capping	93 (*n* = 75)	7 (*n* = 6)	98 (0.95)
Shouting	85 (*n* = 69)	15 (*n* = 12)	93 (0.85)
Watch hut	93 (*n* = 75)	7 (*n* = 6)	95 (0.90)
Chilli pepper			
Burning	10 (*n* = 8)	90 (*n* = 70)	96 (0.94)
Burning and fence	4 (*n* = 3)		
Beehive fence	0	100 (81)	86 (0.98)
Adapt location	25 (*n* = 20)	75 (*n* = 59)	94 (0.87)
Crop			
Type	1 (*n* = 1)	87 (*n* = 68)	86 (0.79)
Composition	10 (*n* = 8)		
Both	1 (*n* = 1)		
Early ploughing	58 (*n* = 46)	42 (*n* = 33)	89 (0.79)

method choice, but in Seronga people used relatively less mitigation measures overall ($n_{Seronga}$ = 76, compared to a mean of 114), and Eretsha was the only village that used electric fencing (Table 2, Supplementary Information II, Figure S1).

3.1.1 | Motivation criteria

Financial income and the provision of materials were the most important criteria motivation for farmers to use a method (Figure 2a). Income was a motivation criterion for using wire fencing, while the motivation criterion for electric fences was whether the farmer had received material. Financial ability to buy a torch also appeared the main motivation criterion for the use of torches (Figure 2b). The provision of information and the continuous supply of material appeared key in motivating the decision to use or not use chilli fences and chilli burning and beehive fences. Some farmers mentioned that they went for a lesson on the use of beehives or that '*the government came to bring it* [material], *and they proved it can work*', or that it would work because the trunk of the elephant is sensitive. Despite often a focus of those distributing mitigation method materials, belief in effectiveness of methods was not important in motivating farmers to adopt passive or innovative methods. Although traditional fences in the form of bush and wire fences were widely applied in the study area (Table 2), these were generally not considered to be effective at deterring elephants from entering fields. Bush fences were mainly constructed to keep smaller animals like goats and porcupines out of the fields, while wire fences where targeted at cattle and elephants. Therefore, the need to prevent small mammals from entering the field is a motivation criterion for bush fences (Figure 2a).

Uptake of wildlife conscious farming was mainly motivated by belief in effectiveness (Figures 2d and 3b). Most farmers that adapted the composition of their crops to mitigate crop losses to elephants planted crops that elephants did not like near the edges of the fields, and those that elephants preferred in the middle. One farmer mentioned '*I plant millet near the fence, and sorghum and watermelon in the middle of the field, so I wake up in time*', while another preferred to plant millet in the middle and watermelon near the watch hut to keep an eye on it.

3.1.2 | Elimination criteria

Elimination criteria were most dominant in the uptake decisions of farmers (Figure 2a). Reasons for eliminating a passive fencing method

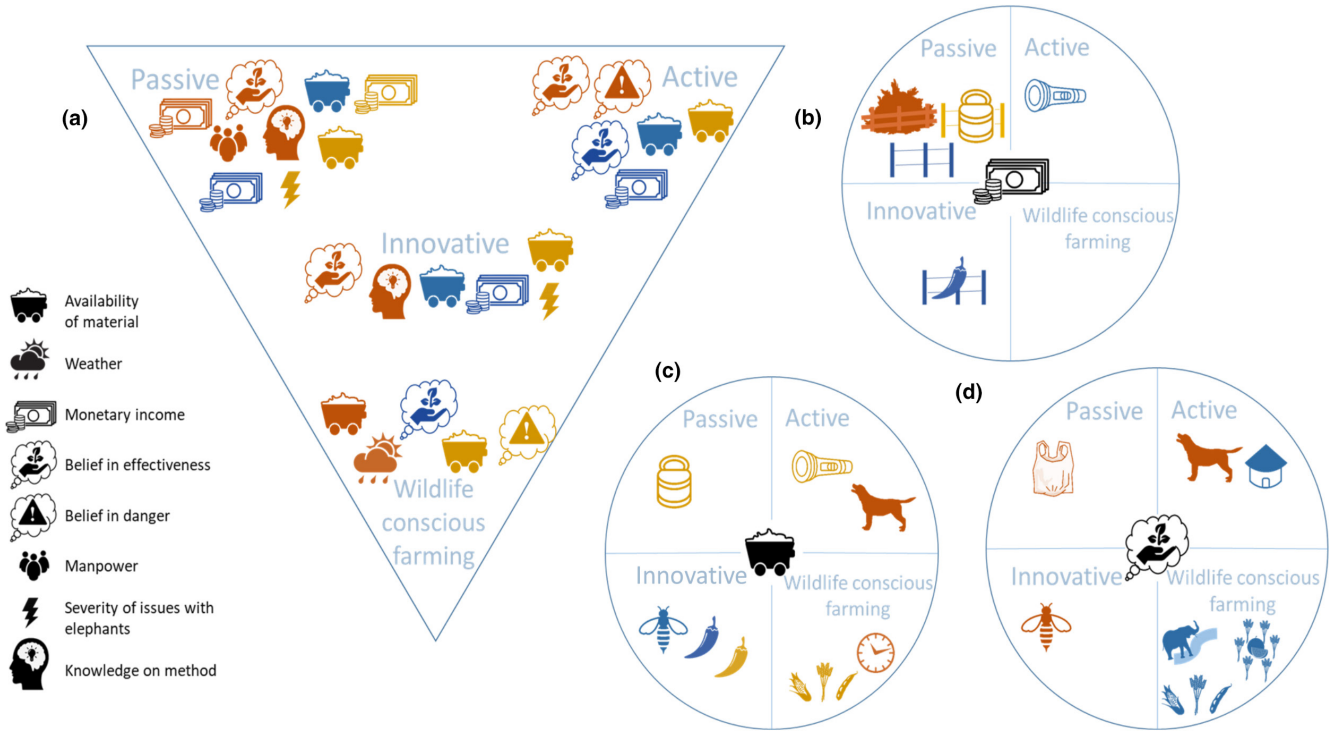

FIGURE 2 (a) Schematic overview of elimination (red) and motivational (blue) criteria, and constraints (yellow) in elephant mitigation method selection mentioned by farmers, summarized over passive, active, innovative (both passive and active) and wildlife conscious (elephant aware) farming methods. Figures (b)–(d) show more detailed information for three of these criteria, for others and details please see Supplementary Information II. (b) Role of monetary income for different mitigation methods, this was considered to be an elimination criteria for: Bush fence; and motivation criteria for: Wire fence, torch, chilli fence; and constraint for: Tin cans (wire/string). (c) Role of availability of materials for different methods as Elimination: Early ploughing (ox and mould), dog; Motivation: beehive, chilli fence, chilli burning, electric fence, tin cans; and Constraint: tin cans, torch (torch and batteries), chilli fence and burning (chilli), crop type (not planted crops not for sale). (d) Role of belief in effectiveness for different methods, as Elimination: dog, beehive, plastic; Motivation: Watch hut, crop type and crop composition, location; no constraints were mentioned.

varied from income (e.g. income eliminated bush fences as people preferred wire fences if they had sufficient funds) to awareness of the existence of a method (electric fences). Whenever farmers considered the application of plastic as efficient against elephants, they applied plastic as a mitigation method (20 farmers). However, if they considered it inefficient against elephants, they would still apply plastic when they considered it useful to deter birds (32 farmers). Of the respondents, only two farmers previously tried to use trenches. Both of them could not continue the maintenance of the trenches due to lack of 'manpower' (emic terminology—as used by the respondents). One farmer mentioned to have tried it in 2015 '*but it* [the trench] *was too shallow and elephants jumped* [over] *it. Someone was digging for water pipes and an elephant got killed by falling* [in] *the ditch, so they should dig deeper*'.

Belief that a mitigation method was dangerous was an important reason for farmers to eliminate the use of active methods (Figure 2a). The only reason farmers would not use a torch, was if they considered it to aggravate elephants. Most farmers eliminated the use of dogs also due to its danger '*it can kill you, it* [the dog] *is the elephant's natural enemy*' or ineffectiveness '*elephants are big, and dogs are small*'. Most respondents agreed that it was dangerous to use dogs to scare elephants from their fields, yet this did not stop farmers from using their dogs to protect their crops from elephants if they thought there was a (small) probability that elephants would be scared of the dog. The adoption or non-adoption of fire, drumming and clapping and shouting appeared solely related to whether the farmer considered it dangerous to use the method, by attracting elephants and making them aggressive. One farmer explained why they considered drumming makes elephants aggressive by stating '*Makgowa* [white people/foreigners] *gave sweets and bread to the elephants after beating a bell, now they come after drumming*'.

A few farmers used beehives, yet for commercial purposes and not to deter elephants. Most farmers responded jokingly about beehive fences, distrusting the effectiveness (Figure 2d): '*A bee cannot work at night, elephants are active at night, so the bee cannot spot it*', '*the leather* [of elephants] *is too hard to be stinged*', '*It would be funny if an elephant would run from a small bee*', '*bees are seasonal*' and '*I am scared of bees, they cannot scare elephants because they are too big*'. Or they did not consider themselves capable of using it: '*Who can find bees?*', '*Nobody explained this too me, I do not have the skills, how would I catch bees?*', '*I have to see it* [that it works] *with my eyes first*'. However, people kept referring to a particular farmer that did apply the beehive fence as mitigation methods, yet in order to feed the bees they planted papaya trees and elephants entered their field and destroyed the fence and trees. Farmers referring to this stated that '*others used it and it did not work*', or that '*on this side it does not work*', one respondent explained this lack of effectiveness was because there was not enough water for bees. One of the farmers who adapted his crop type to reduce elephant impact, mentioned to avoid planting the 'short millet' that farmers received for free from the government, because '*elephants like that type of millet the most*'.

3.1.3 | Constraints

There were several methods that farmers, despite being motivated to use the method and providing no reasons for eliminating the method, still not used because they faced constraints (Figure 2a). Regarding bush fences, farmers face the constraints of lack of 'manpower' and fence breakage by elephants. Some farmers mentioned that they could not gather tin cans from dustbins as this was considered socially undesirable behaviour. Because collecting tin cans requires effort, farmers also only applied tin cans when they consider elephant crop consumption to be a severe issue. Most farmers were unable to use the torches they had bought because they were constrained by a broken torch or run-down batteries, or farmers could not buy a torch because they were sold out. Lack of chilli supplies and fences broken by elephants were important reasons not to use these methods. If the supply of chillies would not have been an issue, 15 of the consulted farmers would have a chilli fence and burn chillies and 32 would burn chillies (Figures 2c and 3a). Additionally, if elephants had not broken their fences, 19 of these latter farmers would additionally have a chilli fence.

Many farmers mentioned that their father or husband picked the location of the field, which made them unable to adapt the location. In order for farmers to adapt the location of their field, they had to be convinced that elephants use some areas more than others, and that the plots in those areas highly utilized by elephants ('elephant corridors') did not have better soil and vegetation conditions than those outside of them. If possible, farmers would plough early. Therefore, farmers were only constraint on whether or not they had access to equipment early enough (Figure 2c), and whether the rains arrived early enough. Some farmers mentioned that the lack of rain early in the wet season was a constraint for them to plough early; however, we would classify this as a perceived constraint since all farmers in this study experienced the same rainfall.

3.2 | Mitigation choice predictability

3.2.1 | Testing of the EDMs

Of our 16 decisions, only two models did not accurately predict farmers' decision criteria for at least 85% of the farmers, that is, the models predicting the use of traditional fencing (77%) and of plastic (84%; Table 2). Supplementary Information V contains the EDMs not displayed here and detailed information on their errors. Most of the errors of the EDMs occurred related to 'other sources of income' such as ISPAAD, inheriting or borrowing materials, having some—yet insufficient—funds for required material, or farmers '*tried it* [method] *anyway*' even though they reported to be convinced it did not work.

Despite the complexity of the chilli model (Figure 3a), we managed to predict 96% (Klecka's tau = 0.94) of the test decisions correctly. During the test, four farmers did buy material to construct chilli fences themselves, and one created a chilli fence with traditional poles and wire made from tree materials. Only one farmer

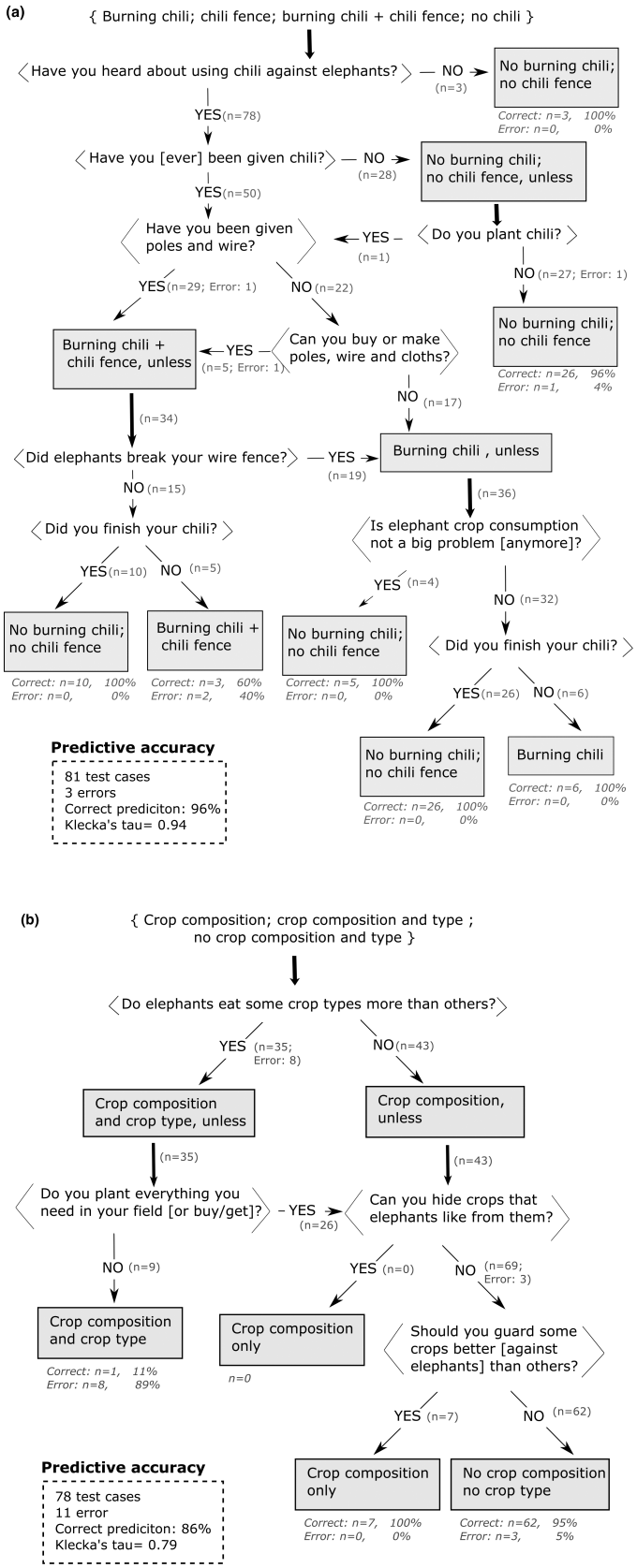

FIGURE 3 Ethnographic decision model (EDM) that correctly predicts >85% of model construction decisions ($n = 20$), including results from testing phase ($n = 81$), for (a) chilli burning and fences and (b) on adapting crop composition and crop type.

tried planting their own chilli plants, although they complained about the difficulty of watering the plants. No farmers used chilli fences without also burning chilli. Both methods required input of energy, but chilli fences also required input of extra materials such as poles, wire, oil and cloths. By 'using chilli fence', we made sure that farmers only said yes if they recently applied new chilli grease on the cloths, and old non-maintained fences were reported as non-use.

Although we managed to accurately predict whether or not farmers adapted the type of crops they used and the composition they planted their crops in, the Klecka's tau of this model was relatively low (Table 2). Most errors occurred because we predicted farmers adapt their crop type and crop composition, while they had not considered doing this. Of the other errors, one farmer mentioned they place the watermelons in the middle not because of the elephants, but just because they like to plant them in the middle. Another farmer did adapt the crop composition because of elephants, but not in order to hide or protect the crop. They planted millet along the fence and sorghum in the middle of the field to make it easier to see the elephants come through the millet. Finally, one farmer planted watermelon and other crops they thought elephants prefer along her fence where they would expect elephants to enter in order to make them stay there, since '*hiding does not work*'.

3.3 | Role of different agents in supporting or restricting farmers

3.3.1 | Provision of material support

On several occasions, farmers referred to provisions by external agents in the interviews. The government played an important role in aiming to support farmers by the provision of materials by providing subsidies for cluster farming and electric fences to protect fields (Ministry of Agriculture Botswana, 2008a). Excluding ISPAAD financial benefits which almost all farmers reported, 79.5% of respondents also reported to receive physical governmental support, compared to, for example, only 8.5% of respondents reporting physical support from the NGO Ecoexist, mostly in the form of chilli peppers or hoes.

An example often brought up was a collaboration between the government and a NGO was a project implemented by the World Bank and the DWNP in 2009, where the World Bank provided a grant of several million dollars to the DWNP to distribute beehives and chilli fences among farmers (World Bank, 2009), though with limited uptake success, especially in the case of beehives (MEWT & DWNP, 2016; Noga et al., 2017). Our results show that beehive material was rarely accepted by farmers and never applied by farmers, and that this was mainly due to farmers' lack of knowledge and belief of effectiveness of the method. This indicated that the efficiency and equity of the provisions may have been overlooked, losing out on both the opportunity to achieve maximal conservation gain for the least money and dividing funds equitable across people (Chan et al., 2017). However, evaluations from both research and the project itself showed that low and levels of uptake, lack of ownership and commitment of the farmers towards provided mitigation methods could also be linked to inadequate involvement and consultation with farmers during design and implementation, or farmers feeling disrespected (Noga et al., 2015, 2017) and supply issues (MEWT & DWNP, 2016).

For chilli methods, it was not the distributed knowledge, but the availability of material to farmers by the combined efforts of the Department of Wildlife and the World Bank, through their Human–Wildlife Coexistence project between 2010 and 2016 (World Bank, 2016), that was decisive of farmers adopting the method, while the termination of chilli supplies formed a constraint on farmers to apply the method. The farmers part of Ecoexist's conservation-agriculture programme still regularly received chilli peppers, yet most other farmers had to stop using the chilli methods due to lack of material while considering it an effective method. This exposed the risks of trialling mitigation techniques, or temporary involvement of external bodies in providing mitigation methods. As the provision of materials created the expectation of continuous supplies and thus a form of dependence of farmers on those suppliers, farmers lost autonomy in their mitigation. Since there were no alternative sources of chilli peppers available in the area, it also reinforced a sentiment of resentfulness in the interviews with farmers. The evaluation report of the chilli and beehive Human–Wildlife Coexistence project similarly mentioned an unwillingness of farmers to invest own resources in maintaining the methods (MEWT & DWNP, 2016).

3.3.2 | Knowledge sharing support

Throughout our interviews, knowledge of methods was mentioned to be a motivator for multiple mitigation methods, especially those to be considered innovative (beehives, chilli fences) or recent developments (electric fences). Generally, farmers mentioned they heard about methods from the Department of Wildlife, the NGO Ecoexist or their neighbours. The NGO Ecoexist was mainly reported to play an informing role, with 20.5% of the people interviewed mentioned they received information from the NGO on how to avoid physical conflicts with elephants, use chilli pepper to deter them, or how to use planting basins and plant seeds early in the season. Besides learning how to apply chilli methods to their fields, farmers mentioned they were taught not to shout at or irritate elephants, and when coming across elephants to try to avoid them. Some farmers also mentioned it was explained to them that it would be better to plough once the early rains started, by either the Department of Wildlife or the Department of Crop Production or Ecoexist, and that they were encouraged to report crop consumption incidents at the Kgotla. A few of the interviewed farmers were part of a conservation-agriculture project by NGO Ecoexist, of which one of the elements is to provide support and logistics for farmers to plough early. In general, information on mitigation measures appeared not to be homogenously distributed and large parts of the population had not

heard about certain methods, especially when it comes to elephant conscious farming.

3.3.3 | Perceived restrictions

Besides providing both physical support and sharing knowledge, the government was also perceived to play a restricting role, for example by some farmers who mentioned not being allowed to gather tin cans, or being charged for poaching if an elephant would fall into their trench. In this way, political factors can undermine the uptake of individual mitigation methods by farmers, due to issues like political rumours. This could also be related to insecurity and distrust among different community groups such as agriculturalists and pastoralists (Graham & Ochieng, 2008) or community's suspicion of the use of fences to appropriate land (O'Connell-Rodwell et al., 2000).

4 | DISCUSSION

Our study allowed farmers to identify their reasoning behind their decision-making, increasing understanding about the hierarchical structure of importance of each of the types of reasons (*motivation*, *elimination* or *constraint* criteria) to uptake or not uptake a mitigation measure. Farmers were motivated by the availability of material, sufficient monetary income and belief in effectiveness. Farmers eliminated the option of using a method if material, money or manpower was not available, weather was not suitable, people did not believe in effectiveness or did believe in danger, or people had no knowledge of the method. Finally, lack of availability of material, monetary income, and belief in danger of a method or severity of elephant issues were constraints in farmers' decisions to use a certain method. Some of these constraints reflect the remoteness of the study site, which results in a relative lack of monetary income and lack of availability of materials needed to create mitigation measures, or farming in general, despite willingness to adopt methods.

Despite the consistent importance of availability or provision of methods, our results show a disparity between the materials farmers received and the methods they wished to adopt. One could argue that NGO's and government agencies have a moral obligation to test and demonstrate new, innovative mitigation techniques that have proved successful elsewhere or that show considerable promise in mitigation elephant crop consumption. Yet, one-off inputs of materials did not result in a sustainable use of mitigation methods, even if people were convinced by the effectiveness of a method, suggesting that if the right material were consistently available, adoption would be higher for those methods farmers preferred.

The complex powerful influence of government agencies and international NGOs in aiming to support farmers to live with elephants can have the effect of reinforcing systems of authority and ownership, ultimately reducing farmers' autonomy and ability to protect their fields (DeMotts & Hoon, 2012; Evans & Adams, 2016; Ogra, 2008; Ogra & Badola, 2008). Our study confirms that temporary interventions, especially when guided by ideas of outsiders and their interpretations of farmers' needs, instead of farmers themselves, can disempower farmers. These issues could be related to the hierarchical, top down, decisions regarding choice for mitigation method to be distributed, instead of a system based on voluntary exchange or on cooperation linked to community management (Chan et al., 2017; Vatn, 2010). This emphasizes the need for bottom-up approaches and participatory conservation initiatives where community members are truly involved in co-designing and leading mitigation techniques and strategies (Bowie & Dietrich, 2020).

We were able to hierarchically describe farmers' mitigation decisions and successfully predict 14 of 16 of the measures we analysed with our EDMs. Including a second testing phase to test predictability was a strength of our study, as it is often omitted or minimalized (Bravo-Monroy et al., 2016; Fairweather, 1999; Miller et al., 2014; Roth & Botha, 2009), making it impossible to validate the predictive power of their constructed decision trees (Gladwin, 1989b). This choice of method inherently puts its trust in the ability of farmers to identify the reasons behind their decisions. Asking respondents to rationalize their decision-making had the result that some elements that could be important in decision-making were unrecorded and therefore left out of our analyses, such as emotional arguments and changes in preferences (Levine et al., 2015). This could be the reason behind our inability to explain some deterrent choices, such as the preference for adding plastic to fences even when convinced of its ineffectiveness.

5 | CONCLUSION

Our results provide evidence that unlike often assumed when providing mitigation method materials, the adoption of mitigation method does not mainly rely on farmers' belief in the method's effectiveness. Instead, they will likely not uptake a method if they are—or perceived to be—constrained by the weather and lack of monetary income, manpower, or availability of material and knowledge. We therefore recommend the following five considerations when aiming to support farmers with methods to coexisting with wildlife:

1. *Co-design and sustainability of collaborations.* One-off inputs of materials did not result in a sustainable use of mitigation methods. This highlights the importance of working with the resources, skill sets, and existing inputs already present to make techniques more sustainable and the need to consult farmers and carry out co-design procedures when aiming to support farmers mitigation strategies.
2. *Logistical support to increase autonomy.* Most of the constraining factors could be solved by addressing logistical challenges obstructing involvement of farmers in business endeavours and from obtaining the desired method materials. Here we see an opportunity for external bodies such as government or NGOs to invest in logistical opportunities, such as transport abilities and by encouraging small business enterprises in the sale or construction

of mitigation materials that farmers want, increasing farmers' autonomy.

3. *Sharing of knowledge within farmers and between farmers and external bodies*. Although there were clear signs of the distribution of knowledge on different available methods, there was heterogeneity in this distribution that caused farmers to either be mis- or uninformed. There is an opportunity for the government or NGOs to facilitate community sharing of mitigation method ideas, especially regarding wildlife conscious farming, as only a few farmers used these techniques yet money plays no role in eliminating or constraining these methods.
4. *Diversification of approaches*. Farmers mentioned diverse wishes, beliefs and experiences with elephants, and a method highly preferred by one farmer was disregarded or unknown by another, and farmers mentioned that some methods worked well for some elephants but not for other 'types' of elephants, referring to elephant sex or area of origin. It is therefore important to incorporate this diversity of farmer (Evans & Adams, 2016) and wildlife (Barua, 2014; Chiyo et al., 2012; Evans & Adams, 2018) individuals in mitigation strategies.
5. *Further exploration of potential of sustainable approaches*. Although only a few farmers mentioned they used elephant aware—or wildlife conscious—farming techniques, all of these farmers were positive about their experiences. This shows the promising potential of wildlife conscious farming techniques and a need to combine long-term trials and demonstrations of new and innovative mitigation techniques to assist in the decision-making and adoption preferences of farmers during long-term strategies for coexistence.

AUTHOR CONTRIBUTIONS

Susanne Vogel conceived the idea, and Susanne Vogel, Anna Songhurst and Graham McCulloch designed the methodology; Susanne Vogel collected the data and analysed the data; Susanne Vogel and Amanda Stronza led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST

As stated in the positionality statements, all authors were involved with one of the NGO's who aimed to support farmers coexist with elephants in the study area. Please see the Extended reflexivity statement in Supplementary Information II for more details.

DATA AVAILABILITY STATEMENT

Data from Ethnographic Decision Model testing are stored on Dryad Digital Repository http://doi.org/10.5061/dryad.1jwstqjxs (Vogel et al., 2022).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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