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Abstract

In sub-Saharan Africa human-wildlife conflict (HWC) is a growing conservation issue and human-elephant conflict (HEC) is of special concern. Crop loss to wildlife comprises a main component of HWC. Deterrent methods for crop loss are numerous and such schemes could be made more effective by an improved understanding of how farmers' perceptions align with actual causes of crop loss. Our objective was to compare the perception by farmers of the causes and extent of crop damage to the measured crop damage in fields of maize (*Zea mays*) using different deterrent methods. We interviewed agriculturalists in the farming village of Miti Mirefu in northern Tanzania and documented the amount and causes of crop damage. Most participants were accurate in their perception of damage, but those who were not tended to overestimate damage. Elephant damage was infrequent but severe and participants attributed crop damage to elephants more than any other cause. Agriculturalists must also realize the detrimental effects of regular, low-level impacts such as water-scarcity and small-scale crop raiders. Our methodological approach could be useful in other areas where elephants are one but not the sole contributing factor to crop loss. In such locales, aligning human perception and actual causation of crop loss could result in more efficient and effective crop protection programs.

Additional key words: Mitigation, perception

Résumé

En Afrique sub-saharienne, le conflit humains-faune sauvage (HWC) est un problème croissant de conservation et le conflit humains-éléphants (HEC) est particulièrement préoccupant. La perte des cultures à cause de la faune sauvage comprend une composante principale du HWC. Des méthodes de dissuasion pour les pertes de récoltes sont nombreuses et ces programmes pourraient être plus efficaces par une meilleure compréhension de la façon dont les fermiers perçoivent les causes réelles de la perte des récoltes. Notre objectif était de comparer la perception par les agriculteurs sur les causes et l'ampleur des dégâts causés aux cultures par rapport aux dommages des récoltes mesurées dans des champs de maïs (*Zea mays*) en utilisant différentes méthodes de dissuasion. Nous avons interrogé des agriculteurs dans le village agricole de Miti Mirefu dans le nord de la Tanzanie et documenté le montant et les causes des dommages aux cultures. La plupart des participants étaient exacts dans leur perception des dégâts, mais ceux qui ne l'étaient pas avaient tendance à surestimer les dommages. Les dégâts causés par les éléphants étaient rares mais graves et les participants ont attribué les dommages dans les cultures aux éléphants plus que toute autre cause. Les agriculteurs doivent aussi se rendre compte des effets néfastes d'impacts réguliers et de bas niveau tels que le manque d'eau et de pilleurs de récoltes à petite échelle. Notre approche méthodologique pourrait être utile dans d'autres domaines où les éléphants sont un facteur mais pas le seul à contribuer à la perte des récoltes. Dans de tels environnements, en alignant la perception humaine et la cause réelle de la perte des récoltes, des programmes plus efficaces et rentables pour la protection des récoltes pourraient être résolus.

Mots clés supplementaires: Atténuation, perception

Introduction

In sub-Saharan Africa, crop raiding comprises a pervasive and economically damaging form of human-wildlife conflict (HWC) (Webber et al. 2007). Crop losses to wild animals are often the top perceived economic problem by small farm holders (Naughton-Treves and Treves 2005; Osborn and Hill 2005), especially in boundary areas between farms and wild lands (Woodroffe et al. 2005). While numerous species can damage crops, African elephants (*Loxodonta africana*) where prevalent are often considered the primary source of crop damage (Kangwana 1995). Further costs to communities attributed to elephants include property damage, human injury, competition over water for livestock, social disruption and the loss of productivity due to choosing guard duties over sleep (Hoare 1999; Naughton et al. 1999; Osborn and Parker 2003). Passive (e.g. fences) and active (e.g. guarding, banging pots and pans) means are used to deter elephants, but in retaliation to events such as crop-raiding, humans often kill any readily located elephants (Webber et al. 2007). Such interactions affect perceptions of those where human-elephant conflict (HEC) exists, and negative perceptions adversely affect conservation efforts (Woodroffe et al. 2005), further motivating means to reduce conflict.

Over the past 15 years, important advances have been made to address HWC and HEC (Nelson et al. 2003; Dublin and Hoare 2004; Hoare 2012). In his review of these advances, Hoare (2012) evinces the need for the implementation of socio-political measures to continue progress toward more harmonious cohabitation by humans and wildlife. Such measures entail consideration of land use practices and the successful employment of such practices necessitates acceptance by farmers. Hence, understanding the perception of farmers relative to the actual sources of crop loss is essential for the long-term reduction of HWC related to agriculture.

Interviews provide the best means for determining the attitude of the farmers toward wildlife (Badola 1998; Gadd 2005). The views by locals on HWC and HEC are shaped by the frequency and extent of crop loss, efficiency of deterrent methods, and sociological factors that shape coping strategies and risk perception (Naughton et al. 1999). Recent work on indigenous ecological knowledge of the Maasai community around Masai Mara National Reserve in Kenya shows the value of combining surveys of humans with ecological data quantification to investigate HEC and its potential mitigation (Sitati and Ipara 2012). Gadd (2005) indicated that crop raiding by elephants was a greater issue to agriculturalists than to pastoralists; hence, we examined the perceptions of farmers. We conducted interviews to evaluate the attitudes of the farmers toward elephants in comparison with alternative factors (e.g. other wildlife and lack of irrigation) that may affect crop success. Because people assess risk based on their perceptions (Renn 2004), we asked participants about sociological factors that may influence their attitudes toward wildlife. We also quantified the actual causes of crop damage following accepted practices (Hoare 1999; Dublin and Hoare 2004).

Other studies have assessed the causes of crop damage (e.g. Naughton-Treves 1998; Chiyo et al. 2005) but typically not simultaneously with assessing the perception of farmers. We realize that caution is required to generalize from a single study site and season (Naughton-Treves and Treves 2005), but the simultaneous evaluation of perception of damage and quantification of damage provides insight into how historical crop raiding has influenced the attitudes of farmers in dealing with current and future crop raiding incidents. Such an approach may be useful in other areas in which elephants are one of potentially many causes of crop loss. Thus, the main objective of our study was to compare the perception by farmers of the causes and extent of crop damage to the measured crop damage in fields of maize (*Zea mays*) using different deterrent methods.

Materials and methods

Study area

Endarakwai Ranch encompasses 4,300 ha of woodland and savannah habitat in northern Tanzania (Fig. 1; 03°00.663'S, 37°00.113'E). Since 2004, we have studied African elephants at this property, which serves as a wildlife corridor for elephants between Amboseli, Mt. Kilimanjaro and Arusha National Parks (Castelda 2011; Nasseri et al. 2011). The borders of Endarakwai Ranch are unfenced.

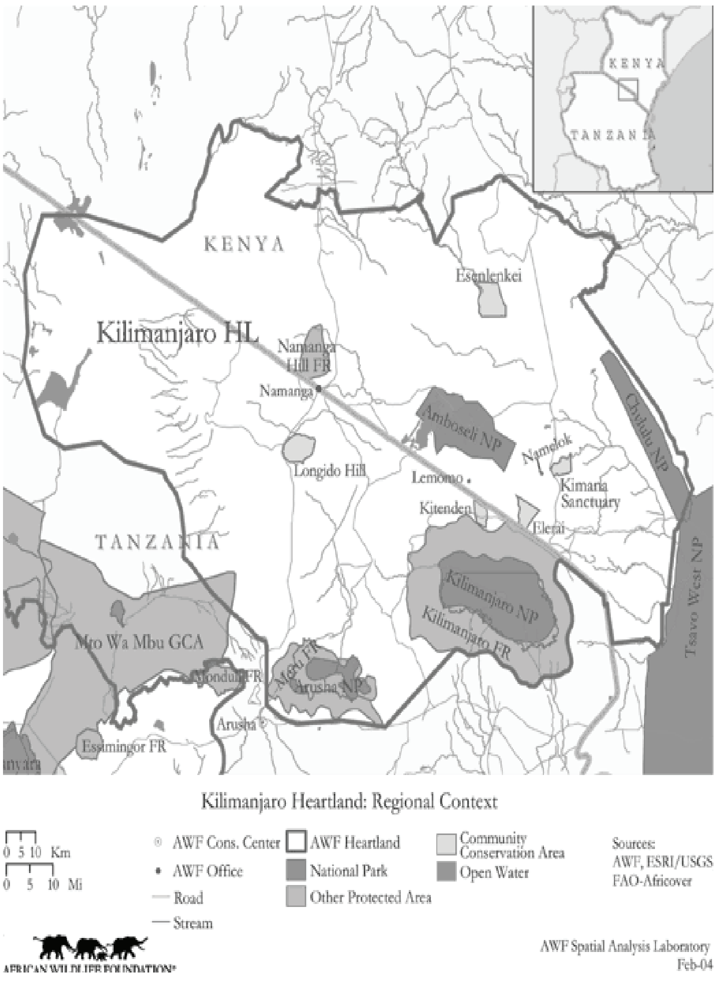

Figure 1. Location (marked by star) of the study site, Endarakwai Game Ranch (Map courtesy of African Wildlife Foundation).

The village of Miti Mirefu is composed mainly of Masai pastoralists, and agriculturalists, primarily of the Wachagga and Pare tribes. Crop seasons correspond to the expected rainy seasons. Farmers irrigate their crops by diverting water from the river. The frequency of irrigation was highly variable among farmers.

Assessment of farmers' perceptions

Interviews

We conducted the study from May to December 2008. We held two interview sessions in Kiswahili with each participant. The survey questions and interview technique were reviewed with a colleague in the psychology department at Georgia Southern University. We employed a local villager to facilitate the interview process although one of us spoke Kiswahili. During the first ten-minute interview, we obtained a signed consent form, established a relationship with the participants and gathered background information on farming practices and experience. The second interview session occurred at least two weeks later.

The second interview consisted of three sections (Appendix 1). Each section had questions that required either a yes/no response, or a selection from one of five options on a Likert Scale (e.g. strongly agree to strongly disagree), or were open-ended with specific follow-up questions explained below (Appendix 1). We used pictures (available upon request) to represent possible answers to ensure clear understanding. In section one, we asked questions to assess the participants' perception of past crop damage (pictures of damage categorized as 10%, 25%, 50%, 75% or 100% of a field). In section two, we assessed the participants' use and perception of deterrent methods and included pictures of possible active (burning fires, making noise, guarding crops at night) and passive (fences, wind chime noise makers, trenches) deterrent methods as well as means of crop maintenance such as using pesticides, herbicides, or irrigation. In section three, we focused on the present growing season. We asked participants to attribute damage to particular biotic factors (again with accompanying pictures), specifically elephants, insects, rodents, domestic animals and non-domestic animals, as well as the abiotic factor of insufficient water. We had them rank those factors by extent of damage caused and to provide an overall estimate of damage, using the same pictures of categorical damage from section one.

Perception Analysis

We interviewed 39 farmers. We used the answers to questions on their background to describe their past demographics and experiences. Because of the labour intensive nature of the damage quantification (described below), we did not measure damage at the fields of 25 participants. Therefore, we omitted questions that focused on the quantification of damage for these participants. For questions involving ranking answers from most to least, we used a five-point scale with a value of 5 given to the cause of the greatest damage.

Quantification of crop damage

We limited quantification of damage to maize, the major crop under cultivation. Fourteen fields were available for quantification of crop damage within our logistic constraints. All fields were in full sun with no shade trees. We visited fields between 0830 h and 1530 h. We measured basic initial abiotic characteristics of the fields (N, K, P categorical levels, soil moisture, light and pH) but because of low variation between fields, we did not consider these factors further. Using a Garmin GPSMAP® 60CSx, we recorded GPS coordinates at the corners of each field to determine area. We classified the stage of maize as follows: (1) <0.3 m, (2) location of ears visible but not yet present, (3) immature ears present, (4) mature ears present on less than 50% of stalks, (5) mature ears present on the majority of stalks, or (6) varying, indicating two or more of the previous five stages were present in a single field.

We estimated yield for the fields that were classified as categories 3–5. We performed two perpendicular samples in areas without damage, each of 12 m length, to estimate yield. To minimize edge effect, we sampled 6 m from the edge. We recorded the number of stalks and ears of maize that were present within each 1.2 m belt transect, and we calculated the mean ears per stalk for each field.

On small fields, we estimated damage around the perimeter. On larger fields, where the sum of the belt transect did not equal 10% or more of the area, we also used a centre belt transect parallel to the longest side. We categorized damage by causative factor (baboon, bird, bushpig, cattle, elephant, goat, insect and/or lack of water); we attributed damage to the predominant factor when damage from multiple factors was evident. While we assessed maize growth and damage weekly, we analysed final damage assessed within the week prior to harvest.

We calculated the mean proportion of damage (d) for each factor. We further examined crop damage by calculating the frequency of damaging visits (Fd) by each of the damage factors. This frequency was multiplied by the average proportion of damage (Fd × d). We used the resulting ranked damage factors to compare quantified damage to the perceived damage. We estimated the yield of a field that was damaged by each factor by calculating the total undamaged yield (Yu) of a field; this value was multiplied by the proportion of damage (Pd) attributed to each damage factor (Yu × Pd). The result was an estimate of the yield damaged by each factor for individual fields. From all fields, we determined the median of estimated loss of yield for each factor. We noted whether farmers used deterrent methods and whether these were active (e.g. night-guarding and scaring animals away) or passive (e.g. trenches or acacia fences) or both.

Comparison of crop damage and farmers' attitudes

We compared the actual quantification of crop damage and the factors that caused damage to the factors the farmers perceived as contributing to damage. We calculated the accuracy of perception by using the difference between perceived (P) and actual (A) damage. We used linear regression to examine if actual damage was related to perceived damage. A value of zero for the difference (P – A) would indicate perfect accuracy (slope of one and y-intercept of zero). A negative accuracy of perception indicated that the farmer underestimated damage (positive y-intercept); a positive accuracy of perception indicated damage was overestimated (negative y-intercept). Interviewees were considered inaccurate if the difference between perceived and actual proportions of damage exceeded 0.2. A small difference between perceived damage and actual damage was expected due to the use of categorical data during the interview sessions. We examined if attributes of farmers (background, practices such as means of protecting their fields) were associated with perception of damage. We used answers to the interview demographic questions to identify distinguishing characteristics of the groups (accurate or inaccurate farmers). Statistical analyses were performed using JMP 7.0.1.

Results

Background of farmers

The participants that completed both interview sessions had similar backgrounds. The average duration of living in Miti Mirefu was 18 ± 2.1 yr, with 77% (30/39) living in the village for over 10 yr. Eight participants were born in Miti Mirefu, while 79% (30/38) immigrated from nearby (within 200 km) towns or villages. Participants depended on agriculture as their primary source of income for 19.8 ± 2.1 yr. The majority (77%: 30/39) did not have an occupation outside of farming, while seven (18%: 7/39) had a previous occupation other than farming but had changed to farming only. The majority of participants had attended school for seven years (64%: 25/39); two participants (5%) had more than seven years of schooling; five (13%) had no schooling. Two participants (5%) had taken agricultural courses, but the majority (95%: 37/39) had no formal agricultural education. All participants depended on the yield from their crop as a source of income.

Perception assessment

The majority of participants (77%: 30/39) had lost an entire crop's yield in the past. Some farmers experienced more than one complete loss over their history of farming, so we included each event, which is why the grand sum of the percentages exceeds 100%. Of those experiencing one or more complete loss events, participants attributed complete loss to elephants (*Loxodonta africana*; 83%: 25/30), bushpig (*Potamochoerus larvatus*; 47%: 14/30), baboons (*Papio anubis*; 33%: ; 33%: 9/30), or a lack of rain or irrigation (33%: 9/30). Sixty-seven percent (20/30) of complete damage in a single season was perceived to be caused by combinations of these factors.

Ninety-five percent of participants (37/39) had repeated problems with the same damage factor. Among insects, rodents, domestic animals, elephants and other wildlife, the majority of participants (69%: 27/39) predicted that elephants were most likely to damage their crop during the current growing season. This followed from the majority of participants (72%) answering that elephants had caused the most damage to their fields historically. Most participants (59%: 23/39) strongly agreed that they were worried about factors that had damaged their crops in the past affecting their crop yield again. These factors were primarily elephants, other wildlife and insects; no participants chose domestic animals or rodents.

Crop damage quantification

Damage by elephants had an interesting profile. The

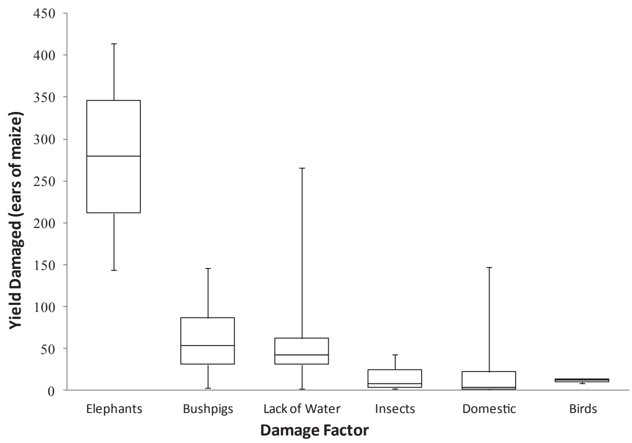

Figure 2. Damage to maize occurring in measured fields was attributed to several damage factors. Estimated yield damaged was calculated by multiplying the mean proportion of damage from each factor by the mean yield of the crop. Upper box marks the third quadrant and lower box indicates the second quadrant. The dividing line marks the median and bars encompass the full range of measured data.

largest median of loss of yield (ears of corn) in a field was attributed to elephants (Fig. 2). Elephants caused damage to fields significantly less frequently than other wildlife (Likelihood ratio, $\chi 2 = 13.07$, df = 3, p = 0.0045). When the damage factors were categorized by combining bushpig, baboon, and birds, the maximal damage was similar to that caused by elephants (Fig. 3). Damage by insects was evident in 58% of the fields compared to 21% by elephants.

Crop damage was not related to deterrent method. There was no difference in mean proportion of damage to fields using active only (n = 6, 43 ± 12.8%) or active plus passive (n = 6, 26 ± 7.0%) deterrents (t = 1.16, df = 8, p = 0.28). No farmers used just passive deterrents. The two fields that used no deterrents had 34.6 ± 12.6% mean damage; one of these field incurred crop raiding by elephants as did one field with active deterrents.

Actual damage and perceived damage

Of the fourteen fields and farmers from which both damage was quantified and perceptions assessed, nine participants were accurate (<0.2 difference in perceived minus actual proportion of damage) in their perceptions of crop damage experienced (Fig. 4). Five participants overestimated crop damage (Fig. 4). These two groups of farmers did not significantly differ in the following attributes (median values, all p > 0.05): years of formal education (7–7 yr), field size (1590–2482 m2), farming experience (18–31 yr) and duration of stay in Miti Mirefu (12–13 yr). The relatively small sample size (n = 9 for accurate and n = 5 for over-estimators, respectively) and the high variance for each measure contributed to the inability of these measures to distinguish the two groups.

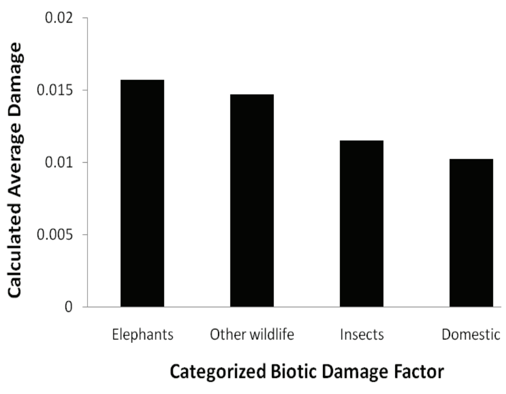

Figure 3. The proportion of fields damaged multiplied by the average damage proportion of a field by each biotic damage factor. Y-axis = (proportion of fields damaged* average damage); for the sake of clarity, the scale bar has been truncated at 0.02

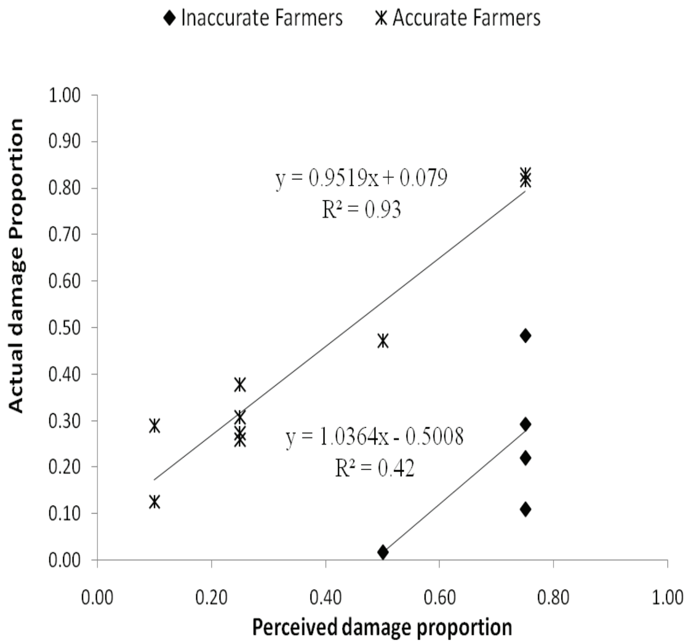

Figure 4. Perceived verses actual damage proportions. Nine participants were accurate in their perception of crop damage experienced (n = 9). Five participants overestimated crop damage experienced (n = 5).

While 79% (11/14) of participants strongly or mildly agreed that their crop was irrigated adequately, 93% (13/14) listed a lack of water as a factor that affected crop success. We determined that 86% (12/14) of fields experienced damage due to a lack of water. The average percentage of maize that was damaged by a lack of water was 18%, while the mean area damaged by other biotic factors excluding elephants was 11%.

There was no association between farming experience and damage attributed to a lack of water (pairwise correlation, $r = -0.33$, $p = 0.24$).

Discussion

The objective of this study was to compare the perception by farmers of the extent and factors causing crop damage to the actual damage experienced in their fields of maize over a single growing season. The application would be to implement this dual approach in other areas and on a larger scale with the goal of improving the efficiency of yield production for farmers. The 39 interviewees perceived elephants to be the greatest risk to debilitating crop yield. Our quantified data indicated that elephant damage was infrequent but severe when it occurred. Overall, elephants were in fact the greatest risk to the maize crop. However, this is treating the farmers communally. Most farmers did not experience elephant raiding in the current season but all experienced other, regular damage. Nevertheless, our study suggests that participants base their perception on the severity more than the frequency of damage. We need to determine if this infrequent but severe impact is broadly applicable across the range of elephants. Naughton-Treves (1998) stated that only crop damage by elephants led to farm abandonment. Elephants also can damage property, disrupt schedules and kill humans (Gadd 2005). Hence, this relationship between damage frequency, extent of destruction and human perception may be unique to elephants. Community-based conservation programs that inform community members on the positive aspects of elephant ecology could be beneficial (Kuriyan 2002), but such programs would work better if the severity of elephant impacts on humans were reduced (O'Connell-Rodwell et al. 2000).

While we only sampled in this one area, Miti Mirefu has characteristics that are typical of many areas that experience crop losses from a multitude of sources across East Africa and much of sub-Saharan Africa. It is a self-contained village for which farming is the primary source of sustenance and income. It also borders a protected area that offers refuge to wildlife. We felt it was better to focus our efforts over a region for which we could quantify crop damage, rather than to conduct broad scale surveys, which have been done before in Africa and Asia. We also had a good rapport with the local people, facilitating participation and interest in our study.

Interviewees rated the destruction of a cornstalk as more detrimental than the removal of or damage to maize ears. Lack of water, elephants and bushpigs were the most likely means by which maize stalks were destroyed. In contrast, baboons and insects foraged on particular ears, permitting some harvest from these plants. Inadequate water was a persistent and visible problem, although participants responded that their fields were adequately watered. Throughout the study, there was no rain, requiring participants to use laborious irrigation. This strenuous work may have reduced the regularity of irrigation (Sutton et al. 2004). Improving crop viability is at odds with increased attractiveness to wildlife. Irrigation that requires lower effort and growing drought resistant varieties would likely improve crop success; however, richer crop fields could also be more attractive to wildlife.

Some individuals (5/14) overestimated damage to their crop fields. Through our questionnaire, we examined the factors of education, field size, farming experience, and time spent in the area. None of these factors was related to perception. These five farmers had lived on average for over a decade longer in Miti Mirefu and had been farming for almost twice as many years as the nine accurate estimators. Clearly, overestimation is not because of inexperience or unfamiliarity. We need further work to identify characteristics useful for predicting the accuracy of farmers in assessing damage.

Land-use planning can be helpful in reducing the likelihood of crop raiding; farms in low-density settlements such as Miti Mirefu and located near wildlife refuges are particularly susceptible to crop damage (Nyhus et al. 2000; Graham et al. 2010). Where elephants are somewhat infrequent causes of crop damage, the perception of future damage appears to be formed by the severity and not the frequency of past damage. This may occur despite other factors such as lack of water and small-scale crop raiders having more regular impact on crop yield. Informing farmers of the results of surveys and crop damage quantification might be helpful in enhancing the efficiency of crop production. Thus, it may be worthwhile to extend our two-pronged approach to other regions. An understanding of the perception and the actual causes of crop reduction or failure is integral to development of successful conservation and agricultural strategies.

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Appendix 1

The second interview session was divided into 3 groups of questions and assessed the perceptions of participants' past damage, use of deterrents, and current damage attributed to certain factors.

Group A. Past damage perception

Participants were asked to assign an extent to the following questions:
1 = some; 2 = medium amount; 3 = large amount; 4 = near complete; or 5 = complete damage.

A1.* What is the most damage you have experienced in the past?
A2.* How much damage did you experience last season?
A3. What is the minimum amount of damage you have experienced in the past?
A4.* How much damage can you withstand and still have enough to feed your family?
A5.* Is this income earned from the crop? (y/n)
A6.* Is this food from the crop itself? (y/n)

Participants were shown pictures depicting: 1 = some damage (<10% of a field); 2 = medium amount of damage (10–25%); 3 = large amount of damage (25–50%); 4 = near complete (50–75%); or 5 = complete damage (75–100%)

A7. How much damage can you withstand and still have enough to feed your family?
A8. Is this income earned from the crop? (y/n)
A9. Is this crop used to feed your family directly? (y/n)
A10. What is the most damage you have experienced in the past?

Group B. Deterrent method perception

For some of the following questions, participants were asked to identify to which extent they agree with the statements: A = strongly agree; B = mildly agree; C = undecided or unsure; D = mildly disagree; or E = strongly disagree.

B1 Have you used methods to prevent damage in the past? (y/n)
B2 When I used methods to prevent damage, it was effective and less damage was experienced.
B3* Do you use pesticides? (y/n)
B4* Have you used pesticides? (y/n)
B5* Do you use fertilizer? (y/n)
B6* Have you used fertilizer? (y/n)
B7 I provide adequate water for the crops in my fields.
B8 There are deterrents I believe would be effective for my crops.
B9 If you strongly agree with B8, why haven't you tried them? (a) they are expensive; (b) they take a lot of work; (c) it is difficult to find the needed materials; (d) other

Participants were presented with a number of pictures including: (1 = active) a guard, a gun, a fire; (2 = passive) a trench, a string fence, a string fence with 'bells' attached, a chilli pepper, a 3-m clearing on both sides of a fence; (3 = crop maintenance) pesticides, fertilizer, water diversion.

B10 Do you see any pictures of methods that you feel will reduce crop damage in your fields? (y/n)
B11 If yes to #B10, which pictures show the methods you feel will be effective?
B12 If more than one answer to B11, rank them.
B13 Have you used any of the deterrent methods pictured? (y/n)
B14 If yes to #B12, which pictures shows the methods you have used?
B15 If yes to #B12, were they effective? (y/n)
B16 Are any of these deterrent methods are successful in farms in the area? (y/n)
B17 If yes to #B16, which methods are successful in the area?
B18 If more than one answer to #B17, rank them:

Group C. Perceived factors causing damage

Open- ended

C1 In the past, have you lost an entire season's yield? (y/n)
C2 If yes to #C1, which factor was the loss due to?
C3 What has caused damage to your crops in the past?
C4 If more than one answer to #C3, rank them from most damage to least damage caused:
C5* What factors are you worried will affect your crop success?
C6* If more than one answer to #C5, rank them from most worried to least worried:

Participants were presented with a variety of pictures including: 1/2 = insects & rodents: locusts, grasshopper, beetles, tomato insects; field mice, rats; 3 = domestic: cattle, goats, sheep, donkeys; 4 = non-domestic: bushpig, impala, wildebeest, zebra, baboons; 5 = elephants.

C7 Which of these pictures is most likely to damage your crop this season?
C8 Which factor has caused damage to your crop this season?
C9 Using pictures of damage, how much damage did the factor from #C8 cause?

1 = some damage (<10% of a field); 2 = medium amount of damage (10–15%); 3 = large amount of damage (25–50%); 4 = near complete (50–75%); or complete damage (75–100%)

C10 Which factor has caused the most damage in the past?
C11 I am worried that the factor from the answer to #C10 will again cause damage during the present growing season. A = strongly agree; B = mildly agree; C = undecided or unsure; D = mildly disagree; or E = strongly disagree.
C12 Using past experiences, which factor could cause the most damage?
C13 Have there been repeated problems with a particular factor(s)? (y/n)
C14 If more than one, rank them from most worried to least worried.

* indicates questions that were excluded for the interviews that excluded damage quantification