Human–African buffalo conflict: perceptions of damage, and mitigation strategies, in villages bordering Ngorongoro Conservation Area, Tanzania

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Abstract Human–wildlife conflict is a critical and complex challenge in wildlife conservation. It arises when humans and wildlife interact and one or both parties suffer negative consequences from the interaction. This research assessed the extent of damage resulting from human–African buffalo *Syncerus caffer* conflict and explored mitigation strategies. We used a semi-structured questionnaire-based survey of 131 households randomly selected in Kambi ya Simba, Oldeani and Tloma villages surrounding Ngorongoro Conservation Area, Tanzania. Our results revealed that resource competition was the main factor inducing human–African buffalo conflict. The impacts reported most frequently were crop damage (especially during the wet seasons) and human casualties. Crops that were most often damaged included maize, beans, wheat, peas and coffee. To minimize buffalo crop depredation, farmers currently use traditional mitigation approaches such as guarding farms, lighting fires, using torchlight and vocal and other auditory deterrents. In addition, a local coffee estate installed electrified fencing around its plantation. Our findings demonstrate the impacts of human–African buffalo conflict on local communities and the importance of continuing human–African buffalo conflict monitoring to improve conservation action and increase the participation of the local community in conservation activities. To minimize human–African buffalo conflict, we recommend conservation strategies that improve the natural habitat of the African buffalo. Most importantly, providing communities affected by human–African buffalo conflict with modern and more effective mitigation methods, paired with increased community awareness of the use of these methods, could result in significant reductions in the human cost of human–African buffalo conflict.

Keywords African buffalo, crop damage, crop raiding, human–buffalo conflict, Ngorongoro Conservation Area, *Syncerus caffer*, Tanzania

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Introduction

Human–wildlife conflict is a critical and complex challenge facing wildlife conservation in many areas (Lamarque et al., 2009; Erena et al., 2019; Zimmermann et al., 2020; Kiffner et al., 2021). Human–wildlife conflict occurs when interactions between humans and wildlife lead to negative outcomes for one or both parties (Hariohay et al., 2018, 2019; Abukari & Mwalyosi, 2020). Although this problem has been recognized for many years, an escalation in conflicts, especially in areas with large or increasing wildlife populations, underscores the need for improved management strategies to facilitate human–wildlife coexistence (Acharya et al., 2016). Human–wildlife conflict is a growing problem globally, occurring in almost every region where human communities and wildlife share limited resources (Barua et al., 2013; Dickman et al., 2014; Mukeka et al., 2019; IUCN, 2023). Various management approaches have been used to mitigate such conflicts, but they are often ineffective, inadequate, technologically challenging or too costly for rural communities (Zahle, 2013).

In East African countries most human–wildlife conflicts arise because of changing land uses in regions close to protected areas (Hariohay & Røskaft, 2015; Hariohay et al., 2017; Mayengo et al., 2017). Most rural people in East Africa depend on livestock herding and agriculture, livelihoods that are vulnerable to increased human–wildlife conflict (Raikes, 1981; Dickman et al., 2014; Togoch et al., 2018). Conflicts occur in the form of livestock depredation, crop damage or human injuries or deaths caused by wildlife (Mashalla & Ringo, 2015). Many large mammals are involved in human–wildlife conflict, including large carnivores such as the lion *Panthera leo*, leopard *Panthera pardus* and spotted hyaena *Crocuta crocuta*, and large herbivores such as the African savannah elephant *Loxodonta africana*, hippopotamus *Hippopotamus amphibius* and African buffalo *Syncerus caffer* (Mukeka et al., 2019). Human–wildlife conflict can result in the death of both animals and people, and threatens the livelihoods of millions of people, potentially jeopardizing the long-term goals of conservation. Losses incurred by farmers and livestock owners have considerable consequences for community livelihoods, affecting the safety and well-being of people and also leading to food shortages (Dickman et al., 2014). People often retaliate by killing problem animals (Megaze

et al., 2017), and some retaliatory approaches, such as poisons and snares, are non-selective and can kill non-target animals (Fay, 2022).

Human–African buffalo conflict is exacerbated by encroachment of agricultural activities and livestock into protected areas, resulting in reduced quantity and quality of natural habitat for buffalo populations (Ntongani et al., 2010). The expansion of human activities in critical wildlife movement corridors both limits use of space by wildlife and increases interactions between wildlife and people, heightening overall human–wildlife conflict. Where protected areas are not fenced, animals can freely move in and out (Okello et al., 2015; Acharya et al., 2016). Conflict often arises where animals move outside protected areas into human-dominated landscapes (Beck et al., 2019; Shaffer et al., 2019; Sibanda et al., 2022). For example, African buffaloes that leave protected areas have been found to feed on crops, resulting in costly damages to farmers' livelihoods (Sawyer et al., 2011). Furthermore, direct interactions between people and buffaloes roaming outside protected areas can result in human injuries and even deaths (Dunham et al., 2010; Hariohay et al., 2017). These in turn can lead to retaliatory killings of buffaloes (Kaswamila, 2009).

Resolving human–wildlife conflict and achieving peaceful human–wildlife coexistence is a complex endeavour because conflicts vary with spatial and cultural dynamics. Various approaches have been recommended for mitigating such conflict, involving both long- and short-term preventative strategies (Distefano, 2005; Osipova et al., 2018; MNRT, 2020). However, these are often difficult to realize, especially if the conflict is not well understood (O'Brien et al., 2018). Here we investigate human–African buffalo conflict in villages adjacent to a protected area in northern Tanzania, to establish the causes of this conflict, determine the extent of damage caused by buffaloes and examine the mitigation measures used by farmers. We tested two hypotheses: (1) because crops are more accessible close to protected area boundaries, the impact of human–African buffalo conflict will be greater on farms < 1 km from protected area boundaries than on farms further away from these boundaries, and (2) because crops are cultivated in the wet season (January–June), there will be a higher frequency of crop damage incidents in this season than in the dry season (crops such as maize and pigeon peas develop energy-rich seeds at the end of the wet season).

A detailed understanding of conflict dynamics would enable management authorities to tailor their interventions to specific areas and demographics. This could involve targeted education and awareness programmes (i.e. equipping communities with knowledge about buffalo ecology, coexistence practices and conflict prevention strategies), implementing buffer zones and wildlife corridors (to reduce direct interactions between people and buffaloes) and providing livelihood support or compensation schemes (to mitigate the negative economic impacts of such conflict and foster coexistence). Furthermore, the findings from this study could inform policy decisions at the local and national level, such as those regarding the development of land-use policies (i.e. ensuring peaceful coexistence by balancing conservation needs with human development aspirations), the allocation of resources for conflict mitigation (i.e. prioritizing areas with the highest levels of conflict and the most vulnerable communities) and support for community-based conservation initiatives (i.e. empowering local communities to participate in finding solutions and managing conflict effectively).

Study area and species

We conducted this study in the villages of Oldeani, Tloma and Kambi ya Simba in the Karatu district adjacent to the southern border of Ngorongoro Conservation Area (Fig. 1). Karatu is the fourth largest district in the Arusha region, covering c. 2,300 km², and is home to various ethnic groups, including the Iraqw, who are agro-pastoralists, the Hadzabe and Datooga, who are hunter-gatherers, and nomadic pastoralists. Karatu district is characterized by bimodal seasonal rainfall (TMA, 2022). During October–December there is a short rainy season followed by a short dry season, and during March–May there is a long rainy season (Seregina et al., 2019; TMA, 2022). Consequently, there are harvest periods in February and July following the short and long rainy seasons, respectively (Mwabumba et al., 2022).

The African buffalo is present in most Sub-Saharan African countries (Caron et al., 2023). Its morphology and diet resemble those of domesticated cattle. It is categorized as Near Threatened on the IUCN Red List, with a declining population (IUCN SSC Antelope Specialist Group, 2019; IUCN, 2023). The global estimate of the buffalo population is 569,000–573,000 (398,000–401,000 mature individuals), with a decline of 18% during 1999–2014 (IUCN, 2019). The African buffalo is one of the largest mammal species involved in human–wildlife conflict (Mahaney, 1987). This conflict is a result of the increased human population, loss of wildlife habitat and land-use change, which can lead to crop damage by buffaloes and subsequent confrontations with people (Butynski et al., 1997; Kagoro-Rugunda, 2004), and poaching (Macandza et al., 2004; Kahler & Gore, 2015; Erena et al., 2019; Moreto, 2019). These interactions result in an estimated 200 human deaths annually (Mukamuri et al., 2023), highlighting the need to study human–African buffalo interactions, especially in densely populated ecosystems.

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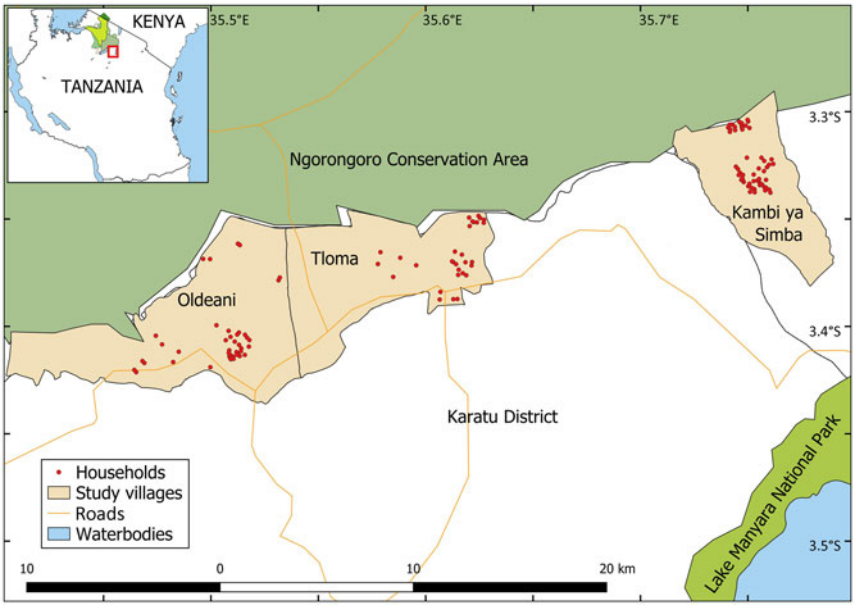

FIG. 1 The Karatu district, showing the three study villages of Oldeani, Tloma and Kambi ya Simba adjacent to Ngorongoro Conservation Area in northern Tanzania.

Methods

Sample units and design

During May–June 2022, we conducted a questionnaire-based survey of 131 households in the three villages (Supplementary Material 1) and key informant interviews with the district Game Officer and Village Executive officer of each village (Supplementary Material 2). We purposively selected three of the 14 villages that have a shared boundary with the southern border of Ngorongoro Conservation Area. The estimated number of households, as obtained from each village leader at the time of this survey, were 1,762 in Oldeani, 2,541 in Tloma and 1,308 in Kambi ya Simba.

We used a mixed methods approach to obtain data on human–African buffalo conflict, including primary data from the questionnaires and key informant interviews, and secondary data from human–wildlife conflict official reports. The 131 heads of household were randomly selected from the register books of the three selected villages. Before the questionnaires were administered, we explained the main purpose of the study to the village executive officer or chairperson, to obtain permission to administer questionnaires in the respective households. To ensure we obtained a representative sample, questionnaires were administered to any adult member of the household if the head of the household was not present. We prepared the questionnaire in English, and the interviewer translated it into Kiswahili or into a local language with the help of local translators if the respondent did not understand Kiswahili. Respondents were asked whether they had encountered conflict with African buffaloes during 2016–2022.

Authors KMH and EBM administered the questionnaires and conducted the key informant interviews. We anonymized respondent data by numerically coding the names of the 131 heads of household. We did not ask respondents for their names at any time during the data collection stage, and we avoided leading questions.

We recorded age, gender, level of education and occupation, and anecdotal information on the nature and causes of any human–African buffalo conflict in the area, specifically the extent and type of damage and mitigation strategies used by local communities over the previous 12 months.

We collected secondary information from human–wildlife conflict reports for 2016–2022 prepared by the Ngorongoro Conservation Area Authority, the Karatu District Wildlife Officer and the coffee estate managers in Karatu (personal communications). To understand the extent and impact of human–African buffalo conflict in the study area, we also supplemented these data with field observations and photographed evidence of human–African buffalo conflict and mitigation methods used by local communities.

Data analysis

We coded and analysed the questionnaire data forms using *SPSS 24* (IBM, 2011). We used descriptive statistics to summarize the questionnaire response data, and Pearson's χ^2 analyses to examine any differences in factors causing human–African buffalo conflict and variation in extent of crop damage between the villages. We used multinomial logistic regression analysis to examine the influence of village, gender, age, education level, residency and occupation on the opinion of respondents regarding the extent of human–African buffalo conflict (categorized as severe, moderate, not a problem and do not know). All statistical tests were two-tailed and based on a 95% confidence

interval. We used cumulative linked mixed models to analyse the frequency of conflict events over time, incorporating incident history, socio-economic activity and village-level factors to examine the drivers of human–African buffalo conflict.

Results

Demographic and socioeconomic characteristics of the respondents

All 131 respondents were residents of Kambi ya Simba (55, 42%), Oldeani (46, 35%) and Tloma (30, 23%). The majority of respondents were male (56%). Respondent age groups were 18–30 years (34%), 31–45 years (31%), 46–60 years (32%) and > 60 years (3%). The social and economic activities of most of the respondents were agriculture (cultivation of maize, wheat, pigeon peas, beans and coffee; 64%) followed by business (21%), livestock-keeping (8%), casual labour (3%) and other combined economic activities (4%). The residency durations of the respondents were 1–5 years (10%), 6–10 years (8%), 11–15 years (21%) and > 15 years (61%).

Causes of human–African buffalo conflict

Perception of the factors causing human–African buffalo conflict varied significantly between villages, with the majority of respondents in Kambi ya Simba (69%) and Oldeani (63%) reporting the main factor to be competition for food and water resources, whereas 33% of 30 respondents in Tloma reported encroachment on the buffalo migration route and 23% reported human population increases as the main factors ($\chi^2 = 21.53$, df = 6, P = 0.001). Reported conflict varied significantly between seasons, with the majority of respondents (61%) reporting conflict during rainy seasons, 27% reporting conflict during dry seasons, and 12% being unsure ($\chi^2 = 20.31$, df = 4, P = 0.001).

The extent of human–African buffalo conflict

Most respondents (66%) reported incidents of human–African buffalo conflict in their village, and we recorded numerous examples of buffalo incursions. Respondents noted that they had experienced threats and attacks from buffaloes during 2016–2022; many (44%) reported that family members had been attacked by buffaloes, with most attacks (56%) occurring whilst people tended their farms (Table 1). The perceived extent of the reported conflict varied significantly between villages, with the highest reported in Oldeani (98% of 46 respondents) followed by Kambi ya Simba (71% of 55) and Tloma (10% of 30; $\chi^2 = 63.65$, df = 2, P < 0.0001).

Data from the Karatu District Wildlife Officer indicated that in 2019–2021 a total of 36.62 ha of crops in the vicinity of the three villages had been damaged by buffaloes. The greatest annual mean loss per household was recorded in Oldeani (0.93 ha), followed by Kambi ya Simba (0.89 ha) and Tloma (0.49 ha) but with no significant difference between the villages ($F = 1.03$, df = 2, P = 0.367), and no relationship between crop area damaged and distance of the farm from the protected area boundary ($\beta = 2.2$, SE = 1.4, $t(42) = 4.8$, P = 0.830). Respondents indicated that the crop most frequently damaged by African buffaloes was maize (38% of respondents) followed by coffee (34%), wheat (11%), beans (11%) and peas (6%). There was a significant difference between villages with respect to the type of crop grown: most of the respondents in Oldeani (52%) and Tloma (63%) cultivated coffee, whereas 64% of the respondents in Kambi ya Simba cultivated maize ($\chi^2 = 54.64$, df = 8, P < 0.001).

During 2016–2021 four people were killed and six injured by buffaloes in the study area, whilst guarding their crops or searching for firewood. Of the four people killed, three were from Kambi ya Simba and one was from Oldeani. Three of the reported injuries were in Oldeani, two in Kambi ya Simba and one in Tloma.

TABLE 1 The occurrence and extent of human–African buffalo conflict in three villages bordering Ngorongoro Conservation Area, northern Tanzania, determined from responses to quesions regarding occurence of conflict, threats from buffaloes, attacks on family members and damage to crops (Fig. 1).

Question	Response	n	Response by village (%)			χ^2	df	P
			Oldeani	Kambi ya Simba	Tloma			
Are there human–buffalo conflicts in your village?	Yes	87	51.7	44.8	3.5	63.64	2	< 0.0001
	No	44	2.3	36.4	61.3			
Did you face attacks/threats from buffaloes during 2016–2022?	Yes	100	35.0	42.0	23.0	0.003	2	0.998
	No	31	35.5	41.9	22.6			
Have your family members faced attacks from buffaloes?	Yes	57	36.8	45.6	17.6	1.66	2	0.435
	No	74	33.8	39.2	27.0			
Have any of your farms been damaged by buffaloes?	Yes	73	53.4	41.1	5.5	37.62	2	< 0.0001
	No	58	12.1	43.1	44.8			

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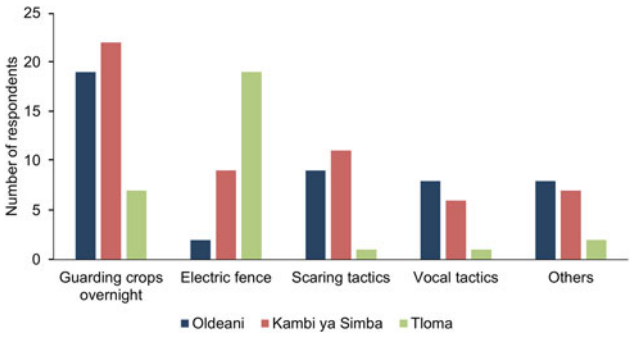

FIG. 2 Human–African buffalo conflict mitigation measures used by the 131 respondents in the villages of Oldeani, Kambi ya Simba and Tloma in Karatu district, northern Tanzania (Fig. 1).

Using multinomial logistic regression to examine the influence of village, age, gender, economic activity and duration of residency on the opinion of respondents regarding the extent of human–African buffalo conflict, only village significantly explained variation in the opinions of respondents on the extent of the conflict (67.2%; $\chi^2 = 112.69$, df = 4, $P < 0.001$).

Most Oldeani respondents (94%) rated the extent of damage by buffaloes as severe, whereas 83% of respondents in Tloma perceived buffaloes as not being a problem in their village and 38% of the respondents in Kambi ya Simba rated the extent of damage as moderate. The cumulative link mixed model showed that the perceived extent of conflict was the result of a mixed interaction between frequency of occurrence (Oldeani: $Z = -1.11$, $P < 0.0001$; Tloma: $Z = 1.35$, $P < 0.0001$) and number of years of residency in the village (Oldeani: $Z = -6.49$, $P < 0.0001$; Tloma: $Z = 2.5$, $P < 0.0001$).

Strategies to minimize human–African buffalo conflict

Various mitigation measures are used to minimize human–African buffalo conflict in villages bordering Ngorongoro Conservation Area, and the main mitigation measures varied significantly between villages ($\chi^2 = 39.94$, df = 8, $P < 0.0001$; Fig. 2). In Tloma 63% of respondents reported that electrified fencing installed around coffee farms is the main mitigation measure, whereas in Oldeani 53% reported using primarily vocal noise tactics, and in Kambi ya Simba 52% reported the use of deterrence tactics such as vocal noise, fire and flashlight torches as the main methods (Fig. 2). All other mitigation measures combined comprised 47% of the methods used. These included the use of beehives and chili fences, especially in Oldeani.

Discussion

Factors underlying human–African buffalo conflict

Competition for water and food resources was the main factor underlying human–African buffalo conflict reported by most of the respondents in the three villages. According to the respondents, buffaloes leave Ngorongoro Conservation Area during the rainy seasons to forage in crops when they are most palatable and nutritious, and during the dry season they remain within the protected area as it is a reliable source of water. These findings support our second hypothesis and are consistent with findings in Kenya (Mukeka et al., 2019) and Ethiopia (Geleta et al., 2019). Other studies, however, found that African buffaloes move out of protected areas in search of water in the dry season when water is a limited resource there (Erena et al., 2019; Moehlman et al., 2020). Consistent with previous findings around Ngorongoro (Nyerembe & Bushesha, 2021), our study shows that human–African buffalo conflict involves crop depredation, human injuries and deaths and damage to property.

Land-use changes are another major reason for human–African buffalo conflict in Ngorongoro Conservation Area, where buffer zones have been converted to agricultural crop fields. Farms nearest the Conservation Area face the highest threats of conflict, especially at night, when many wildlife species are most active before re-entering the protected area early in the morning, as has been shown previously (Meyer & Börner, 2022). However, according to the respondents, during the rainy season buffaloes do not return to the protected area but remain concealed in small patches of bushes, shrubs and unfenced coffee farms outside the protected area. The respondents suggested that buffaloes do not return to the protected area at night to avoid predators and because their movement is restricted by blocked wildlife corridors, most of which have been converted to crop fields and settlements. Previous research has indicated that the conversion of natural habitats to farms results in increased human–wildlife conflict because of crop predation and attacks on humans (Von Gerhardt et al., 2014; Stoldt et al., 2020). Buffaloes require a large home range, and loss of habitat results in changes in their activity pattern and heightens anti-predator aggressive behaviours as they move out of protected areas to forage (Kaszta et al., 2016).

The extent of human–African buffalo conflict

The extent of damage resulting from human–African buffalo conflict varied between the three villages, with 80% of the reported conflict occurring in Oldeani, where the most reported impacts were human deaths and injuries, and crop damage. The African buffalo is an aggressive species and, in many of these cases, human injuries or deaths result from a physical confrontation in which people attempt to defend themselves or interfere with buffalo activity. There was, however, a perceived reduction in the extent of human–African buffalo conflict in Oldeani because of the erection of electric fences around coffee plantations compared with perceptions at Kambi ya Simba, which had unfenced maize and wheat farms.

Our first hypothesis, that farms located < 1 km from the protected area boundary would experience greater crop losses compared to those > 1 km away, was not supported because distant farms also experienced significant losses. This is most likely because most of the farms are within the historical wildlife corridor (Mangewa et al., 2009; Linuma et al., 2022). Elsewhere, crop farms close to a protected area boundary have sufferred more crop damage by wildlife (Eustace et al., 2022), and crop damage and threats to human safety are the most significant aspects of human–wildlife conflict, resulting in negative attitudes towards animals that pose such problems (Datiko & Bekele, 2013).

Around Ngorongoro, patches of bushes and shrubs in the villages and unfenced coffee plantations allowed buffaloes to remain concealed, posing a threat, especially to women gathering firewood for domestic use. Similarly, research elsewhere has reported that elephants and buffaloes remain concealed in small habitat patches in human-dominated landscapes during the day and then emerge during the night, damaging crops and property (Buchholtz et al., 2019). Such damage reports by farmers can be subject to exaggeration and therefore require verification by agricultural extension officers (Gillingham & Lee, 2003). In our study, the famers' self-reported data were verified by the Karatu District Wildlife Officer. The losses incurred by farmers can result in negative attitudes towards wildlife (Dickman et al., 2014).

Buffaloes were reported to mostly damage maize, beans, peas and wheat, but coffee farms were also affected, as buffaloes entered to feed on the grasses that grow between the lines of coffee bushes, often resulting in damage to the coffee plants. Buffaloes prefer monocotyledonous to dicotyledonous plants (Macandza et al., 2004), and this was also the case in our study, with cereal crops experiencing more depredation from buffaloes than crops such as beans.

Mitigation strategies

Around Ngorongoro, respondents mostly used traditional methods to mitigate human–African buffalo conflict, except around Tloma, where respondents on the coffee estate farms have installed electrified fencing. This installation has played a key role in mitigating human–African buffalo conflict, and Tloma experienced few conflicts. Farmers in Oldeani are greatly affected by human–African buffalo conflict, and most of them reported that traditional methods of acoustic repellence such as vocalizing, whistling and percussion (with tins and drums) are ineffective. Farmers in Kambi ya Simba and Tloma reported that they had recently begun using other mitigation strategies, including beehive fences and chili fences comprising pieces of cloth soaked in oil mixed with strong chili and hung on a rope between poles. However, in Ngorongoro, and elsewhere (Denninger & Rentsch, 2020), farmers in rural villages still generally rely on inexpensive methods to mitigate human–wildlife conflict, such as cooperative farm guarding during the night. Farmers in villages bordering Ngorongoro Conservation Area use less effective, traditional methods to reduce human–wildlife conflict, in part because of the prohibitive cost of implementing modern, more effective methods (Kiffner et al., 2021).

Conclusions

Human–African buffalo conflict remains a significant concern in the villages studied. The most significant reported impacts of human–African buffalo conflict in the study area are incursions into crops and human casualties. Buffaloes were reported to damage maize and wheat most frequently, whereas pigeon peas, beans and coffee trees were less frequently damaged. Farmers reported using mostly inexpensive and traditional mitigation approaches that require few resources but are often ineffective, such as cooperative farm guarding, fire-lighting and torch-waving, as well as vocal and percussive auditory deterrence. In Tloma, electrified fencing around the coffee estates is effective in mitigating human–African buffalo conflict, with few conflict incidents reported since 2016 when the fences were installed. According to the respondents, competition for water and food is the main instigating factor in human–African buffalo conflict.

We recommend that local communities be involved in the development and application of mitigation methods and that these are implemented and modified based on field tests. We also recommend conducting research and testing methods such as the use of chili bombs, drones and intense light torches, which have proved effective at mitigating conflict with elephants (Hahn et al., 2017). Because of the prohibitive costs of these methods, we recommend forming communal guard groups in all affected villages, to share resources and implement combined training on how to use these tools. We also recommend continuing efforts by wildlife conservation authorities to prevent local communities planting crops within the 500-m buffer zone around the protected area boundary, as per the Wildlife Conservation Act (Chapter 283).

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Author contributions Study design: all authors; data collection: EBM with the assistance of KMH, EHL, ESB; statistical analysis: KMH, EHL; writing and revision: all authors.

Conflicts of interest None.

Ethical standards The involvement of human participants was in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards, and otherwise abided by the *Oryx* guidelines on ethical standards. A permit was obtained from the relevant wildlife authority prior to fieldwork. All interviewees gave their informed verbal consent prior to being included in the survey. At the beginning of the interviews, we informed respondents that they could seek clarification at any time during the interview. We anonymized the respondents by not asking for their names and assigning a number to each questionnaire.

Data availability Data supporting the findings of this study are available from the corresponding author (KMH) upon reasonable request.

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