University of Kent

Kent Academic Repository

Leneuiyia, Lemayian K., Smith, Robert J., King, Juliet M., Thouless, Christopher, Williams, Harry F., Wittemyer, George, Kokiro, Paul and Milgo, Purity (2025) *Transitions and conflicts: patterns and drivers of human–elephant conflict in a changing pastoral landscape of northern Kenya.* Pachyderm, 66 . pp. 85-100. ISSN 1026-2881.

Downloaded from

https://kar.kent.ac.uk/112469/ The University of Kent's Academic Repository KAR

The version of record is available from

https://pachydermjournal.org/index.php/pachyderm/article/view/1331

This document version

Publisher pdf

DOI for this version

Licence for this version

CC BY-NC (Attribution-NonCommercial)

Additional information

Versions of research works

Versions of Record

If this version is the version of record, it is the same as the published version available on the publisher's web site. Cite as the published version.

Author Accepted Manuscripts

If this document is identified as the Author Accepted Manuscript it is the version after peer review but before type setting, copy editing or publisher branding. Cite as Surname, Initial. (Year) 'Title of article'. To be published in ***Title of Journal*** , Volume and issue numbers [peer-reviewed accepted version]. Available at: DOI or URL (Accessed: date).

Enquiries

If you have questions about this document contact ResearchSupport@kent.ac.uk. Please include the URL of the record in KAR. If you believe that your, or a third party's rights have been compromised through this document please see our Take Down policy (available from https://www.kent.ac.uk/guides/kar-the-kent-academic-repository#policies).

Transition and conflict: patterns and drivers of human–elephant conflict in a changing pastoral landscape of northern Kenya

Kennedy L Leneuiyia[1,2], Robert J Smith[2], Juliet M King[1,3], Christopher Thouless[1], Harry F Williams[1], George Wittemyer[1], Paul Kokiro[1], Purity Milgo[1], Giacomo D'Ammando[1]

[1]Save the Elephants, PO Box 54667, Nairobi 00200, Kenya
[2]Durrell Institute of Conservation and Ecology, University of Kent, Canterbury, UK
[3]Northern Rangelands Trust, Private Bag, Isiolo 60300, Kenya

*corresponding author: kennedy@savetheelephants.org (OrcID: 0000-0002-2991-3159)

Submission date: 8 May 2025; Accepted version: 16 July 2025.

Abstract

Human–elephant conflict (HEC) represents a major challenge for elephant conservation, as it not only fosters negative attitudes towards elephants, but also has socio-economic consequences, including loss of human lives, damage to property, and loss of livelihoods. These effects often motivate retaliatory actions against elephants, including illegal killing. While abundant research exists on the socio-economic impacts of crop raiding in agricultural areas, HEC in pastoral areas remains understudied and poorly understood as a conservation challenge. Here, we explore the nature, spatiotemporal trends, and potential drivers of HEC in 12 community conservancies of the Laikipia–Samburu ecosystem, a pastoral landscape of northern Kenya interspersed with expanding areas of agriculture. We analysed a decade of HEC records (2012–2021) and interviewed ten key informants working within community conservancies in the region. We found that HEC in our conservancies occurred throughout the study period, but different incident types peaked at different times of the year. Most HEC incidents occurred during the dry season when competition for resources increased. Incidents involving livestock and human injuries and fatalities were more spatially dispersed compared to crop raiding, which was concentrated in agricultural areas. The interviews revealed an array of issues that drive conflict, including environmental changes, socio-economic pressures affecting pastoral communities, and political motivations. Accumulated frustration due to the ongoing conflict emerged as a primary cause of increasingly negative attitudes toward elephants among the pastoral communities, leading to elephant mortalities. Understanding the underlying causes of conflict will be essential for developing effective mitigation strategies.

Résumé

Les conflits humains-éléphants (CHE) représentent un défi majeur pour le domaine de la conservation, car, non seulement ils engendrent des attitudes négatives envers ces animaux, mais ils ont également des conséquences socioéconomiques, dont la perte de vies humaines, la destruction des moyens de subsistance des habitants, et les dommages matériels. Ces effets entraînent souvent des représailles contre les éléphants, notamment des abattages illégaux. Bien que de nombreuses recherches existent sur les impacts socioéconomiques des dégâts infligés aux cultures dans les zones agricoles, les CHE dans les espaces pastoraux restent sous-étudiés et mal compris en tant que défis de la conservation. Nous explorons ici la nature des CHE, leurs tendances spatiotemporelles et leurs facteurs potentiels dans douze réserves communautaires de l'écosystème de Laikipia-Samburu, un paysage pastoral du nord du Kenya jalonné de zones agricoles en pleine expansion. Nous avons analysé l'historique des CHE entre 2012 et 2021 et interrogé dix informateurs clés qui travaillent au sein des réserves communautaires de la région. Nous avons observé que les CHE dans ces réserves se sont produits tout au long de la décennie étudiée, mais que certains types d'incidents ont atteint leur apogée sur différentes périodes de l'année. La plupart des cas se sont déroulés durant la saison sèche, lorsque s'intensifie la concurrence pour l'accès aux ressources. Les faits impliquant des blessures et des décès chez les humains et le bétail étaient plus dispersés d'un point de vue géographique que les dégâts infligés aux cultures, qui eux, se concentraient sur les zones agricoles. Les entretiens ont mis en lumière qu'un ensemble de problématiques – changement environnementaux, pressions socioéconomiques affectant les communautés pastorales, motivations politiques – sont à l'origine des conflits. Les frustrations accumulées par ces heurts qui se poursuivent et qui ont pour conséquence la mort d'éléphants, se sont révélées l'une des causes principales de l'attitude négative croissante à l'égard de ces animaux dans les communautés pastorales. La compréhension des facteurs sous-jacents des conflits constituera un élément essentiel pour l'élaboration de stratégies d'atténuation.

Introduction

Biodiversity loss is a pressing global challenge that is driven by the complex interactions between human activities and wildlife (Díaz et al. 2019). Among many exacerbating factors, human–wildlife conflict plays a significant role (Hoare et al. 2022). In Africa and Asia, human–elephant conflict (HEC) is a particular concern because it threatens the conservation of elephant populations while impacting some of the world's poorest people (Hoare 2015). The African savannah elephant (*Loxodonta africana*) is recognized as a flagship species, renowned for its iconic status in popular culture and its importance as an ecosystem engineer (Haynes 2012; Skibins et al. 2016). Despite this recognition, the species faces three imminent threats: habitat loss, poaching for ivory, and HEC (Courchamp et al. 2018). A surge in poaching resulted in severe population declines in the 1970s and 1980s (Douglas-Hamilton 1987), and a further 30% continent-wide decline between 2007 and 2015 (Schlossberg et al. 2020), while habitat loss has resulted in the species currently occupying only 17% of its former range (Wall et al. 2021). Understanding the role of HEC as an obstacle to effective elephant conservation is critical but remains a complex issue due to its combined impact on elephant population dynamics and human livelihoods.

HEC has been documented across elephant range states in Africa (Hoare 2015), where humans and elephants compete for available space, food, and water resources (Bastille-Rousseau et al. 2020). Competition over resources is exacerbated in agricultural areas, where elephants feed on both subsistence and commercial crops, with escalating conflicts often leading to human injuries and deaths, and the illegal killing of elephants (Nyumba 2017). For this reason, most HEC studies have focused on the conflict between crop-farming communities and elephants, with studies spanning from determinants of spatiotemporal patterns of crop raiding (Graham et al. 2010), drivers of crop raiding (Naha et al. 2019), and community attitudes towards crop-raiding elephants (Kiffner et al. 2021).

While extensive studies have explored crop raiding by elephants, HEC outside of agricultural areas is less well understood. This is particularly true for pastoral systems (Gadd 2005), defined as livestock-dominated systems with minimal or no crop production, which distinguishes them from agricultural (crop production) and agro-pastoral (mixed) systems (Adicha et al. 2023). With over 70% of the current elephant range outside protected areas (Blanc et al. 2007), and pastoral landscape covering approximately 43% of Africa's land area (FAO 2018), and serving as critical wildlife corridors and seasonal habitats, HEC in these systems may be more significant than commonly acknowledged. Moreover, patterns of HEC in pastoral landscapes are likely to differ from HEC in agricultural landscapes, since the former are more dynamic systems driven by both livestock and wildlife, including elephants, constantly moving in search of water and pasture (Young et al. 2005). Competition for these limited resources can fuel tensions, creating intricate and shifting challenges for coexistence and management. Such conflict may also be exacerbated by climate change, which is already affecting pastures and water distribution in semi-arid savannahs. In this study, the authors explored the nature and spatiotemporal patterns of HEC within the community wildlife conservancies of the Laikipia–Samburu ecosystem (LSE) of northern Kenya, an area where expanding agricultural land use is encroaching into traditional pastoral landscapes.

In recent years, there has been a perceived increase in HEC incidents within the LSE, resulting in a spike in the number of elephants illegally killed due to conflict (CITIES 2017). Despite the existence of a solid legal structure and political will to support elephant conservation in Kenya, information on HEC incidents remains insufficient to identify the drivers of these trends. To address this, we first examined data collected by the Kenya Wildlife Service (KWS) and by the Northern Rangelands Trust (NRT) (a membership organization run by local community wildlife conservancies), to understand the spatial and temporal distribution of HEC incidents affecting both pastoralism and agriculture in the LSE. Secondly, we identified potential drivers of HEC within this landscape through interviews with conservancy wardens, managers, and rangers.

Methodology

Study site

The study was conducted in the Laikipia–Samburu ecosystem in northern Kenya. The LSE corresponds to the drainage basin of the Ewaso Nyiro River and its tributaries (Thouless 1995) and comprises the Laikipia and Samburu sections, covering 9,500 km^2 and 21,022 km^2, respectively. The area is semi-arid, with wet and dry seasons alternating throughout the year. Average annual temperatures range from 16–26°C and 24–33°C (Georgiadis et al. 2007) and annual rainfall from 400–750 mm and 250–500 mm (Esilaba et al. 2007), in Laikipia and Samburu respectively. Human populations total 518,560 in Laikipia and 310,327 in Samburu, based on national census [data of 2019] (KNBS 2019), with livestock numbers (of cattle, sheep, goats, donkeys and camels) estimated at 1.35 million Laikipia and 1.49 million in Samburu as of the 2023 National Agriculture Report (KNBS 2024) Approximately 12% of the ecosystem consists of protected areas (PAs), including three IUCN Category II PAs, namely the Samburu, Shaba, and Buffalo Springs national reserves, as well as various forest reserves. The remaining areas comprises private ranches (13%), community wildlife conservancies (34%), communal pastoral land (25%), and settlements and smallholder agriculture (17%) (Ihwagi et al. 2015). We focused on the Samburu and northern Laikipia components of the ecosystem, which are characterized by various land uses, but dominated by community wildlife conservancies (Fig. 1). Community wildlife conservancies aim to harmonize wildlife conservation and livestock grazing, and generate revenues from tourism for the local communities. PAs and community conservancies in the Samburu component of the ecosystem are unfenced, except for a rhino sanctuary in Sera Conservancy, to maintain critical wildlife corridors while supporting pastoral mobility. Biodiversity in the area is uniquely adapted to the arid and semi-arid environment and includes wildlife such as beisa oryx (*Oryx beisa*), Grevy's zebra (*Equus grevyi*), pancake tortoise (*Malacochersus torneri*), African wild dog (*Lycaon pictus*), pangolin (*Smutsia temminckii*), and various primates, as well as the African savannah elephant. The LSE is home to the country's second largest elephant population, estimated at around 7,475 as per the 2021 national wildlife census (Waweru et al. 2021).

Data collection

We collated the available data on HEC incidents from 12 community conservancies in the LSE between 2012 and 2021, namely: Greater Namunyak (encompassing four sub-units: Namunyak, Kalepo, Ngilai, and Nalowuon), Il Ngwesi, Kalama, Lekurruki, Leparua, Meibae, Naibunga, Nakuprat Gotu, Nasuulu, Nkoteiya, Sera, and West Gate (Fig. 1). All conservancies are members of the NRT, except for the Greater Namunyak. The data were collected by trained scouts/rangers from multiple conservation organizations, including the KWS and the NRT. Each incident was reported by members of the local community, and scouts or rangers visited the site as soon as possible afterwards. On reaching the incident site, the observers used a standardized data collection form to record the type of conflict, time, GPS location, and wildlife species involved.

We examined a total of [556] reports. Of these, we excluded 11 records because they contained insufficient details. We analysed the temporal distribution of HEC data with respect to time of day (day or night), month, and seasonal variation in rainfall patterns (wet or dry

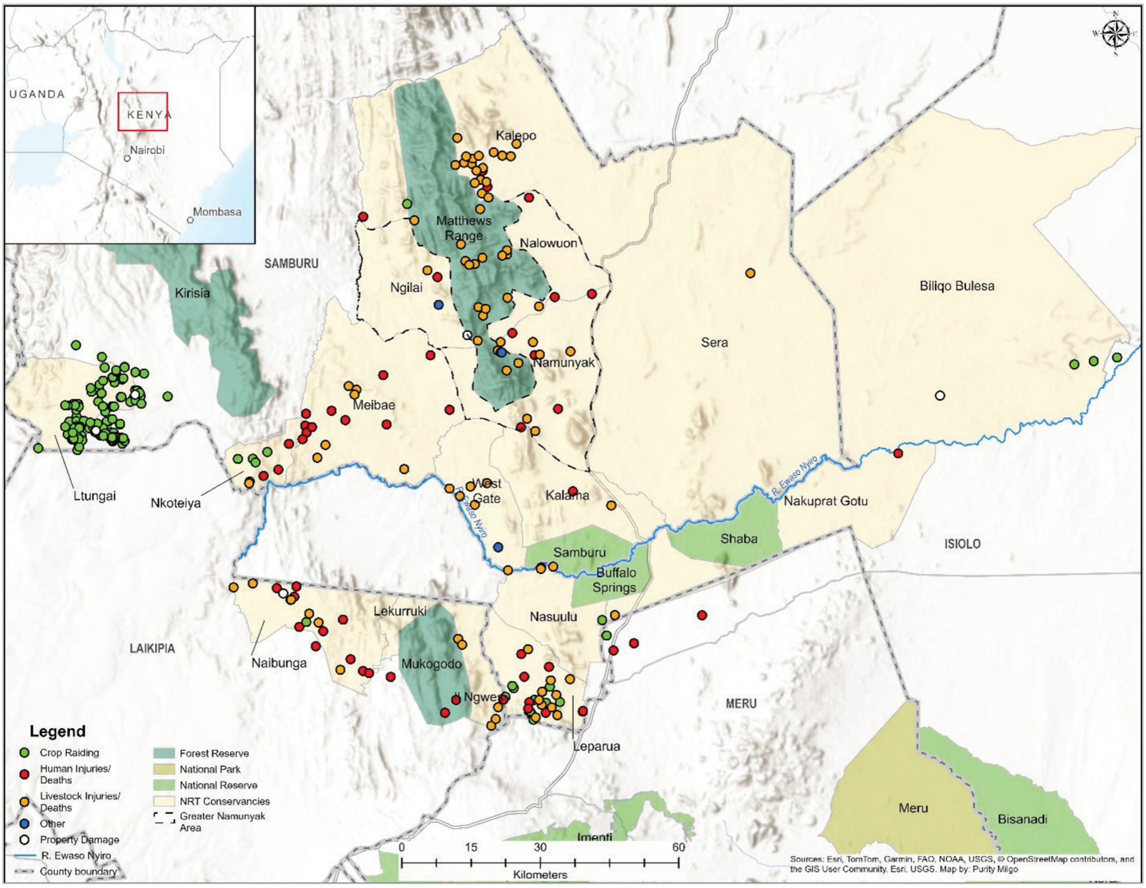

Figure 1. The Laikipia–Samburu ecosystem, showing the location of the community conservancies in which the study was conducted, and the distribution of different types of HEC incidents across the landscape. (Data source: NRT 2012–2021)

Table 1. Example of an incident report, showing information typically recorded on the standardized human–wildlife conflict data collection form.

Information collected	Example
Location name/ Conservancy	Kalama
Date/time (day/night)	20/03/2021 Day
GPS coordinates	0.6989° N, 37.6930° E
Species	Elephant
Conflict type	Human injury
Impact records	One person injured
Additional notes	One person was injured on the leg by a bull elephant as he was walking home from the market

seasons). Using rainfall gauge data from the Save the Elephants Research Camp in Samburu National Reserve, we defined the wet season as starting seven days after a cumulative rainfall of >15 mm since the end of the dry season, and the dry season as starting 30 days after the last day of rainfall since the onset of the wet season. One to two days of rainfall in two weeks of dry weather were considered insufficient to trigger the onset of the wet season. Based on these criteria, we divided our study period into wet and dry seasons.

Data analysis

We first calculated the proportion of each type of HEC incident (as defined in incident reports as crop-raiding, human injury and/or death, livestock injury and/or death, property damage, and "other") in relation to the total number of incidents recorded. We then calculated the proportion of different types of HEC incidents by time of day, month, and season. We performed multinomial logistic regression to determine whether and how temporal predictors (day/night, wet/dry season) affected the probability of occurrence of different conflict types. The inclusion of month as a predictor caused failed model convergence, and this variable was therefore excluded from this analysis. The model was fit using maximum likelihood estimation, with crop raiding as the reference outcome and wet season and daytime as reference levels for predictors. Model performance was assessed via likelihood ratio tests against a null model, with significance determined at $\alpha = 0.05$. Property damage and "other" conflict types were excluded from the model due to very small sample sizes. A further three records were excluded since information on time of day was missing. Since the sample size was small and unbalanced, with a far larger number of crop-raiding incidents recorded compared to human and livestock injuries and deaths, the modelling approach might have produced spurious coefficients and p-values. We thus also used chi-square tests of independence to investigate the association between the proportion of HEC incidents and time of day, month, and season. Quantitative analyses were performed using the nnet package in R statistical software (version 4.3.1; R Core Team, 2023). To determine the spatial distribution of HEC incidents, we identified hotspots by plotting incident locations in ArcGIS Pro using the heatmap function (with a distance radius of 30 m).

To investigate the changes in HEC over longer periods of time, we grouped the HEC incident data for two periods: 2012–2016 and 2017–2021. We structured the analysis in this manner due to likely underreporting of HEC before 2017. For example, in 2012, there were only seven incidents recorded. Although data from 2012–2016 were included in maps and in the overall calculation of proportion of conflict types over the entire study period (where sample sizes did not significantly impact interpretation), analyses of daily, seasonal, and monthly patterns of HEC incidents were restricted to the 2017–2021 period, as the underreporting of incidents before 2017 might have misrepresented the spatiotemporal distribution of different conflict types.

Community perceptions of HEC and conflict-related killing of elephants

We carried out ten semi-structured interviews with key informants. The informants comprised three community conservancy wardens, two conservancy managers, one researcher, and four NRT Security Department personnel working within the study area. While the interviewees provided valuable institutional perspectives, we acknowledge that the limited sample size may not capture the full diversity of community experiences with HEC. The interviewees were selected through purposive sampling techniques (Campbell et al. 2020), ensuring that specific individuals with valuable insights were part of the study. A pilot study was conducted to ensure the efficacy of the interview guide in gathering the necessary information (Fig. 2). Each interview lasted for approximately 35 minutes, and a distinct code was assigned to identify each of the ten interviewees (W1 to W10). Questions revolved around: (a) HEC data collection, processing and storage; (b) the motivations behind the killing of elephants; and (c) the general attitude of the community towards elephants and the conflict situation. We then carried our thematic coding of the interview transcripts using NVivo (v14), which yielded two primary themes. The first theme centred on participants' perspectives regarding drivers of HEC and the surge in conflict killings of elephants. The second theme was the intricate nature of conflicts between local communities and elephants, highlighting the social-political and economic challenges of mitigating HEC.

Results

Nature of conflict

A total of 345 HEC incidents were reported in the study area between 2012 and 2021. Of these, 55% were crop-raiding incidents (Table 1). Livestock injuries and deaths represented 26% of all incidents, while human injuries and deaths represented 16% of all incidents (Table 2). Property damage and "other" conflict types (defined as incidents for which information on conflict type was not available) represented only 3% of the incidents when combined (Table 2). After removing crop-raiding incidents from the calculations, livestock death and injury represented 58% of the remaining 155 incidents, while human death and injury represented 35%. Property damage and other conflict types combined

Interview guide

HEC

1. Do you collect data on HEC? Please share the process briefly (what type of information do you collect, is it part of a monitoring system or just ad hoc, where do you store your data – OB/datasheets/database)
2. What challenges do you encounter during the data collection process and reporting-who do you report this information to, how is this data used?
3. Are there any follow-ups after the data collection?
4. Do you think HEC has stayed the same, increased, or decreased in the past 5 and 10 Years, explain?
5. What do you think are the main drivers of HEC in your area? explain?
   a. Drought ( )
   b. Settlement in corridors ( )
   c. Grazing space ( )
   d. Water scarcity ( )
   e. Demographics change ( )
   f. Others specify..................
6. What challenges are elephants causing?
7. Is anything being done by the conservancy/authorities to reduce conflict with elephants? what do you think could be done?

Elephant mortality – conflict killing

1. When reporting elephant mortalities, how is it identified as conflict killing? How is the decision made? Any follow-ups?
2. What are the main motivations for conflict killings? Why?
3. Why do you think morans are doing shooting practice/target on elephants?
4. Do you think the communities are killing more elephants now than in the past? Why?
5. What is the general feeling in this community towards elephants and conflict situations?

Thank you so much for your time. Do you know or would you recommend any other person, warden, or conservancy manager, who you think has more information on these issues?

Figure 2. Semi-structured interview guide used to explore local data collection processes, perceptions and experiences of HEC, and responses to HEC, in the Samburu–Laikipia landscape.

Table 2. HEC incidents categorized by conflict type in the study area during 2012–2021 and showing the data for 2017–2021 that was used for statistical analysis due to the underreporting of HEC before 2017.

Conflict type	No. of incidents (2012–2021)	Proportion (%) of incidents (2012–2021)	No. of incidents (2017–2021)
Crop raiding	190	55	144
Livestock injuries/deaths	91	26	57
Human injuries/deaths	55	16	40
Property damage	6	2	4
Other	3	1	2
Totals	345		247

N.b. It has not been easy to extract accurate figures of retaliatory killings of elephants in the Laikipia/Samburu area from the literature. However, as a rough estimate for the year 2018 (n = 169), figures can be accessed in this report: https://elephantconservation.org/wp-content/uploads/2022/10/Final-IEF-Report-Jan-December-2018-.pdf. For more information on elephant deaths which are HEC related, and not just the illegal killing for ivory, in the East African context, see: https://cites.org/sites/default/files/documents/E-CoP20-076-04.pdf

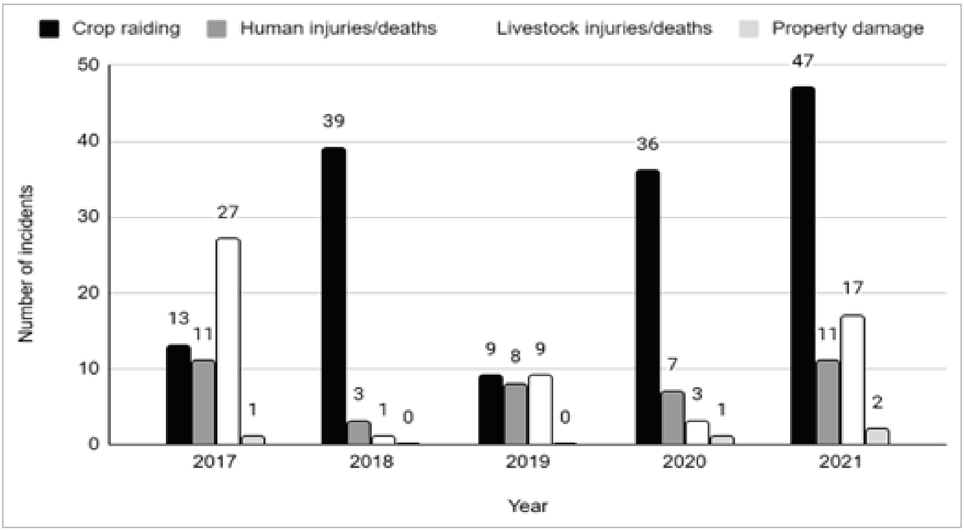

Figure 3. Annual numbers of HEC incidents by conflict type between 2017 and 2021.

represented only 7% of the non-crop-raiding incidents. Numbers of incidents by conflict type between 2017 and 2021, which were used for statistical analyses, are also reported in Table 1. We excluded property damage and "other" incidents from further analyses due to the very small sample size, but we still report descriptive statistics for both conflict types.

Unfortunately, the underreporting of HEC incidents before 2017 prevented us from identifying long-term trends in different types of conflict, since reliable data only spanned five years. During 2017–2021, numbers of human and livestock injuries and deaths were generally high in 2017 (human injuries/deaths, n = 11; livestock injuries/deaths, n = 27), lower in 2018–2019, and then high again in 2021 (human injuries/deaths, n = 11; livestock injuries/deaths, n = 17; Fig. 3). By contrast, crop-raiding incidents were markedly lower in two years, namely 2017 (n = 13) and 2019 (n = 9), and higher in the other three years, with the highest number of crop raids recorded in 2021 (n = 47; Fig. 3). No clear increase or decrease in the annual number of HEC incidents could thus be discerned. In 2018, a total of 169 elephant deaths were recorded in the Laikipia-Samburu landscape, with the proportion of illegally killed elephants (PIKE) rising from 34% in 2017 to 38% in 2018 (NRT 2018). Unpublished MIKE data indicate that conflict-related elephant killings have continued to rise in the years following 2018. Due to the small sample sizes of HEC incidents per year, data across the 2017–2021 period were pooled for further analyses.

Multivariate analysis

The multinomial logistic regression model containing the temporal predictors significantly outperformed a null model ($\chi^2 = 243.579$, df = 4, $p < 0.001$). Time of day (day or night) was the strongest predictor of conflict type ($\chi^2 = 220.852$, $p < 0.001$), with human and livestock injuries and deaths significantly more likely to occur during daytime compared with crop-raiding, which was more likely to occur at night (Table 3). Season did not have a significant effect on conflict type ($\chi^2 = 2.247$, $p = 0.266$). However, non-significant directional trends suggested that human and livestock injuries and deaths were less likely to occur during the dry season compared to crop-raiding incidents (Table 3).

HEC day/night patterns

The chi-square test confirmed a significant association between the type of conflict, and the time of day (day or night) at which incidents occurred ($\chi^2 = 195.59$, df = 2, $p < 0.001$). Crop raiding was mainly nocturnal, with 98.6% of incidents (139 out of 141 incidents for which time of day was reported) occurring at night (Fig. 4). By contrast, human injuries and deaths were mostly diurnal incidents, with 77.5% of incidents (31 out of 40) occurring during the day versus 22.5% (9 out of 40) occurring at night (Fig. 2). Livestock injuries and deaths exhibited an even stronger diurnal bias, with

Table 3. Coefficient estimates and standard errors from a multinomial logistic regression model, with type of conflict (crop raiding, human injuries and deaths, and livestock injuries and deaths) as a categorical response variable. Predictors include time of day and season. Reference levels for each categorical variable are crop raiding (conflict type), night (time of day), and wet season (season). Statistically significant effects are highlighted in bold.

Conflict type	Predictor	Coefficient	Standard Error	p
Logit 1 (Human Injury/Death versus Crop Raiding)				
Human Injury/Death	Daytime	5.316	0.811	<0.001
Human Injury/Death	Season: Dry	-1.052	0.721	0.145
Logit 2 (Livestock Injury/Death versus Crop Raiding)				
Livestock Injury/Death	Daytime	8.184	1.236	<0.001
Livestock Injury/Death	Season: Dry	-0.599	0.808	0.458

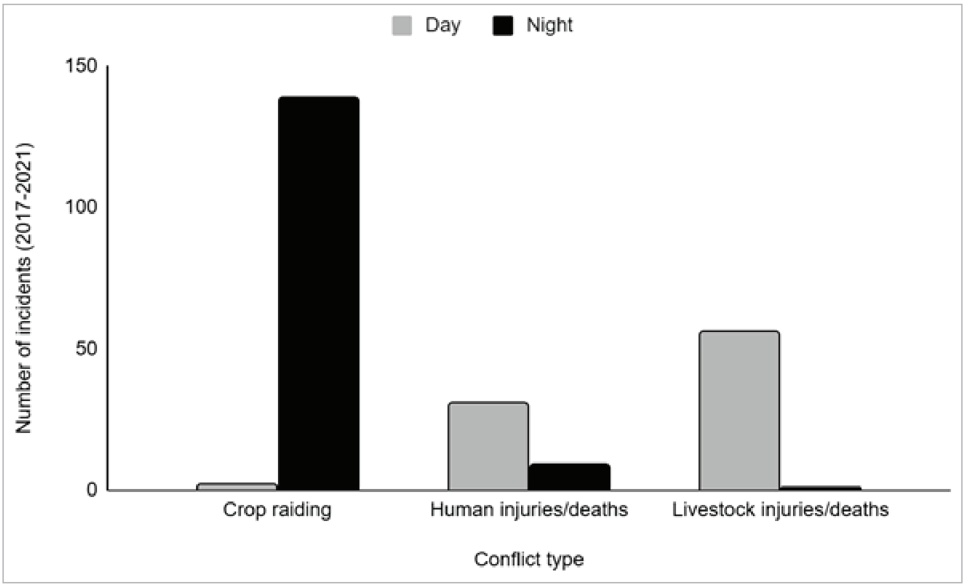

Figure 4. Day and night occurrences of HEC incidents by conflict type, 2017 to 2021.

98.2% (56 out of 57) of incidents happening in daytime hours, likely due to the night penning of livestock (Fig. 4). Property damage incidents (n = 3) were exclusively nocturnal (Fig. 4).

HEC seasonal patterns

We found that 79% of conflict incidents occurred in the dry season; specifically, 89% of crop raiding incidents (n = 128), 60% of human injuries and deaths (n = 24), and 67% of livestock injuries and deaths (n = 38; Fig. 3). Property damage was recorded too sporadically to identify seasonal trends. There was a statistically significant association between conflict type and the season in which incidents happened ($\chi^2 = 22.289$, df = 2, p<0.001). However, this pattern was no longer significant after excluding crop-raiding incidents ($\chi^2 = 0.210$, df = 1, p = 0.647). This could be due to the relatively small sample size of incidents associated with human and livestock injuries and deaths.

HEC monthly patterns

We found a significant association between conflict type and month ($\chi^2 = 115.13$, df = 22, p < 0.001). Crop raiding followed a clear monthly pattern, with most of the incidents occurring in August (42%, n = 60) and July (26%, n = 37; Fig. 4). The months with the lowest number of crop-raiding incidents were February (n =

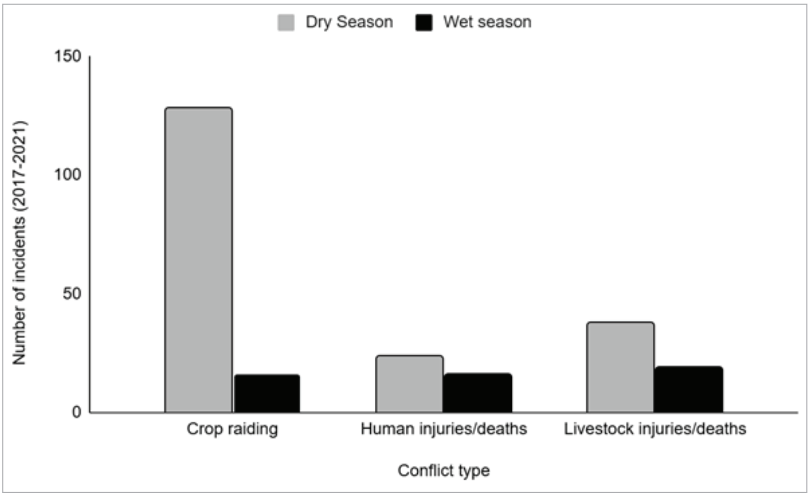

Figure 5. Seasonal distribution of HEC incidents by conflict type, between 2017 and 2021.

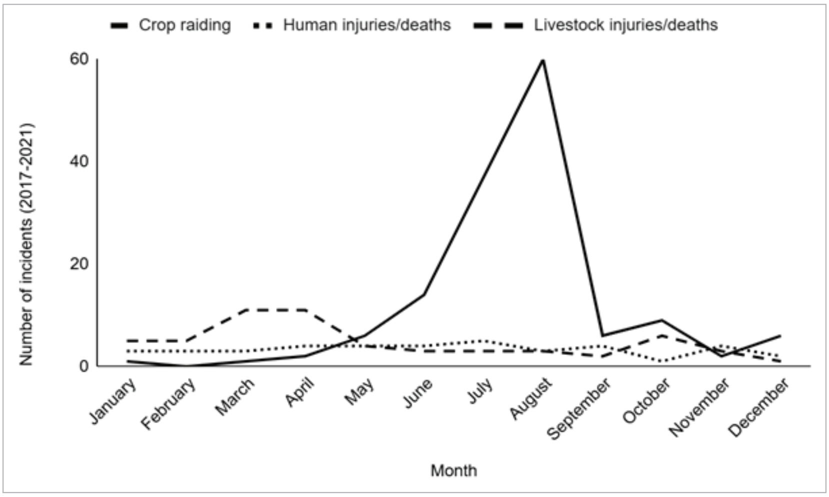

Figure 6. Monthly distribution of HEC incidents by conflict type, between 2017 and 2021.

0), January (n = 1), and March (n = 1; Fig. 4). The highest number of livestock injuries and deaths occurred in March (19%, n = 11) and April (19%, n = 11; Fig. 4), while human injuries and deaths were most common in July (15%, n = 5; Fig. 4). However, after excluding crop-raiding incidents, the association between conflict type and month was no longer significant ($\chi^2 = 11.571$, df = 11, p = 0.397). Again, this was likely due to the small sample sizes.

Spatial distribution of HEC incidents

Crop-raiding was mostly limited to the western sector of the ecosystem, concentrated in and around Ltungai conservancy (Fig. 1). This is an area of recent agricultural development, where existing communal grazing land has been subdivided into individually owned plots and converted to crop farming. Ltungai accounted for 89% of all crop-raiding incidents in the 2017–2021 study period. The remaining crop-raiding incidents were concentrated in smaller areas of crop farming at the southern and eastern edge of the ecosystem (Fig. 1). After excluding crop-raiding incidents from analyses, a heatmap revealed that the main hotspot for human and livestock injuries and deaths (i.e. the area with the highest density of incidents) was the Kalepo area of the Greater Namunyak conservancy (Fig. 5).

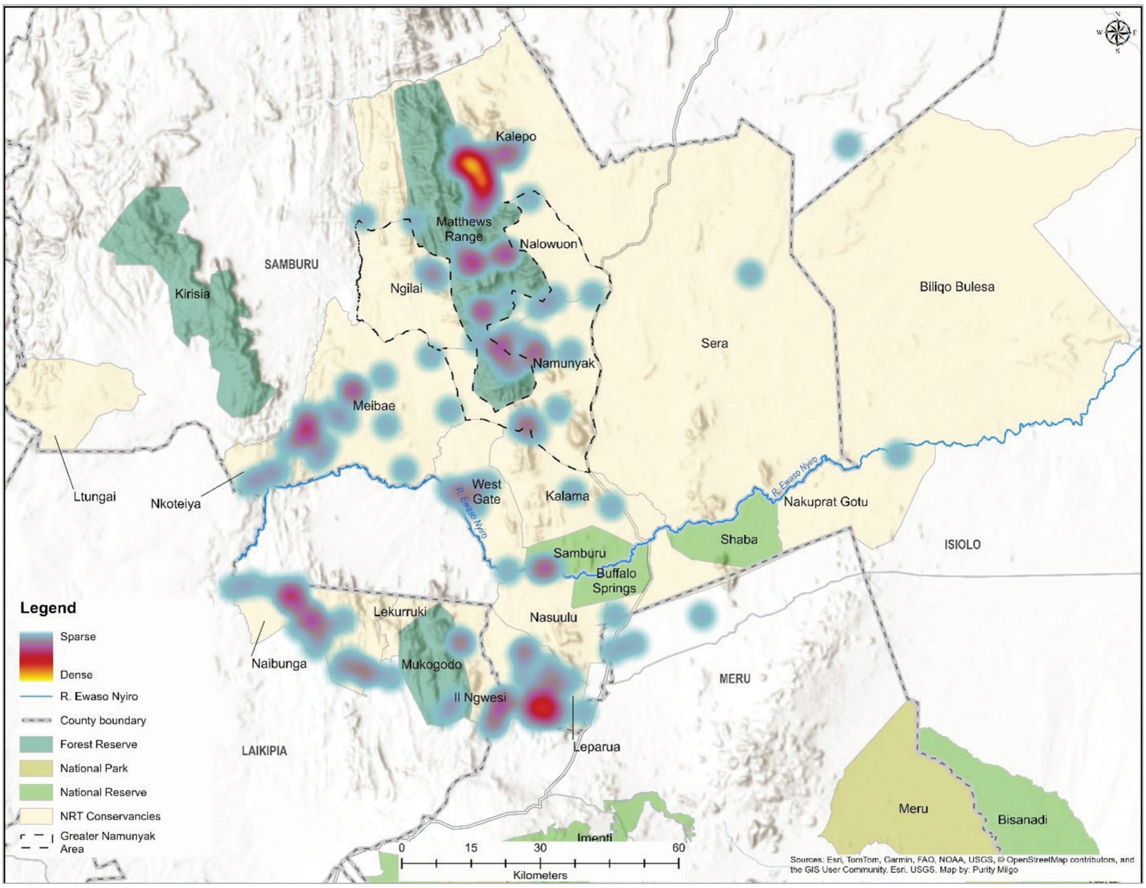

Figure 7. Distribution of human and livestock injuries and deaths as a heatmap, highlighting conflict hotspots across different conservancies (2012–2021).

Other hotspots of human and livestock injuries and deaths could be observed in the Leparua, Naibunga, and Meibae conservancies (Fig. 5). This was confirmed by calculating the proportion of incidents by conservancy: Greater Namunyak accounted for 36% of human/livestock injuries and deaths (n = 35), followed by Leparua (18%, n = 17), Naibunga (14%, n = 14), and Meibae (13%, n = 13). Nonetheless, differences in the proportion of incidents across multiple conservancies need to be interpreted with caution, as conservancies differ by size, human and elephant population densities, and ranger patrol efforts (for example, Greater Namunyak is also the largest of the study conservancies).

Interview results

The interviewees generally felt that HEC is increasing in the region, and with it, conflict-related mortalities, with conflict particularly likely during failed rainy seasons. Several social and ecological factors emerged as potential drivers of HEC and the conflict killing of elephants during the interviews. These included socio-cultural breakdown, consumerism and an increasing focus on economic rather than cultural valuation of elephants, invasive species, feelings of marginalization, and discontent with the lack of response to HEC incidents, among others (Fig. 8).

According to the interviewees, increasing occurrences of HEC and elephant killing in areas like Greater Namunyak could be attributed to the influx of herders from surrounding areas during drought periods. These herders are unfamiliar with the location and afraid of elephants, partly because of a lack of knowledge about elephant behaviour. This leads to more encounters when livestock herding and a high likelihood of herders shooting elephants out of fear.

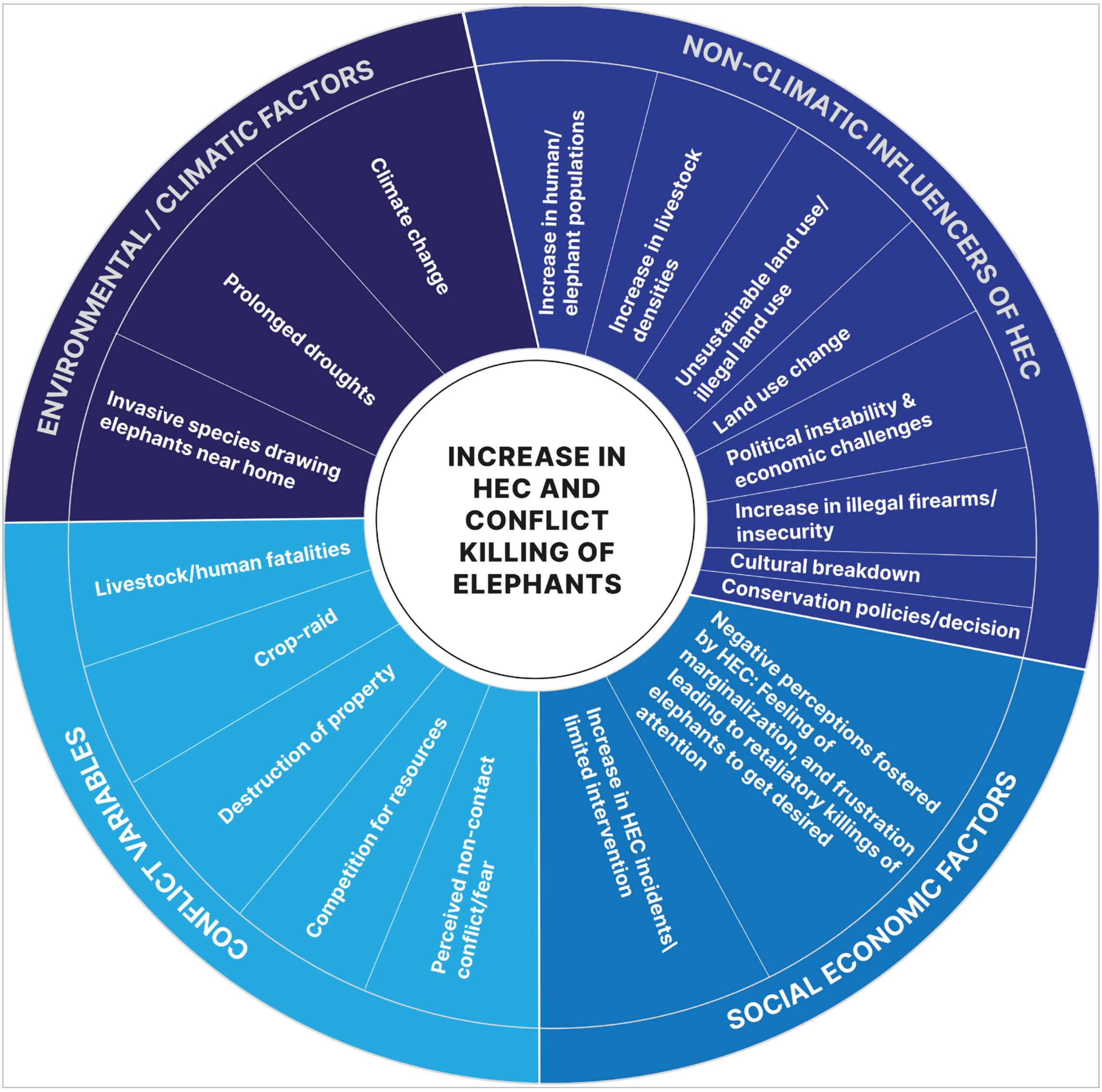

Figure 8. Diagrammatic representation of the factors that contribute to the increase in HEC and conflict-related elephant mortalities identified from interviews with conservation practitioners and researchers[1].

Although HEC was perceived as increasing, one interviewee (W4) noted that with conservancies having a history of recruiting reformed poachers, "*people are shooting elephants to see if they will be hired like poachers were hired ...*"; although, the shooting might also be "*to retaliate against HEC.*" These violent reactions stem from accumulated frustration and neglect that have remained unresolved over time. Another interviewee (W5) emphasized that "*...one of the reasons that conflict cases are underreported is because the communities are tired of reporting cases which are unaddressed... the collection of these records is [perceived as] an extra attack on people, by raising their hopes but not addressing the problem. The collection of the records is like stepping on a fresh wound*".

[1]It is worth noting the difficulty of obtaining elephant mortality data, particularly retaliatory killings due to data access and release policies stipulated in CITES Resolution Conf. 10.10. We include this here to guide future research.

Discussions

In this study, we aimed to elucidate the spatiotemporal trends and potential drivers of HEC in a landscape formerly dominated by pastoralism, but increasingly comprising a mosaic of pastoral and agricultural land uses. While traditional pastoralists historically coexisted with elephants (Galvin 2009), recent research reveals escalating HEC in Kenya. Between 1992 and 2017, 19.9% of 9,182 elephant deaths in Kenya were HEC-related. Laikipia recorded the highest national elephant mortality due to HEC incidents (22.1% of total HEC-related mortality), with Samburu ranking fourth (13.0%); thus, together the LSE accounted for 35.1% of all cases (Mukeka et al. 2022). Our findings confirmed that HEC is a serious issue in the LSE. Although we could not prove that HEC incidents have increased, based on available data, this was the perception of key informants we interviewed. The results of this study suggest that socio-economic, political, and environmental changes such as land-use changes, resource scarcity, and climate change are disrupting long-standing patterns of human–elephant coexistence. These results highlight the urgent need for conservation strategies that account for shifting socio-ecological dynamics while balancing elephant conservation with the livelihoods of affected communities to foster sustainable coexistence in rapidly changing landscapes.

Patterns of HEC

While crop-raiding incidents represented most HEC cases in the LSE, they were limited to a small part of the study area under agricultural development. These events took place at night, when humans are not in the fields and are less likely to be guarding their crops (Hichoonga et al. 2024), conforming to elephant crop-raiding patterns in other sites (Munyao et al. 2020). In contrast, elephant-induced human and livestock injuries and deaths were spread much more widely across the ecosystem and occurred primarily during the day. This is likely because humans and livestock shelter in pastoral settlements (bomas) after dark. This pattern reflects the temporal overlap within shared landscapes between human routines such as herding, and other outdoor activities such as water and firewood collection, and wildlife movements. Thus, HEC in pastoral landscapes requires alternative mitigation strategies that favour co-existence during daily routines, different from the strategies used to mitigate crop-raiding incidents that involve creating barriers to prevent human–elephant interactions.

Our interview respondents reported that conflict intensity increased during the peak of the dry season, or during years characterized by failed rainy seasons or sporadic rain events. They linked this to livestock and elephants converging in areas that receive rain and those that tend to remain green during drought, where they compete for the available pasture and water resources. This aligns with the HEC incident data, which show that the majority of human and livestock fatalities occurred during the dry season. Previous studies highlight the competitive relationship between livestock and elephants for vital resources (Gadd 2005; Young et al. 2005) and the association between low or failed rainfall and HEC (Montero-Botey et al. 2024). Future mitigation strategies should thus take seasonal variation into account when considering conflict risk.

The observed spatial distribution of human and livestock injuries and deaths could also indicate competition over scarce resources in areas that both elephants and pastoralists use as dry-season refuges. For example, the Greater Namunyak conservancy is likely a HEC hotspot due to the presence of permanent water in mountain streams and green forage in evergreen montane forests, as during dry periods these features attract herders and livestock from the entire LSE and even beyond. The accounts of interviewees support this interpretation, as they attributed the high number of HEC incidents in this area to the influx of herders, particularly herders from areas where elephants are absent, and who are thus unfamiliar with the risks associated with elephant encounters. While NRT supports community-led grassland restoration and other measures to revitalize pastoral systems (NRT 2022) these efforts continue to face persistent HEC-related challenges. This suggests that ecological interventions in pastoral landscapes require complementary strategies specifically aimed a mitigating HEC.

Drivers of HEC and conflict-related elephant mortality

Anecdotal evidence from most of the interviews states that numbers of HEC incidents are positively associated with numbers of conflict-related elephant mortalities, a pattern consistent with unpublished MIKE data indicating a recent upward trend. This suggests that retaliation for conflicts plays a major role in HEC in not only in agricultural landscapes, but agro-pastoral landscapes (Mariki et al. 2015). These retaliatory killings are exacerbated by ongoing transitions in pastoralist societies where shifts from nomadic traditions to agro-pastoralism (land-use change), sedentarization (socio-cultural change), privatization of communal lands, and livelihood diversification are creating new frontiers of conflict. The interview transcripts also documented a variety of other perceived drivers of the conflict killing of elephants. Pastoralists rely on livestock as their source of livelihood and cultural identity (Spencer 2013). Human and livestock fatalities contribute to negative attitudes toward elephants (Gadd 2005). According to the interviewees, delayed or lack of compensation for property and livestock loss from HEC fosters sentiments of marginalization, alienation and frustration. These sentiments might produce a sense of distrust toward the authorities, creating a "broken promises effect" (Anthony 2021). This can then lead to communities distrusting government and non-governmental conservation agencies, and to the killing of elephants both as "revenge" against authorities and as a cry for help, to attract their attention to the conflict situation. These social issues should thus be accounted for when planning mitigation strategies in pastoral landscapes, with compensation schemes extended to people and communities in marginalized areas for the loss of human life and livestock.

The interviews identified socio-cultural breakdown, marked by a shift from traditional values to capitalism, consumerism and individual private ownership of land, as another driver of HEC. Kuriyan (2002) notes that the tolerance of the Samburu towards elephants is rooted in their traditions and cultural values. In our study, interviewees commented on the decline in traditional reverence for elephants, linked to the disappearance of the cultural norms that once protected the species. For example, the Samburu viewed elephants as tribemates; when they encountered a carcass they showed their reverence by adorning it with green twigs, signifying deep respect and honour (Kuriyan, 2002). Elephants also played crucial roles in cultural customs; for instance, elephant dung was burned to ward off malevolent spirits, and during marriage rites, newlyweds would light their first fire using dung from a young elephant, symbolizing a fresh start and a prosperous union blessed with the strength and longevity of an elephant (Kahindi 2001). Interviewees highlighted an increasing focus on the economic benefits of elephants, suggesting a shift in societal valuation of elephants (Gadd 2005). Valuing wildlife purely for economic gains might heighten elephants' vulnerability, casting them in an unfavourable light if income from conservation is lost and/or does not meet expectations and/or fails to compensate for the perceived burdens of coexistence. Thus, it is important to strike a balance between the tangible benefits of wildlife resources and the preservation of cultural values. As the situation evolves, the fusion of both dimensions should be seen as essential to safeguard not only wildlife but also the rich tapestry of human cultural heritage.

According to one interviewee, the spread of *Opuntia* cactus species is also exacerbating HEC. Conflict is thought to occur because this invasive, non-native species draws elephants closer to settlements as they feed on its fruits, where people are using the species as a fence. Additionally, elephants might contribute to spreading the seeds of the invasive species. For example, in Kruger National Park, elephants contribute to the local spread of *Opuntia* through endozoochoric dispersal, while baboons facilitate long-distance dispersal, significantly enhancing the species' invasive potential (Foxcroft and Rejmánek, 2007). Additional research is needed to understand how to deal with this additional challenge, combining mitigation of HEC with invasive species management.

Conclusions and implications for management

The increase in HEC across Samburu and Laikipia reflects profound transitions reshaping this landscape. As pastoral communities navigate the complex shift from nomadic traditions to agro-pastoral livelihoods, driven by climate pressures, economic change, and cultural evolution, new dynamics of conflict are emerging. Our findings demonstrate that these intersecting transitions (land-use change, livelihood transformation, and socio-cultural shifts) amplify the risks of HEC. This new reality demands conservation strategies that bridge ecological and social systems. While organizations like NRT have made important advances in grassland restoration, job creation, and environmental education, persistent gaps remain, including inadequate responses to HEC, uneven community engagement, and limited integration of local knowledge into conflict mitigation. Successful solutions will require pairing institutional strengths, with deeper integration of indigenous knowledge systems (Kuriyan 2002; Williams et al. 2022), particularly those that embody cultural values fostering tolerance towards elephants. Moving forward, effective management requires a threefold approach: 1) adapting conservation planning to irreversible transitions towards agro-pastoralism via corridor designation and seasonal zoning (e.g. crop protection in July–August); 2) strengthening institutional responsiveness through expanded ranger patrols and alerts for herder communities; and 3) embedding local knowledge in coexistence strategies via stakeholder forums that balance biodiversity and livelihood priorities. By systematizing these spatial, temporal, and social interventions, governance challenges become opportunities for scaling solutions. Coexistence in a transitioning landscape requires policies that address both the ecological drivers of HEC and its human dimensions, to align conservation with contemporary realities while preparing for future challenges.

Acknowledgements

We are grateful to all the individuals and organizations involved in this study, including the Northern Rangelands Trust, Kenya Wildlife Service, and Save the Elephants. Sincere thanks to all those who participated in the interviews; their contributions were invaluable to this study.

References

Adicha A, Darcho D, Ermias G, Kuse K, Kelifa Z. 2023. Analysis on crop-livestock and agro-pastoral farming system. *Journal of Innovative Agriculture* 10 (3): 1–21. https://doi.org/10.37446/jinagri/rsa/10.3.2023.1-21

Anthony BP. 2021. Paying for the past: the importance of fulfilling promises as a key component to resolving human–wildlife conflict. *Sustainability* 13 (13): 7407. https://doi.org/10.3390/su13137407

Bastille-Rousseau G, Wall J, Douglas-Hamilton I, Lesowapir B, Loloju B, Mwangi N, Wittemyer G. 2020. Landscape-scale habitat response of African elephants shows strong selection for foraging opportunities in a human dominated ecosystem. *Ecography* 43 (1): 149–160. https://doi.org/10.1111/ecog.04240

Blanc J, Barnes R, Craig G, Thouless C, Dublin H, Douglas-Hamilton I, Hart J. 2007. *African elephant status report 2007: an update from the African elephant database*. 10.2305/IUCN.CH.2007.SSC-OP.33.en

Bunney K, Bond WJ, Henley M. 2017. Seed dispersal kernel of the largest surviving megaherbivore—the African savannah elephant. *Biotropica* 49 (3): 395–401. https://doi.org/10.1111/btp.12423

Campbell S, Greenwood M, Prior S, Shearer T, Walkem K, Young S, Bywaters D, Walker K. 2020. Purposive sampling: complex or simple? Research case examples. *Journal of Research in Nursing* 25 (8): 652–661. https://doi.org/10.1177/1744987120927206

CITES. 2017. Levels and trends of illegal killing of elephants in Africa to 31 December 2016: Preliminary findings. Convention on International Trade in Endangered Species of Wild Fauna and Flora. https://cites.org/sites/default/files/eng/prog/MIKE/MIKE_report_released_WWD_3Mar2017.pdf

Courchamp F, Jaric I, Albert C, Meinard Y, Ripple WJ, Chapron G. 2018. The paradoxical extinction of the most charismatic animals. *PLoS Biology* 16 (4): e2003997. https://doi.org/10.1371/journal.pbio.2003997

Díaz S, Settele J, Brondízio ES, Ngo HT, Agard J, Arneth A, Balvanera P, Brauman KA, Butchart SHM, Chan KMA. 2019. Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science* 366 (6471): eaax3100. https://doi.org/10.1126/science.aax3100

Douglas-Hamilton I. 1987. African elephants: population trends and their causes. *Oryx* 21 (1): 11–24. https://doi.org/10.1017/S0030605300020433

Esilaba MO, Maara NT, Tangus JK. 2007. Impact of human–wildlife conflict resolution on wildlife conservation and socioeconomic welfare of pastoral communities: a case study of Samburu pastoralists, Samburu District, Kenya. *Eastern Africa Social Science Research Review* 23 (2): 41–54.

FAO. 2018. *Pastoralism in Africa's drylands*. https://openknowledge.fao.org/server/api/core/bitstreams/e4f7f0d6-87ff-4dc8-8afe-ac4bc2e28180/content

Foxcroft C, Rejmánek M. 2007. What helps Opuntia stricta invade Kruger National Park, South Africa: Baboons or elephants? *Applied Vegetation Science* 10 (2): 265–270. https://doi.org/10.1111/j.1654-109X.2007.tb00525.x

Gadd ME. 2005. Conservation outside of parks: attitudes of local people in Laikipia, Kenya. *Environmental Conservation* 32 (1): 50–63. https://doi.org/10.1017/S0376892905001918

Galvin KA. 2009. Transitions: pastoralists living with change. *Annual Review of Anthropology* 38: 185–198. https://doi.org/10.1146/annurev-anthro-091908-164442

Georgiadis NJ, Olwero JGN, Ojwang' G, Romañach SS. 2007. Savannah herbivore dynamics in a livestock-dominated landscape: I. Dependence on land use, rainfall, density, and time. *Biological Conservation* 137 (3): 461–472. https://doi.org/10.1016/j.biocon.2007.03.005

Graham MD, Notter B, Adams WM, Lee PC, Ochieng TN. 2010. Patterns of crop-raiding by elephants, *Loxodonta africana*, in Laikipia, Kenya, and the management of human–elephant conflict. *Systematics and Biodiversity* 8 (4): 435–445. https://doi.org/10.1080/14772000.2010.533716

Haynes G. 2012. Elephants (and extinct relatives) as earth-movers and ecosystem engineers. *Geomorphology* 157–158: 99–107. https://doi.org/10.1016/j.geomorph.2011.04.045

Hichoonga E, Carter KD, Kalinda C, Namukonde N, Nyirenda VR. 2024. Smallholder farmers' knowledge and perceptions towards elephants and the restraining poliwire fences in Mambova wildlife corridor, southern Zambia. *Discover Animals* 1: 19. https://doi.org/10.1007/s44338-024-00018-x

Hoare G, Leneuyia K, Higgins P, Lowerikoi J. 2022. Wildlife and indigenous communities in Kenya: the influence of conservation education in supporting co-existence between wildlife and a Maasai community. *Southern African Journal of Environmental Education* 38. https://doi.org/10.4314/sajee.v38i.08

Hoare R. 2015. Lessons from 20 years of human–elephant conflict mitigation in Africa. *Human Dimensions of Wildlife* 20 (4): 289–295. https://doi.org/10.1080/10871209.2015.1005855

Ihwagi FW, Wang T, Wittemyer G, Skidmore AK, Toxopeus AG, Ngene S, King J, Worden J, Omondi P, Douglas-Hamilton I. 2015. Using poaching levels and elephant distribution to assess the conservation efficacy of private, communal and government land in northern Kenya. *PLoS ONE* 10 (9): e0139079. https://doi.org/10.1371/journal.pone.0139079

Kahindi O. 2001. Cultural perceptions of elephants by the Samburu people in northern Kenya. Unpublished MSc. dissertation, University of Strathclyde.

Kenya National Bureau of Statistics (KNBS) 2019. 2019 Kenya population and housing census: Volume I – Population by county and sub-county. Nairobi, Kenya: KNBS. https://www.knbs.or.ke/wp-content/uploads/2023/09/2019-Kenya-population-and-Housing-Census-Volume-1-Population-By-County-And-Sub-County.pdf

Kenya National Bureau of Statistics. 2024. National Agriculture Production Report 2024. Nairobi, Kenya: KNBS. ISBN 978-9914-9649-5-0. https://www.knbs.or.ke/wp-content/uploads/2025/01/National-Agriculture-Production-Report-2024.pdf

Kiffner C, Schaal I, Cass L, Peirce K, Sussman O, Grueser A, Wachtel E, Adams H, Clark K, König HJ, Kioko J. 2021. Perceptions and realities of elephant crop raiding and mitigation methods. *Conservation Science and Practice* 3 (3): e372. https://doi.org/10.1111/csp2.372

Kuriyan R. 2002. Linking local perceptions of elephants and conservation: Samburu pastoralists in northern Kenya. *Society & Natural Resources* 15 (10): 949–957. https://doi.org/10.1080/08941920290107675

Mariki SB, Svarstad H, Benjaminsen TA. 2015. Elephants over the cliff: Explaining wildlife killings in Tanzania. *Land Use Policy* 44: 19–30. https://doi.org/10.1016/j.landusepol.2014.10.018

Montero-Botey M, Kivuyo E, Sitati N, Perea R. 2024. Deforestation and water availability as main drivers of human-elephant conflict. *Global Ecology and Conservation* 54: e03068. https://doi.org/10.1016/j.gecco.2024.e03068

Mukeka JM, Ogutu JO, Kanga E, Piepho HP, Røskaft E. 2022. Long-term trends in elephant mortality and their causes in Kenya. *Frontiers in Conservation Science* 3: 975682. https://doi.org/10.3389/fcosc.2022.975682

Munyao M, Siljander M, Johansson T, Makokha G, Pellikka P. 2020. Assessment of human–elephant conflicts in multifunctional landscapes of Taita Taveta County, Kenya. *Global Ecology and Conservation* 24: e01382. https://doi.org/10.1016/j.gecco.2020.e01382

Naha D, Sathyakumar S, Dash S, Chettri A, Rawat GS. 2019. Assessment and prediction of spatial patterns of human–elephant conflicts in changing land cover scenarios of a human-dominated landscape in North Bengal. *PloS ONE* 14 (2): e0210580. https://doi.org/10.1371/journal.pone.0210580

Northern Rangelands Trust. 2018. Final report to the International Elephant Foundation—FY 2018: Support of anti-poaching teams 9-1 & 9-2 of Northern Rangelands Trust conservancies, Kenya (Final report). Northern Rangelands Trust. https://elephantconservation.org/wp-content/uploads/2022/10/Final-IEF-Report-Jan-December-2018-.pdf

Northern Rangeland Trust 2022. State of the Conservancies Report. https://static1.squarespace.com/static/5af1629f12b13f5ce97ca0b5/t/6419b01bfa984426480b9874/1747161510554/NRT+SOCR+2023.pdf

Nyumba T. 2017. Coping with human-elephant conflict in Laikipia District, Kenya. Unpublished MSc dissertation. University of Cambridge.

O'Connell-Rodwell CE, Rodwell T, Rice M, Hart LA. 2000. Living with the modern conservation paradigm: Can agricultural communities co-exist with elephants? A five-year case study in East Caprivi, Namibia. *Biological Conservation* 93 (3): 381–391. https://doi.org/10.1016/S0006-3207(99)00108-1

Schlossberg S, Chase MJ, Gobush KS, Wasser SK, Lindsay K. 2020. State-space models reveal a continuing elephant poaching problem in most of Africa. *Scientific Reports* 10 (1): 10166. https://doi.org/10.1038/s41598-020-66906-w

Skibins J, Powell R, Hallo J. 2016. Lucky 13: conservation implications of broadening "Big 5" flagship species recognition in East Africa. *Journal of Sustainable Tourism* 24 (7): 1024–1040. https://doi.org/10.1080/09669582.2015.1101126

Spencer P. 2013. *The Samburu: a study of gerontocracy in a nomadic tribe*. Abingdon: Routledge, Milton Park. (Originally published 1965.)

Thouless CR. 1995. Long distance movements of elephants in northern Kenya. *African Journal of Ecology* 33 (4): 321–334. https://doi.org/10.1111/j.1365-2028.1995.tb01042.x

Wall J, Wittemyer G, Klinkenberg B, LeMay V, Blake S, Strindberg S, Henley M, Vollrath F, Maisels F, Ferwerda J, Douglas-Hamilton I. 2021. Human footprint and protected areas shape elephant range across Africa. *Current Biology* 31 (11): 2437–2445. https://doi.org/10.1016/j.cub.2021.03.042

Waweru J, Omondi P, Ngene S, Mukeka J. 2021. National Wildlife Census 2021 Report. Technical Report, Kenya Wildlife Service, Nairobi. https://www.tourism.go.ke/wp-content/uploads/2021/08/NATIONAL-WILDLIFE-CENSUS-2021-REPORT-ABRIDGED-FINAL-WEB-VERSION.pdf

Williams H, Leneuyia K, Mwalavo B, Serem G, Sempeyo V, Nyakundi B, Tiller L, Pope F, King L. 2022. Part II: Using cinema, theatre and a virtual toolbox to address the conflict between humans and elephants. *Pachyderm* 63: 158–164. https://doi.org/10.69649/pachyderm.v63i.487

Young TP, Palmer TM, Gadd ME. 2005. Competition and compensation among cattle, zebras, and elephants in a semi-arid savannah in Laikipia, Kenya. *Biological Conservation* 122 (2): 351–359. https://doi.org/10.1016/j.biocon.2004.08.007