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Research Article

Human–carnivore conflict in the human-dominated Sirso landscape, southern Ethiopia

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Abstract

Effective management of human–carnivore conflict (HCC) is essential for promoting sustainable coexistence in shared landscapes. This study investigated the patterns, economic costs, determinants, and mitigation strategies of livestock depredation in the Sirso landscape of southern Ethiopia. An agro-ecology-based stratified random sampling approach was used to select six kebeles, from which 343 households were proportionally sampled using a systematic random technique. Data were collected in 2025 through semi-structured interviews and key informant interviews (KIIs). Overall, 43.4% of respondents reported a total of 349 HCC events. Livestock depredation was the predominant form of conflict (74.5%), followed by attacks on humans (19.2%). A total of 1,280 head of livestock were lost during the study period (≈256 annually), with small stock most affected, particularly poultry (39.7%) and sheep (31.3%). The main problematic carnivores identified were spotted hyenas, leopards, jackals, cheetahs, and small carnivores. Agro-ecologically, lowland areas experienced most conflicts (65.7%); spatially, homesteads experienced most conflicts (70.8%). Temporally, conflict peaked in the wet season (77.3%) and at night (65.5%). The estimated carnivore-induced economic loss during the study period was US$118,167.2 (≈US$23,633.4 annually), and spotted hyenas (35.4%, ≈US$41,830.6) were the primary predators. Cattle depredation caused the greatest economic impact on households, amounting to US$80,580.1 during the study period. In response to depredation, most households (58.6%, *n* = 201) reported lethal control of predators; as a result, 110 carnivores were killed during the study period. Hunting was the most commonly employed retaliatory method (61.83%, *n* = 68), and spotted hyenas were the most targeted (*n* = 50, 45.45%). Applying physical barriers was the most common preventive strategy (40.4%), followed by active guarding (37.2%). The findings highlight the urgent need for context-specific conflict mitigation strategies, improved livestock management practices, and community-based education programs to support both wildlife conservation and rural livelihoods in human-dominated landscapes. The presence of guarding dogs, economic status, and the location of predation were key determinants of livestock depredation. To foster both sustainable wildlife conservation and rural development, effective conflict mitigation and community education are essential.

Key words: Carnivores, economic loss, human–carnivore conflict, mitigation strategies, retaliatory killings, Sirso landscape

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Introduction

Humans and carnivores have coexisted for millennia, sharing landscapes and ecological resources. However, rapid human population growth, agricultural expansion, and habitat fragmentation have increasingly intensified interactions between humans and carnivores, often resulting in human–carnivore conflict (HCC) (Salerno et al. 2025). Carnivores require large ranges and ecological corridors to access resources. However, expanding human activities increasingly disrupt these patterns, forcing carnivores into modified landscapes, where encounters with people and livestock become more frequent (Storch et al. 2025). As a result, both humans and carnivores must adapt while navigating a shared environment (Fletcher and Toncheva 2021). Despite these conflicts, carnivores improve productivity, influence prey populations and ecosystem processes, contribute to biodiversity conservation and ecological stability (Salerno et al. 2025), contribute to human well-being (Yerbury and Lukey 2021), and regulate zoonotic diseases (O'Bryan et al. 2018). However, increasing anthropogenic pressures intensify competition over limited resources, leading to increased HCC due to economic losses, safety concerns, and negative attitudes toward wildlife (Ranjan et al. 2025). Under such conditions, conflict becomes increasingly inevitable, and effective evidence-based management strategies are therefore essential to ensure long-term coexistence (Gatew and Azadge 2025).

HCC manifests in multiple forms, including livestock depredation, human injury and fatalities, disease transmission, and property damage (Linuma et al. 2022). Among these, livestock predation is the most widespread and economically significant driver of human–carnivore conflict globally (Chinchilla et al. 2022). The occurrence and severity of livestock depredation are shaped by a combination of ecological and socio-economic factors, including carnivore species traits, habitat characteristics, prey availability, livestock husbandry practices, and local socio-economic conditions (Inskip and Zimmermann 2009; Miller 2015; Moreira-Arce et al. 2018; Lorand et al. 2022). Carnivore attacks on livestock not only result in direct economic losses but also increase the risk of injury to herders (Salerno et al. 2025). While carnivores affect livestock and occasionally threaten human safety, humans also negatively affect carnivore populations through retaliatory killings (Salerno et al. 2025; Torres-Romero et al. 2025). In developing countries, the economic burden of livestock loss can be severe, sometimes exceeding half of household income (Braczkowski et al. 2023). This often leads to retaliatory killings, undermining conservation efforts (Maheshwari et al. 2014). Therefore, integrated approaches combining land-use planning, community engagement, and sustainable livelihoods are essential to mitigate conflict (Inskip and Zimmermann 2009). Moreover, in some contexts, recovering carnivore populations may aggravate depredation pressures, further intensifying economic losses and human–wildlife tensions (Davoli et al. 2022). The economic implications of HCC are particularly severe in developing countries, where rural livelihoods depend heavily on livestock production and financial resilience is limited. In such settings, livestock losses can represent a substantial proportion of household income, in some cases exceeding half of annual earnings (Braczkowski et al. 2023). These economic burdens often reinforce negative perceptions of carnivores and undermine local support for

conservation initiatives, leading to increased retaliatory killings and further destabilization of carnivore populations (Dickman et al. 2011; Maheshwari et al. 2014). Although a range of mitigation strategies has been proposed, including improved livestock husbandry, physical barriers, guarding animals, compensation schemes, and community-based conservation approaches, their effectiveness varies across ecological and socio-cultural contexts, and implementation remains inconsistent (van Eeden et al. 2018; Chinchilla et al. 2022; Mkonyi 2022; Lazure and Weladji 2024). Importantly, risk assessment and context-specific planning are still insufficiently integrated into carnivore management and land-use policies (Dickman et al. 2011; Atwood and Breck 2012).

In Ethiopia, studies on HCC have been increasing (Shanko and Tona 2022). Studies conducted in national parks have provided valuable insights into conflict dynamics, yet comparatively little attention has been given to human-dominated landscapes, where interactions between humans and carnivores are often more frequent and complex (Acha et al. 2018; Gebresenbet et al. 2018b; Mekonen 2020; Sebsibe 2022; Kidane et al. 2024; Shibru et al. 2024). In contrast, the few existing studies outside protected areas are limited, leaving significant gaps in understanding the drivers, impacts, and mitigation of conflict in shared landscapes (Deneke et al. 2022; Derso 2023; Asaye et al. 2024; Jaleta and Tekalign 2025).

The Sirso landscape represents a typical human-dominated system where mixed farming practices, livestock dependence, and habitat modification create conditions conducive to frequent human–carnivore interactions. However, empirical evidence on the extent, patterns, and drivers of HCC in this region remains lacking. Identifying ecological and socio-economic factors associated with conflict-prone areas is essential for developing targeted and effective mitigation strategies (Moreira-Arce et al. 2018). Addressing these knowledge gaps is critical for informing conservation planning and promoting sustainable coexistence between humans and carnivores.

Therefore, this study aimed to: (1) characterize the patterns and nature of HCC in the Sirso landscape; (2) quantify the economic losses associated with livestock depredation; (3) identify the key determinants influencing livestock predation; and (4) assess the mitigation strategies currently employed by local communities. By providing empirical evidence from a previously understudied region, this study contributes to the development of context-specific management interventions that balance biodiversity conservation with rural livelihood needs.

Materials and methods

Description of the study area

The study was conducted in the Sirso landscape, located between 6°23'–6°27'N latitude and 36°00'–36°37'30"E longitude (Fig. 1). The landscape encompasses the community-conserved Sirso moist evergreen Afromontane forest, which covers approximately 35 km^2 and is surrounded by eight kebeles, the lowest administrative units (Weldearegay and Awas 2021). The mean annual rainfall ranges from 750 to 1,500 mm, with the wet season ranging from March to September. Mean annual temperatures range from 15.1 °C to 27.5 °C, with the dry season ranging from October to April (Mekuria 2018). Agro-ecologically, the landscape is classified into three zones: highland (29.73%), midland (32.43%), and lowland (37.84%).

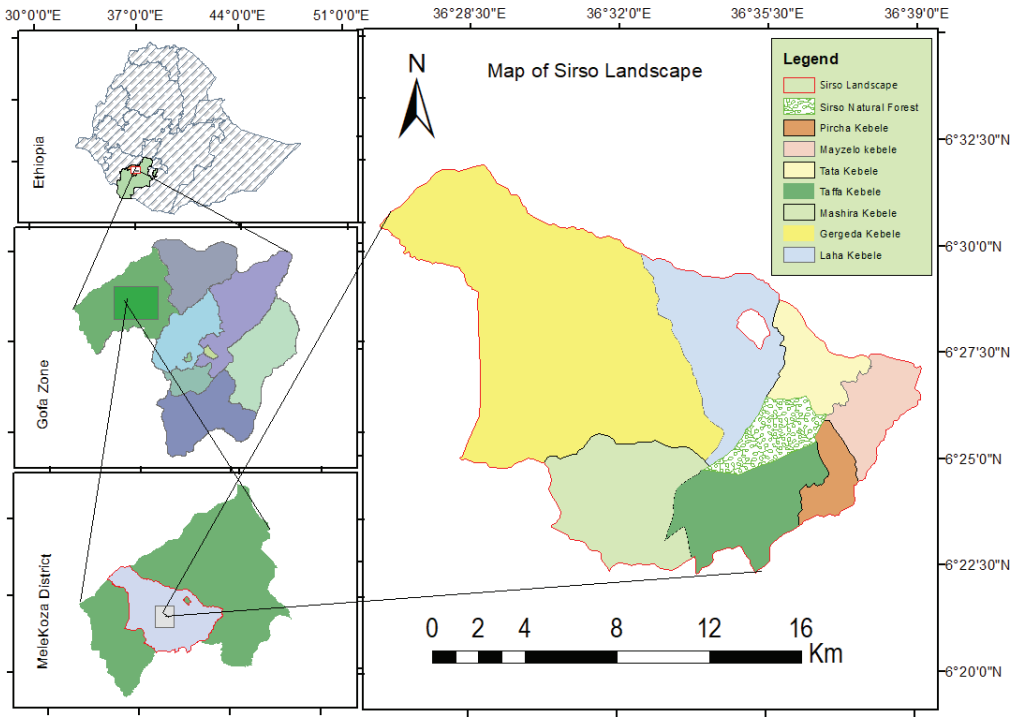

Figure 1. Map of the Sirso landscape.

Agriculture is the dominant subsistence activity (Yokamo et al. 2018). Major food crops cultivated include enset (*Ensete ventricosum*), yam (*Dioscorea* spp.), taro (*Colocasia esculenta*), sweet potato (*Ipomoea batatas*), maize (*Zea mays*), sorghum (*Sorghum bicolor*), barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), and teff (*Eragrostis teff*). Key cash crops cultivated include coffee (*Coffea arabica*), sesame (*Sesamum indicum*), kororima (*Aframomum corrorima*), ginger (*Zingiber officinale*), mung bean (*Vigna radiata*), and red pepper (*Capsicum annuum*). Households also commonly raise livestock such as cattle (*Bos taurus*), sheep (*Ovis aries*), goats (*Capra hircus*), donkeys (*Equus africanus asinus*), horses (*Equus ferus caballus*), mules (*Equus mulus*), and poultry (*Gallus gallus domesticus*) (Mekuria 2018). The district population was 119,694, comprising 60,913 (50.89%) women and 58,781 (49.11%) men (Yokamo et al. 2018). The district includes 29,660 households, of which 91.9% (27,283) are male-headed and 8.1% (2,377) are female-headed (Mekuria 2018).

Sample size determination and sampling techniques

The Sirso landscape was selected purposively due to its ecological significance and increasing human encroachment. A questionnaire-based survey was employed to collect data on HCC. Eight kebeles surrounding the Sirso forest are distributed across agro-ecological zones: four in the lowland, two in the midland, and two in the highland. Using a stratified random sampling technique, two kebeles were selected from each agro-ecological zone to ensure representation across ecological gradients. Accordingly, Mashira and Dawula (lowland), Taffa and Pircha (midland), and Mayzelo and Tatta (highland) were selected. People living within a 10 km radius of the forest interact closely with the ecosystem, influencing and being influenced by ecological dynamics (Afriyie et al. 2022). A total of 27 villages located near the Sirso

natural forest were selected. Sample size was determined using Cochran's formula (Cochran 1977). Cochran recommends applying a finite population correction for a small sample size to improve the accuracy of the estimate. This correction ensures that the sample size more precisely reflects the actual population size. Accordingly, both the desired and adjusted sample sizes were determined, and a confidence level of 95% and a precision (margin of error) of 5% were set following Gebo et al. (2022).

$$\mathrm{SS} = \frac{(P)(q)Z^2}{d^2} \text{ and } \mathrm{ss} = \frac{no}{1 + \mathrm{no} - 1/\mathrm{N}},$$

where:
SS = desired sample size,
ss = adjusted sample size,
Z = standard normal deviation (1.96),
p = 0.5,
q = 1 − *p* (0.5),
N = the total number of populations,
and *d* = the degree of accuracy desired (0.05).

Hence, *SS* = (1.96)2 (0.5) (0.5)/ (0.05)2 = 0.9604/0.0025 = 385 households; ss = 385/ (1+ [385 −1]/3034) = 385/1.1265 = 343 households. The sample size of 343 households (sampling unit) was proportionately allocated to the six kebeles (Mashira = 126, Dawula = 36, Taffa = 68, Pircha = 50, Tatta = 37, Mayzelo = 29).

Following sample size determination, sample units were selected using a systematic random sampling technique. The household master books of the respective villages were used as the sampling frame. The sampling interval was calculated by dividing the total population size (3,034 households) by the adjusted sample size (343), resulting in an interval of nine. To initiate the selection process, the first household was chosen randomly from number cards labeled one to 10. Consequently, as the starting point, the sixth household was selected, and every ninth household was included in the sample. Thus, this method ensured unbiased and proportionally selected households across the study area.

Pilot survey

A pilot survey was conducted in a neighboring kebele that was excluded from the final analysis. The purpose was to evaluate the clarity, relevance, and comprehensibility of the questionnaire. A total of 20 households participated in the pilot survey, representing diverse demographic and socio-economic backgrounds. Based on the findings, the questionnaire was revised and translated into Gofatho, the local language, to facilitate effective communication and accurate responses during data collection.

Questionnaire design

A semi-structured questionnaire was designed following Maddox (2003) to assess human–carnivore interactions. The head of each household was interviewed for approximately 1 h. In cases where the household head was unavailable, another knowledgeable adult representative was interviewed. In some

cases where households had permanently relocated or declined participation, the subsequent household was included as a replacement. The survey tool covered multiple dimensions of HCC, such as: (i) respondents' demographic and socio-economic attributes; (ii) livestock depredation patterns and economic losses; (iii) retaliatory killing of carnivores; and (iv) traditional mitigation practices employed. To assess whether respondents had received compensation, compensation trends were also taken into account (Pant et al. 2023). The economic status of respondents was classified into three categories: low (annual income below 30,000 ETB), medium (30,001–80,000 ETB), and high (above 80,000 ETB). In terms of duration of residence, respondents were categorized as newcomers (less than 1 year in the study area), settlers (1–5 years), and long-term residents (more than 5 years). Market values of livestock were obtained from the district market and trade office. Economic losses over the preceding 5 years were estimated and converted to US dollars using the prevailing exchange rate (US$1 = 54 ETB).

Household surveys were conducted by kebele development agents engaged in natural resource conservation under the supervision of district agricultural office experts. To validate respondents' observations, key informant interviews (KIIs) were conducted in each village with village leaders, elders, development agents, and district agricultural experts.

Data analysis

Descriptive statistics were applied to analyze socio-demographic characteristics, patterns, retaliatory killings, mitigation strategies, and economic costs of livestock depredation, and the results were presented using tables, graphs, and charts. All qualitative responses were systematically coded and then subjected to corresponding analysis. Statistical comparisons between groups were conducted using the Pearson chi-square (χ^2) test to assess associations (Kumbhojkar et al. 2019).

To enable comparison of herd sizes across households and to standardize values among different livestock species, livestock holdings were expressed in Tropical Livestock Units (TLUs). The following conversion factors were applied: cattle = 1.0 TLU; goat or sheep = 0.13 TLU; horse = 1.1 TLU; donkey or mule = 0.7 TLU; and poultry = 0.013 TLU (Rothman-Ostrow et al. 2020). Average market prices were estimated at US$660.49 for cattle, US$137.78 for goats, US$128.33 for sheep, US$248.15 for horses, US$242.59 for donkeys, US$559.26 for mules, and US$13.00 for poultry. The total financial cost of carnivore depredation for each livestock species was subsequently calculated using the following formula (Matindike et al. 2023; Kidane et al. 2024):

$$TLS = n * mv,$$

where:
TLS is the total loss for each livestock species,
n is the number of animals killed for each livestock species,
and *mv* is the average market value of each livestock species in US$.

Total economic loss for all livestock species recorded was then calculated using the following derivative formula:

$$TLA = TLS1 + TLS2 + TLS3 + \cdots TLSn,$$

where: *TLA* is the total losses for all livestock species.

Generalized linear models (GLMs) were employed to determine the relationship between the number of livestock killed and different determinant factors. The total number of livestock depredated during the preceding 5 study years (2020–2024) was used as the dependent variable. Explanatory variables included livestock abundance, economic status, time of depredation, season of depredation, and the presence of guarding dogs. Because the dependent variable was continuous and positively skewed, a gamma distribution and log-link function were used in the model (Robert 2019). Candidate models were compared with the null (intercept-only) model on the basis of Akaike's information criterion adjusted for small samples (AICc) (Burnham and Anderson 2004). All data were analyzed using R version 4.5.1 (R Core Team 2025).

Result

Respondent's characteristics

Of the 343 sampled households, 313 (91%) were male-headed, whereas 30 (9%) were female-headed (χ^2 = 233.5, df = 1, p < 0.001). Most respondents were within the productive age group of 31–40 years (41%) (χ^2 = 253.6, df = 5, p < 0.001). A substantial proportion had no formal education (n = 149, 43%) (χ^2 = 246.7, df = 3, p < 0.001). The majority of respondents had low economic status (n = 230, 67%) (χ^2 = 194.3, df = 2, p < 0.001), and farming was the primary source of income (n = 293, 85%) (χ^2 = 1175, df = 5, p < 0.001). Most respondents (94%) had lived in the area long-term (χ^2 = 573.3, df = 2, p < 0.001) (Table 1).

Most respondents (93.3%, n = 320) owned at least one livestock species (χ^2 = 257.17, df = 1, p < 0.001). Cattle were the most commonly reared livestock (n = 293, 85%), whereas mules were the least commonly reared (n = 10, 2.9%) (χ^2 = 601.04, df = 6, p < 0.001). Agro-ecologically, the lowland accounted for the highest proportion of livestock ownership (n = 521, 55.6%), followed by the midland (n = 291, 31.1%) (χ^2 = 74.38, df = 12, p < 0.001). Respondents reared 4,673 head of livestock, comprising cattle (1,071), goats (518), sheep (732), horses (21), donkeys (61), mules (15), and poultry (2,255) (χ^2 = 5873.6, df = 6, p < 0.001). Poultry were the most abundant, with 2,255 (48.3%) heads, whereas mules were the least abundant, with 15 (0.3%) heads. Livestock abundance across agro-ecologies revealed dominance in the lowland (n = 2,892, 61.9%), followed by the midland (n = 1,384, 29.6%) and highland (n = 397, 8.5%) (χ^2 = 393.36, df = 12, p < 0.001).

HCC characteristics

Among the 343 respondents, 149 (43.4%) reported 349 HCC incidents over the preceding 5 years (χ^2 = 5.9, df = 1, p = 0.02). Among these, 92 (61.8%) experienced multiple incidents (χ^2 = 8.2, df = 1, p = 0.004). Of the total respondents, 225 (65.3%) classified the conflict as major, 111 (32.7%) as minor, and seven (2.0%) as uncertain (χ^2 = 209.99, df = 2, p < 0.001). The majority of conflicts involved livestock predation (n = 260, 74.5%), followed by attacks on humans (n = 67, 19.2%) and zoonotic disease transmission (n = 22, 6.3%) (χ^2 = 260.9, df = 2, p < 0.001).

Table 1. Respondents' socio-demographic characteristics.

Characteristic	Overall *N* = 343[1]	Highland *N* = 64[1]	Lowland *N* = 162[1]	Midland *N* = 117[1]	Among respondents (*p*-value[2])	Between Respondents (*p*-value[2])
Gender					233.5(<0.001)	3.7(0.2)
Female	30 (9%)	4 (6%)	11 (7%)	15 (13%)		
Male	313 (91%)	60 (94%)	151 (93%)	102 (87%)		
Age					253.6(<0.001)	12.9(0.2)
18–20	3 (1%)	0 (0%)	1 (0.6%)	2 (2%)		
21–30	104 (30%)	19 (30%)	45 (27.8%)	40 (34%)		
31–40	140 (41%)	31 (48%)	69 (42.6%)	40 (34%)		
41–50	53 (15%)	7 (11%)	27 (17%)	19 (16%)		
51–60	24 (7.0%)	3 (4.7%)	12 (7%)	9 (8%)		
Above 60	19 (6%)	4 (6.3%)	8 (5%)	7 (6.0%)		
Education level					246.7(<0.001)	49.1(<0.001)
Diploma	6 (2%)	0 (0%)	3 (2%)	3 (3%)		
High school	21 (6%)	2 (3%)	9 (5%)	10 (9%)		
Elementary	167 (49%)	28 (44%)	108 (67%)	31 (26%)		
None	149 (43%)	34 (53%)	42 (26%)	73 (62%)		
In come					194 (<0.001)	53(<0.001)
High	24 (7%)	11 (17%)	11 (6.8%)	2 (1.7%)		
Middle	89 (26%)	24 (38%)	56 (34.6%)	9 (7.7%)		
Low	230 (67%)	29 (45%)	95 (58.6%)	106 (90.6%)		
Occupation					1175 (<0.001)	49.9 (<0.001)
Farming	293 (85.4%)	64 (100%)	119 (73.5%)	110 (94%)		
Forest based	1 (0.3%)	0 (0%)	1 (0.6%)	0 (0%)		
Grazing livestock	31 (9.0%)	0 (0%)	29 (18%)	2 (1.7%)		
Payment jobs	6 (1.7%)	0 (0%)	3 (1.9%)	3 (2.6%)		
Shops	2 (0.6%)	0 (0%)	0 (0%)	2 (1.7%)		
Others	10 (3%)	0 (0%)	10 (6%)	0 (0%)		
Residency					573.3 (<0.001)	22.9 (0.0001)
Long-term	323 (94.2%)	57 (89%)	162 (100%)	104 (89%)		
Settled	18 (5.2%)	6 (9.4%)	0 (0%)	12 (10%)		
Newcomer	2 (0.6%)	1 (1.6%)	0 (0%)	1 (1%)		

Overall, 1,280 head of livestock (256 head annually) were depredated in the preceding 5-year period (2020–2024). Small livestock were disproportionately targeted, particularly poultry (n = 508, 39.7%) and sheep (n = 400, 31.3%) (χ^2 = 1215, df = 6, p < 0.001). The major predators identified included spotted hyenas (*Crocuta crocuta*), leopards (*Panthera pardus*), common jackals (*Canis aureus*), cheetahs (*Acinonyx jubatus*), marsh mongooses (*Atilax paludinosus*), civets (*Civettictis civetta*), white-tailed mongooses (*Ichneumia albicauda*), slender mongooses (*Galerella sanguinea*), and Abyssinian genets (*Genetta abyssinica*). The number of livestock lost to different carnivores exhibited significant variation (χ^2 = 525.19, df = 9, p < 0.001). Carnivore contributions to depredation comprised spotted hyenas, 324 head (25.3%); followed by leopards, 208 head (16.3%); and common jackals, 156 head (12.2%) (Fig. 2).

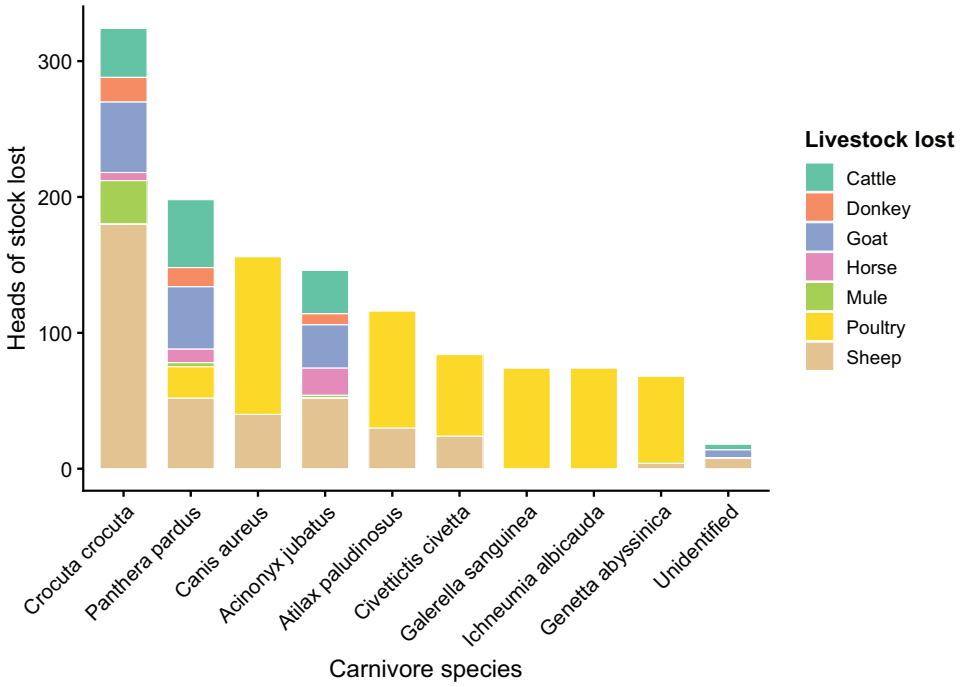

Figure 2. Heads of livestock reportedly preyed upon by carnivores in relation to predator species.

Spatio-temporal pattern of livestock depredation

Livestock depredation varied across agro-ecologies (χ^2 = 128.65, df = 2, p < 0.001). The lowland accounted for the most incidents, 65.7% (n = 171), followed by the midland, 20.8% (n = 54). Depredation incidents varied across agro-ecologies for most predators, such as spotted hyenas, cheetahs, leopards, jackals, marsh mongooses, Abyssinian genets, civets, and slender mongooses (Fig. 3c). Spatial analysis of depredation sites revealed that the majority occurred within homesteads (n = 184, 70.8%) rather than in forest habitats (n = 76, 29.2%) (χ^2 = 44.86, df = 1, p < 0.001). Depredation incidents differed with respect to the place of attack for predator species such as spotted hyenas, cheetahs, leopards, marsh mongooses, Abyssinian genets, civets, and slender mongooses (Fig. 3d). Seasonal trends revealed a higher incidence in the wet season, 77.3% (n = 201), than in the dry season, 22.7% (n = 59) (χ^2 = 77.554, df = 1, p < 0.001). Depredation incidents varied with respect to the season of attack for predators, including spotted hyenas, cheetahs, jackals, marsh mongooses, Abyssinian genets, white-tailed mongooses, civets, and slender mongooses (Fig. 3b). Temporal analysis of depredation indicated that incidents were more prevalent at night (n = 171, 65.5%) than during the day (n = 89, 34.2%) (χ^2 = 25.86, df = 1, p < 0.001). Depredation incidents varied with respect to the time of attack for predators such as spotted hyenas, jackals, civets, and slender mongooses (Fig. 3a).

Economic cost of livestock depredation

Over the 5-year period preceding the study, livestock depredation incurred a total estimated economic loss of US$118,167.2 (US$23,633.4 annually) among the respondents. At the household scale, the burden was also substantial, with

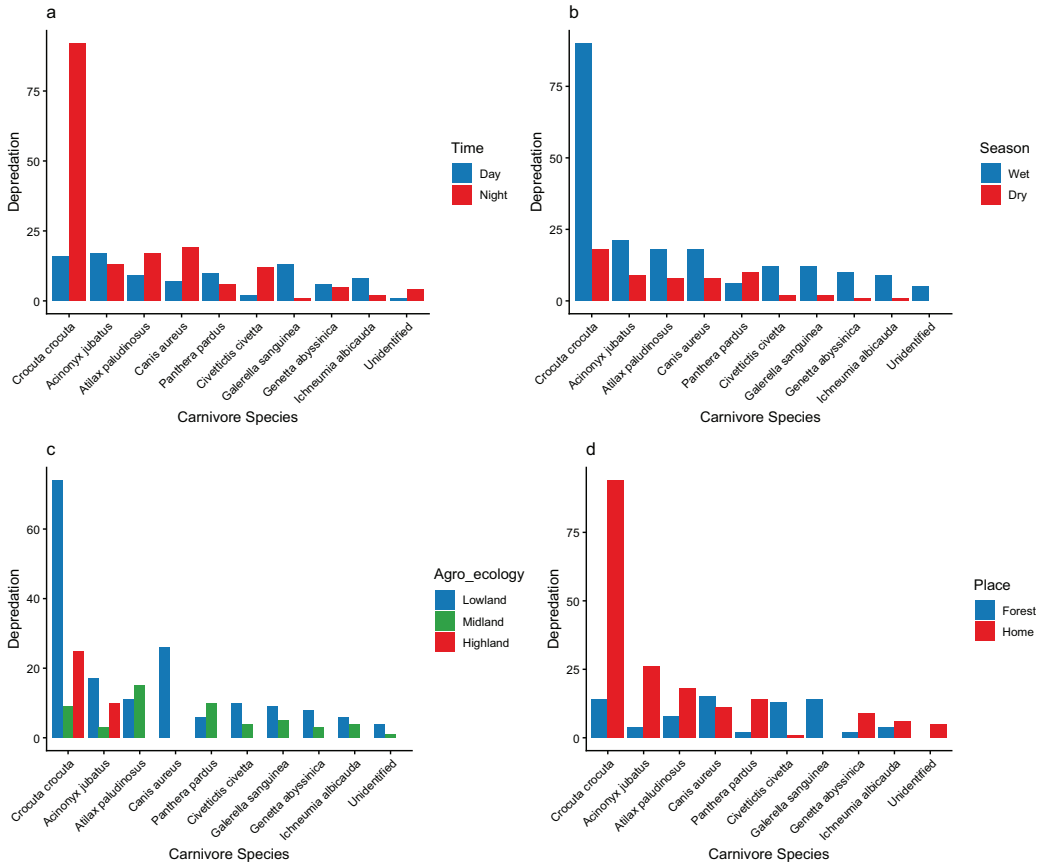

Figure 3. Livestock depredation pattern of carnivore species in relation to time (**a**), season (**b**), agro-ecology (**c**) and place (**d**).

a loss of US$344.5 per household in the preceding 5-year study period. Analysis of the economic loss of depredation revealed that spotted hyenas were the leading predator, accounting for 35.4% (US$41,830.6), followed by leopards, 35% (US$41,394.4), and cheetahs, 25.5% (US$30,177.2). Among the livestock species lost, cattle incurred the greatest economic loss (US$80,580.1), followed by horses (US$9,826.7). Although poultry were the most targeted species, they accounted for the lowest economic loss, US$85.6, due to their low market value and tropical livestock unit. The majority of livestock owners (96.5%, n = 251) reported receiving no compensation for carnivore-related losses, whereas 3.5% (n = 9) had been compensated (χ^2 = 225.25, df = 1, p < 0.001) (Table 2).

Determinants of human carnivore conflict

The GLM identified three key predictive variables influencing livestock depredation. Among these, the presence of guarding dogs emerged as a statistically significant factor. Specifically, respondents with guarding dogs were 66.5% less likely to experience livestock depredation (β = −0.665; 95% CI: −0.908 to −0.415; p < 0.001) than those without guarding dogs. Although economic status and place of conflict did not reach statistical significance at the conventional threshold, they nonetheless offer valuable ecological insights. Compared to respondents with high economic status, those with low economic status were 35% more prone to livestock depredation (β = 0.350; 95% CI: −0.156 to 0.795; p = 0.151), and those with medium economic status were 39.9% more prone to

Table 2. Economic valuation (in US$) of livestock killed by wild predators in the Sirso landscape over the period 2020–2024.

Livestock	TLS	Responsible carnivores for economic cost (US$)										Total losses (US$)
		SH	L	Ch	J	Mm	Ci	Ag	Wtm	Sm	Un	
Cattle	122	23777.7	33024.6	21135.8	0	0	0	0	0	0	2642	80580.1
Goat	136	931.4	823.9	573.2	0	0	0	0	0	0	107.5	2436
Sheep	400	3003	867.5	867.5	667.3	500.5	400.4	66.7	0	0	300.3	6673.3
Horse	36	1637.8	2729.6	5459.3	0	0	0	0	0	0	0	9826.7
Donkey	54	5434.1	2377.4	1358.5	0	0	0	0	0	0	0	9170
Mule	24	7046.7	1565.9	783	0	0	0	0	0	0	0	9395.6
Poultry	508	0	5.4	0	19.6	14.5	10.1	10.8	12.8	12.5	0	85.5
Total	1280	41830.6	41394.4	30177.2	686.9	515	410.5	77.5	12.8	12.5	3049.7	118167.2
% of loss		35.4	35.1	25.5	0.6	0.4	0. 31	0.07	0.01	0.01	2.6	100
Mean annual loss		8366.1	8278.9	6035.4	137.4	103	82.1	15.5	2.6	2.5	609.9	23633.4

Sh, spotted hyena; L, leopard; Ch, cheetah; J, jackal; Mm, marsh mongoose; Ci, civet; Ag, Abyssinian genet; Wtm, white-tailed mongoose; Sm, slender mongoose; Un, unidentified; TLS, total number of livestock lost.

Table 3. Models used in generalized linear models predicting livestock depredation.

Model no.	Predictors	K	AICc	ΔAICc
Model 1	Guarding dogs, economic status, place	6	1,286.55	0.00
Model 2	Guarding dogs, place	4	1,286.83	0.28
Model 3	Guarding dogs, economic status, livestock abundance, season	7	1,288.33	1.77
Model 4	Guarding dogs, livestock abundance, season	5	1,288.51	1.96
Model 5	Guarding dogs, livestock abundance, place, time	7	1,288.64	2.09
Model 6	Guarding dogs, economic status, livestock abundance, time	7	1,288.64	2.09
Model 7	Guarding dogs, place time	5	1,288.68	2.13
Model 8	Guarding dogs, livestock abundance, time	5	1,288.89	2.34

K = number of estimated parameters, including intercept; ΔAICc = difference from the best-fitting model (lowest AICc).

livestock depredation (β = 0.399; 95% CI: −0.137 to 0.886; p = 0.126). Furthermore, spatially, depredation occurring around homesteads was 1.9% more likely than in the forest (β = −0.019; 95% CI: −0.313 to 0.259; p = 0.898) (Table 3).

Retaliatory killing and mitigation measures of HCC

In response to livestock depredation, the majority of respondents (58.6%, n = 201) reported lethally removing the carnivores involved, whereas 41.4% (n = 142) adopted non-lethal measures, such as scaring them away or reporting them to conservation authorities (χ^2 = 10.149, df = 1, p = 0.001). Over the preceding 5 years, 110 carnivores were reportedly killed as retaliatory action. Spotted hyenas were the most frequently targeted species (n = 50, 45.45%), followed by jackals (n = 16, 14.55%) and marsh mongooses (n = 15, 13.64%). Additionally, other killed carnivores were cheetahs (n = 10, 9.09%); leopards and civets (n = 5, 4.55% each); white-tailed mongooses and slender mongooses (n = 3, 2.72% each); Abyssinian genets (n = 1, 0.91%); and unidentified carnivores (n = 2, 1.82%). The number of killed carnivores varied significantly among species (χ^2 = 176.73, df = 9, p < 0.001). Among the reported carnivore removal techniques, hunting was the most frequently employed method, 61.83% (n = 68), followed by trapping (31.83%, n = 35) and poisoning (0.9%, n = 1) (χ^2 = 66.454, df = 2,

$p < 0.001$). Carnivore retaliatory killing methods varied among species, such as trapping for cheetahs and leopards and hunting for jackals, hyenas, marsh mongooses, civets, and slender mongooses. In contrast, white-tailed mongooses and Abyssinian genets were killed by different methods.

Respondents also adopted a range of prevention strategies to reduce livestock depredation ($\chi^2 = 257.37$, df = 3, $p < 0.001$). Physical barriers were the most commonly reported strategy ($n = 261$, 40.4%), followed by active guarding ($n = 240$, 37.2%), fear-inducing stimuli ($n = 142$, 21.9%), and chemical repellents ($n = 3$, 0.5%). Additionally, 181 guard dogs were owned by 116 (33.8%) households. Regarding perceived effectiveness, active guarding was the most frequently cited prevention strategy ($n = 178$, 51.9%), followed by physical barriers ($n = 104$, 30.3%) and fear-inducing stimuli ($n = 61$, 17.8%) ($\chi^2 = 57.116$, df = 2, $p < 0.001$).

Discussion

HCC represents a major challenge to carnivore conservation, particularly in human-dominated landscapes where competition over space and resources is intense (Davoli et al. 2022; Artelle et al. 2024). The present study revealed a substantial level of HCC in the Sirso landscape, consistent with findings from other regions of Ethiopia. Similar patterns have been documented in community-managed forests such as Damota (Deneke et al. 2022), Sodo (Kebede et al. 2016), Gara Bilita (Jaleta and Tekalign 2025), and Alemsaga forest (Gatew and Azadge 2025), as well as in areas such as Konta Special District (Temesgen et al. 2025), Guna Mountain (Derso 2023), eastern Somali Region (Abdella et al. 2024), and the Kafa Highlands (Gebresenbet et al. 2018a). The close spatial association between humans and predators often leads to elevated levels of conflict (Kebede et al. 2016). In the present study, livestock depredation was identified as the primary cause of conflict, aligning with global patterns where livestock loss is the dominant driver of HCC (Inskip and Zimmermann 2009). Such conflicts may be driven by factors including agricultural expansion, human encroachment, habitat degradation, illegal exploitation of resources, and the extensive distribution of both livestock and carnivores (Kidane et al. 2024; Gatew and Azadge 2025; Kiros and Bekele 2025). Addressing these challenges requires integrated approaches that combine habitat conservation, protection of ecological corridors, and improved livestock management practices to reduce depredation while maintaining viable carnivore populations (Nanni et al. 2024).

A total of 1,280 livestock losses (256 annually) were recorded over 5 years in the Sirso landscape, indicating a substantial economic and livelihood impact. This finding is comparable to some studies in Ethiopia, such as 745 losses reported over 3 years in Wolaita Sodo (Kebede et al. 2016). However, it is higher than the 361 losses in 2 years reported by Jaleta and Tekalign (2025), the 511 livestock losses in 5 years reported by Biset et al. (2019), the 941 losses in 3 years reported by Kiros and Bekele (2025), and the 125 livestock losses reported in 1 year. Moreover, it is lower than the 1,390 losses in 5 years reported by Kidane et al. (2024), the 3,320 losses in 10 years reported by Sebsibe (2022), and the 3,210 losses in 5 years reported by Deneke et al. (2022). These variations may be attributed to differences in livestock composition, husbandry practices, predator density, habitat characteristics, prey availability, and carnivore behavioral ecology in different areas (Kolowski and Holekamp 2006; Kidane et al. 2024; Shibru et al. 2024).

The present study found that poultry were the most frequently depredated livestock species, which contrasts with many Ethiopian studies where sheep and goats are typically the primary targets (Kebede et al. 2016; Biset et al. 2019; Deneke et al. 2022; Gatew and Azadge 2025). However, this finding is consistent with studies conducted in other regions, including France (Stahl et al. 2002), southeastern Mexico (Amador-Alcalá et al. 2013), and Tanzania (Holmern and Røskaft 2014), where poultry depredation is prevalent. This difference likely reflects variation in livestock composition and management practices, particularly the relative abundance and vulnerability of poultry in the study area. Small- and medium-sized carnivores were primarily responsible for poultry depredation, including jackals, mongooses, genets, and civets, which are well adapted to exploiting small prey near human settlements (Moreira-Arce et al. 2018; Williams et al. 2018; Desta and Wakeyo 2023). In the Sirso landscape, species such as leopards, jackals, marsh mongooses, Abyssinian genets, white-tailed mongooses, civets, and slender mongooses were identified as key predators of poultry. The opportunistic feeding behavior and adaptability of these carnivores enable them to thrive in human-modified environments, thereby increasing the likelihood of conflict.

Spotted hyenas were responsible for the major livestock depredation in the present study, consistent with trends reported across Ethiopia (Shanko and Tona 2022). This pattern may be attributed to their high population density, opportunistic feeding behavior, territoriality, and strong adaptability to human-dominated landscapes. Increasing human encroachment into natural habitats has intensified contact between carnivores and livestock, thereby influencing predator foraging behavior (Deneke et al. 2022; Kidane et al. 2024; Yirga et al. 2025). Spotted hyenas proved highly adaptable in the study area, preying on virtually all livestock species except poultry. This reflects their generalist feeding behavior and ability to exploit livestock resources across diverse human-dominated landscapes.

The spatial pattern of conflict was high in the lowland agro-ecological zone, consistent with the study of Desta and Wakeyo (2023). However, this contrasts with Thorn et al. (2013), who reported higher predation in highland areas. These differences highlight the importance of agro-ecological context in shaping carnivore behavior and livestock vulnerability. Variations in habitat structure, prey availability, and human activity likely influence these spatial patterns. Livestock depredation in the present study predominantly occurred near homesteads and during nighttime, in agreement with findings from Tanzania (Bell and Raycraft 2025; Mramba et al. 2025). This might be due to ineffective prevention techniques, including poorly constructed enclosures, insufficient nighttime guarding, and seasonal cross-country migration of prey (Gebresenbet et al. 2018b). As a result of the inferior structural quality of livestock kraals, nocturnal incursions occur frequently in unfortified bomas (Bell and Raycraft 2025). Weak structural integrity of kraals allows nocturnal carnivores to access livestock more easily. Therefore, nocturnal carnivore visits to homesteads might be shaped by the presence of fencing, lighting, and immediate livestock enclosures (Kshettry et al. 2017; Kissui et al. 2019; Bell and Raycraft 2025). Consequently, the construction of tin enclosures using durable timber, coupled with enhanced nocturnal protection, is critical for mitigating HCC in African contexts (Butler 2000). In addition, the use of well-trained guarding dogs can enhance early detection of predators and reduce livestock losses (Atickem et al. 2010).

Seasonally, livestock depredation was higher during the wet season, consistent with studies from central and southern Ethiopia (Kiros and Bekele 2025; Shibru et al. 2024). During the rainy season, livestock are often grazed in crop fields where dense vegetation provides cover for predators, increasing encounter rates (Mramba et al. 2025). Seasonal changes may also influence wild prey distribution and behavior, thereby altering predator foraging patterns (Mills et al. 2024). Additionally, herding responsibility is delegated to inexperienced children in the wet season, which increases livestock vulnerability to predators (Deneke et al. 2022). Moreover, increased vegetation cover in the dry season provides enhanced food and shelter availability to wild prey, thereby reducing their vulnerability to predators (Shibru et al. 2024). As a result, livestock are vulnerable to predators during the wet season due to reduced grazing vigilance (Kolowski and Holekamp 2006), predators roaming wider (Abay et al. 2011), and reduced wild prey (Kuiper et al. 2015).

In this study, carnivore-induced livestock depredation was estimated to cause an economic loss of US$118,167.2 and US$23,633.4 annually. The magnitude of loss reported here is comparatively higher than previous findings, such as US$103.9 per year in the Bale Mountains National Park (Sebsibe 2022), US$95.6 per year in the Damota forest (Deneke et al. 2022), and US$12 per year reported for the Bale Mountains (Deneke et al. 2022). This variation might be attributed to habitat fragmentation, reduced natural habitat availability, and disruption of migration corridors that have heightened the frequency of predator–livestock encounters (Kidane et al. 2024). These factors contribute to elevated levels of livestock depredation, which in turn can lead to substantial economic losses.

Comparatively, the poorest households were vulnerable to considerable economic loss. This might be attributed to weaker fence quality, the absence of corrals, and fewer buildings (Abay et al. 2011; Davoli et al. 2022; Kidane et al. 2024). Therefore, implementing effective strategies to mitigate livestock depredation and its associated economic impacts is essential. Households with guarding dogs experienced fewer livestock losses, consistent with previous studies (Ogada et al. 2003; Miller et al. 2016). This is becoming a primary anti-predatory strategy in Ethiopia (Megaze et al. 2017; Biset et al. 2019; Kidane et al. 2024; Shibru et al. 2024). This is because predator attacks occur at night in livestock bomas; therefore, active vigilance using guarding dogs might be an effective strategy for reducing livestock loss (Kidane et al. 2024; Kiros and Bekele 2025). The probability of livestock depredation was influenced by habitat type, with predation incidence being higher in homestead areas than in forest habitats, consistent with Mahajan et al. (2022).

In the present study, respondents preferred lethal methods to remove problematic predators, which is in line with studies in Chebera-Churchura National Park (Acha et al. 2018) and Wabe Valley of Bale, Ethiopia (Atickem et al. 2010). This might be due to insufficient compensation, which develops intolerance and often leads to retaliatory killing (Syamsia 2016). In addition, socio-economic factors can also shape respondents' attitudes toward predators (Kidane et al. 2024). As a result, retaliatory killing poses a significant conservation challenge to carnivores, particularly in shared landscapes (van Eeden et al. 2018). To promote coexistence, ensuring fair compensation for resource loss and facilitating livelihood transitions are critical (Bennett 2016). Sustainable financing derived from ecotourism revenues and conservation fees could provide a viable solution to the conflict (Mach et al. 2020). Quantifying lethal removal is

therefore essential to enhance participatory management involving local communities and address their concerns (Dickman 2008; Reed 2008). Therefore, community capacity-building, sustainable resource use, aligning community needs with conservation goals, and strengthening stakeholders are vital for mitigating conflict (Scheyvens 1999; Berkes 2004; Tessema et al. 2007).

Respondents applied various preventive measures, such as physical barriers, active guarding, fear-inducing stimuli, and chemical repellents. This is consistent with previous studies in Ethiopia: Wolaita Sodo Zuriya (Kebede et al. 2016), Borena Sayint National Park (Biset et al. 2019), Kafta Sheraro National Park (Kidane et al. 2024), Gibe Sheleko National Park (Kiros and Bekele 2025), and Bale Mountains National Park (Mekonen 2020). These preventive measures were commonly practiced throughout the country, likely due to shared husbandry techniques. In contrast, a study in a rural village of France reported that electric fencing was the preferred preventive strategy (Stahl et al. 2002). Comprehensive prevention methods, such as improved livestock management, nighttime kraaling, ecotourism benefit sharing, and compensation schemes, were recommended (Ogada et al. 2003; Mkonyi 2022). The implementation of robust preventive strategies, such as grazing surveillance, herd monitoring, and active defense, is basic for coexistence in shared landscapes (Franco et al. 2018). Therefore, integrated strategies combining livestock protection with conservation of wild prey are needed (Mramba et al. 2025).

Conclusion and recommendations

HCC is a serious factor contributing to the extinction of carnivores, making it critical in conservation efforts. Sirso natural forest is an island ecosystem surrounded by agricultural lands and settlements in the three agro-ecological zones. HCC leads to economic losses for communities and unwillingness to support carnivore conservation. In the Sirso landscape, HCC and its economic impacts are prevalent and persistent. Large carnivores were responsible for the most economic losses. Depredation was rigorous in homesteads, at nighttime, and in the wet season. Livestock loss imposed substantial economic impacts, particularly on the poorest respondents without guarding dogs. Respondents employed physical barriers, active guarding, fear-inducing stimuli, and chemical repellents as preventive strategies. Among these strategies, active guarding of the boma was cited as the most effective. Key determinants of livestock depredation were the presence of guarding dogs, economic status, and place of depredation. Lethal methods were preferred over non-lethal methods in the removal of problematic predators. Context-specific conflict mitigation strategies, improved livestock management practices, and community-based education programs are needed to support both wildlife conservation and rural livelihoods in human-dominated landscapes.

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References

Abay GY, Bauer H, Gebrihiwot K, Deckers J (2011) Peri-urban spotted hyena (*Crocuta crocuta*) in Northern Ethiopia: Diet, economic impact, and abundance. European Journal of Wildlife Research 57(4): 759–765. https://doi.org/10.1007/s10344-010-0484-8

Abdella F, Hailu A, Tilahun S, Johnson PJ, Bauer H (2024) Large carnivore distribution, conflicts and threats in the east of the Somali region, Ethiopia. African Journal of Ecology 62(1). https://doi.org/10.1111/aje.13230

Acha A, Temesgen M, Bauer H (2018) Human–wildlife conflicts and their associated livelihood impacts in and around Chebera-Churchura National Park, Ethiopia. Society and Natural Resources 31(2): 260–275. https://doi.org/10.1080/08941920.2017.1347974

Afriyie JO, Opare MA, Hejcmanová P (2022) Knowledge and perceptions of rural and urban communities towards small protected areas: Insights from Ghana. Ecosphere 13(11): e4257. https://doi.org/10.1002/ecs2.4257

Amador-Alcalá S, Naranjo EJ, Jiménez-Ferrer G (2013) Wildlife predation on livestock and poultry: Implications for predator conservation in the rainforest of south-east Mexico. Or yx 47(2): 243–250. https://doi.org/10.1017/S0030605311001359

Artelle KA, Johnson HE, McCaffery R, Schell CJ, Williams TD, Wilson SM (2024) From causes of conflict to solutions: Shifting the lens on human–carnivore coexistence research. Conservation Science and Practice 6(11): e13239. https://doi.org/10.1111/csp2.13239

Asaye B, Tekalign W, Dobamo T (2024) Livestock predation, crop raiding, and community attitudes towards sustainable wildlife conservation in and around Mankira Forest, Southwest Ethiopia. BMC Ecology and Evolution 24: 85. https://doi.org/10.1186/s12862-024-02279-2

Atickem A, Williams S, Bekele A, Thirgood S (2010) Livestock predation in the Bale Mountains, Ethiopia. African Journal of Ecology 48(4): 1076–1082. https://doi.org/10.1111/j.1365-2028.2010.01214.x

Atwood TC, Breck SW (2012) Carnivores, conflict, and conservation: defining the carnivores, conflict, and conservation: defining the landscape of conflict landscape of conflict. Plant Health Inspection Service. https://digitalcommons.unl.edu/icwdm_usdanwrc

Bell E, Raycraft J (2025) Livelihoods and large carnivores: Identifying social-ecological drivers of interaction dynamics in northern Tanzania to foster coexistence. Journal of Environmental Management 392: 126703. https://doi.org/10.1016/j.jenvman.2025.126703

Bennett NJ (2016) Using perceptions as evidence to improve conservation and environmental management. Conservation Biology 30(3): 582–592). https://doi.org/10.1111/cobi.12681

Berkes F (2004) Rethinking community-based conservation. Conservation Biology 18(3): 621–630. https://doi.org/10.1111/j.1523-1739.2004.00077.x

Biset A, Mengesha G, Girma Z (2019) Human-wildlife conflict in and around Borena Sayint National Park, Northern Ethiopia. Human-Wildlife Interactions 13(1): 15. https://doi.org/10.26076/fk60-mp27

Braczkowski AR, O'Bryan CJ, Lessmann C, Rondinini C, Crysell AP, Gilbert S, Stringer M, Gibson L, Biggs D (2023) The unequal burden of human-wildlife conflict. Communications Biology 6: 182. https://doi.org/10.1038/s42003-023-04493-y

Burnham KP, Anderson DR (2004) Multimodel inference: Understanding AIC and BIC in model selection. Sociological Methods and Research 33(2): 261–304. https://doi.org/10.1177/0049124104268644

Butler JRA (2000) The economic costs of wildlife predation on livestock in Gokwe communal land, Zimbabwe. African Journal of Ecology 38(1): 23–30. https://doi.org/10.1046/j.1365-2028.2000.00209.x

Chinchilla S, van den Berghe E, Polisar J, Arévalo C, Bonacic C (2022) Livestock–Carnivore Coexistence: Moving Beyond Preventive Killing. Animals 12(4): 479. https://doi.org/10.3390/ani12040479

Cochran W (1977) Sampling Techniques, 3rd edn. John Wiley and Sons, Inc, Canada.

Davoli M, Ghoddousi A, Sabatini F, Fabbri E, Caniglia R, Kuemmerle T (2022) Changing patterns of conflict between humans, carnivores and crop-raiding prey as large carnivores recolonize human-dominated landscapes. Biological Conservation 269: 109553. https://doi.org/10.1016/j.biocon.2022.109553

Deneke Y, Megaze A, Tekalegn W, Dobamo T, Leirs H (2022) Population estimation and livestock loss by spotted hyena (*Crocuta crocuta*) in Damota community managed forest, Southern Ethiopia. Global Ecology and Conservation 34: e02037. https://doi.org/10.1016/j.gecco.2022.e02037

Derso TT (2023) Livestock predation around Guna mountain community conservation area, Amhara Region, Ethiopia. Ethiopian Journal of Biodiversity 4(2): 169–186.

Desta TT, Wakeyo O (2023) Predation and theft: the standing threats of the scavenging chicken production system. Journal of Biological Research (Italy) 96(2): 11619. https://doi.org/10.4081/jbr.2023.11619

Dickman AJ (2008) Key determinants of conflict between people and wildlife, particularly large carnivores, around Ruaha National Park, Tanzania (Ph.D. thesis). University College London.

Dickman AJ, Macdonald EA, Macdonald DW (2011) A review of financial instruments to pay for predator conservation and encourage human-carnivore coexistence. Proceedings of the National Academy of Sciences of the United States of America 108(34): 13937–13944. https://doi.org/10.1073/pnas.1012972108

Fletcher R, Toncheva S (2021) The political economy of human-wildlife conflict and coexistence. Biological Conservation 260: 109216. https://doi.org/10.1016/j.biocon.2021.109216

Franco PM, Gine RS, Richard DL, Robert DF, Craig J, Tomas H, Eivin R (2018) Livestock depredation by wild carnivores in the Eastern Serengeti Ecosystem, Tanzania. International Journal of Biodiversity and Conservation 10(3): 122–130. https://doi.org/10.5897/IJBC2017.1165

Gatew S, Azadge W (2025) Human-wildlife conflict and its socio-economic impacts in North West Ethiopia. Discover Life 55: 14. https://doi.org/10.1007/s11084-025-09685-6

Gebo B, Takele S, Shibru S (2022) Knowledge, attitude and practice of the local people towards human–carnivore coexistence in Faragosa–Fura Landscape, Gamo Zone, southern Ethiopia. Wildlife Biology 2022(2): 1–11. https://doi.org/10.1002/wlb3.01018

Gebresenbet F, Baraki B, Yirga G, Sillero-Zubiri C, Bauer H (2018a) A culture of tolerance: Coexisting with large carnivores in the Kafa Highlands, Ethiopia. Oryx 52(4): 751–760. https://doi.org/10.1017/S0030605316001356

Gebresenbet F, Bauer H, Vadjunec JM, Papeş M (2018b) Beyond the numbers: Human attitudes and conflict with lions (*Panthera leo*) in and around Gambella National Park, Ethiopia. PLoS ONE 13(9): e0204320. https://doi.org/10.1371/journal.pone.0204320

Holmern T, Røskaft E (2014) The poultry thief: Subsistence farmers' perceptions of depredation outside the Serengeti National Park, Tanzania. African Journal of Ecology 52(3): 334–342. https://doi.org/10.1111/aje.12124

Inskip C, Zimmermann A (2009) Human-felid conflict: A review of patterns and priorities worldwide. Oryx 43(1): 18–34. https://doi.org/10.1017/S003060530899030X

Jaleta M, Tekalign W (2025) Human-wild mammal interaction and the local people's attitudes towards the mammals in Gara Bilita (Belete Gera) forest, South-West Ethiopia. Human Dimensions of Wildlife 30(3): 362–369. https://doi.org/10.1080/10871209.2024.2372098

Kebede Y, Tekalign W, Menale H (2016) Conservation challenge: Human-carnivore conflict in Sodo community managed conservation forest, Wolaita Sodo Zuriya District, Southern Ethiopia. Journal of Environment and Earth Science 6(9): 44–52. www.iiste.org

Kidane EE, Gebremichael WB, Siyum ZG, Yirga G, Kidane YT (2024) Human–carnivore conflict in and around Kafta Sheraro National Park, Northern Ethiopia: Determinants, costs, and conservation implications. International Journal of Zoology 2024: 8309142. https://doi.org/10.1155/2024/8309142

Kiros S, Bekele A (2025) Assessment of predation effects of the wild carnivore towards the livestock in and around Gibe Sheleko National Park, Central Ethiopia. European Journal of Wildlife Research 71(4): 85. https://doi.org/10.1007/s10344-025-01958-9

Kissui BM, Kiffner C, König HJ, Montgomery RA (2019) Patterns of livestock depredation and cost-effectiveness of fortified livestock enclosures in northern Tanzania. Ecology and Evolution 9(19): 11420–11433. https://doi.org/10.1002/ece3.5644

Kolowski JM, Holekamp KE (2006) Spatial, temporal, and physical characteristics of livestock depredations by large carnivores along a Kenyan reserve border. Biological Conservation 128(4): 529–541. https://doi.org/10.1016/j.biocon.2005.10.021

Kshettry A, Vaidyanathan S, AthreyaV (2017) Leopard in a tea-cup: A study of leopard habitat-use and human-leopard interactions in North-eastern India. PLOS ONE 12(5): e0177013. https://doi.org/10.1371/journal.pone.0177013

Kuiper TR, Loveridge AJ, Parker DM, Johnson PJ, Hunt JE, Stapelkamp B, Sibanda L, Macdonald DW (2015) Livestock herding patterns influence vulnerability to lion depredation seasonal herding practices influence predation on domestic stock by African lions along a protected area boundary. Biological Conservation 192: 346–354. https://doi.org/10.1016/j.biocon.2015.08.012

Kumbhojkar S, Yosef R, Benedetti Y, Morelli F (2019) Human-leopard (*Panthera pardus fusca*) co-existence in Jhalana Forest Reserve, India. Sustainability (Switzerland) 11(14): 3912. https://doi.org/10.3390/su11143912

Lazure L, Weladji RB (2024) Methods to mitigate human–wildlife conflicts involving common mesopredators: a meta-analysis. Journal of Wildlife Management 88(2): e22526. https://doi.org/10.1002/jwmg.22526

Linuma OF, Mahenge AS, Mato RRAM, Greenwood AD (2022) Drivers of human–wildlife interactions in a co-existence area: a case study of the Ngorongoro conservation area, Tanzania. Discover Sustainability 3: 45. https://doi.org/10.1007/s43621-022-00113-7

Lorand C, Robert A, Gastineau A, Mihoub JB, Bessa-Gomes C (2022) Effectiveness of interventions for managing human-large carnivore conflicts worldwide: Scare them off, don't remove them. Science of the Total Environment 838: 156195. https://doi.org/10.1016/j.scitotenv.2022.156195

Mach L, Winner C, Rojas C, Klemond M (2020) Protected area entry fees and governance quality. Tourism Management 77: 104003. https://doi.org/10.1016/j.tourman.2019.104003

Maddox TM (2003) The ecology of cheetahs and other large carnivores In a pastorallst-domlnated buffer zone. PhD Dissertation, Department of Anthropology, University College London and Institute of Zoology, London.

Mahajan P, Chaudhary R, Kazi A, Khandal D (2022) Spatial determinants of livestock depredation and human attitude toward wolves in Kailadevi Wildlife Sanctuary, Rajasthan, India. Frontiers in Ecology and Evolution 10: 855084. https://doi.org/10.3389/fevo.2022.855084

Maheshwari A, Midha N, Cherukupalli A (2014) Participatory rural appraisal and compen sation intervention: Challenges and protocols while managing large carnivore-human conflict. Human Dimensions of Wildlife 19(1): 62–71. https://doi.org/10.1080/10871209.2013.828247

Matindike S, Chibememe G, Mahakata I (2023) Livestock Losses and Predation Crisis in Communal Areas around Sengwa Wildlife Research Area (SWRA), Zimbabwe. OALib 10(04): 1–13. https://doi.org/10.4236/oalib.1110000

Megaze A, Balakrishnan M, Belay G (2017) Human-wildlife conflict and attitude of local people towards conservatin of wildlife in Chebera Churchura National Park, Ethiopia. African Zoology 52(1): 1–8. https://doi.org/10.1080/15627020.2016.1254063

Mekonen S (2020) Coexistence between human and wildlife: The nature, causes and mitigations of human wildlife conflict around Bale Mountains National Park, Southeast Ethiopia. BMC Ecology 20: 51. https://doi.org/10.1186/s12898-020-00319-1

Mekuria DG (2018) Analysis of Sesame Market Chain: The Case of Melokoza District, Gamo Gofa Zone, SNNPRS, Ethiopia.

Miller JRB (2015) Mapping attack hotspots to mitigate human–carnivore conflict: approaches and applications of spatial predation risk modeling. Biodiversity and Conservation 24(1): 2887–2911. https://doi.org/10.1007/s10531-015-0993-6

Miller JRB, Stoner KJ, Cejtin MR, Meyer TK, MiddletonAD, SchmitzOJ (2016) Effectiveness of contemporary techniques for reducing livestock depredations by large carnivores. Wildlife Society Bulletin 40(4): 806–815. https://doi.org/10.1002/wsb.720

Mills KL, Bennitt E, Zhu K, Bartlam-Brooks HLA, Hubel TY, Wilson AM, Carter NH, Sanders NJ (2024) Dynamic primary resources, not just wild prey availability, underpinlion depredation of livestock in a savanna ecosystem. Ecology and Evolution 14(9): e70208. https://doi.org/10.1002/ece3.70208

Mkonyi FJ (2022) An integrated approach for the management of human-carnivore conflict: a review of conflict management interventions in Tanzania. Mammalian Biology 102(5–6): 2061–2081. https://doi.org/10.1007/s42991-022-00255-1

Moreira-Arce D, Ugart CS, Zorondo-Rodríguez F, Simonetti JA (2018) Management tools to reduce carnivore-livestock conflicts: Current gap and future challenges. Rangeland Ecology and Management 71(3): 389–394. https://doi.org/10.1016/j.rama.2018.02.005

Mramba RP, Hello N, Mrimi DJ (2025) Assessing determinants of livestock predation by spotted hyenas in Nyang'hwale district and mitigation approaches adopted by the community. Discover Conservation 2: 18. https://doi.org/10.1007/s44353-025-00038-y

Nanni AS, Ghoddousi A, Romero-Muñoz A, Baumann M, Burton J, Camino M, Decarre J, Martenllo F, Regolin AL, Kuemmerle T (2024) Mapping opportunities and barriers for coexistence beween people and pumas in the Argentine Dry Chaco. Diversity and Distributions 30(10): e13920. https://doi.org/10.1111/ddi.13920

O'Bryan CJ, Braczkowski AR, Beyer HL, Carter NH, Watson JEM, McDonald-Madden E (2018) The contribution of predators and scavengers to human well-being. Nature Ecology and Evolution 2(2): 229–236. https://doi.org/10.1038/s41559-017-0421-2

Ogada M, Woodroffe R, Oguge NO, Frank LG (2003) Limiting depredation by African carnivores: The role of livestock husbandry. Conservation Biology 17(6): 1521–1530. https://doi.org/10.1111/j.1523-1739.2003.00061.x

Pant B, Sharma HP, Dahal BR, Regmi S, Belant JL (2023) Spatio-temporal patterns of human-wildlife conflicts and effectiveness of mitigation in Shuklaphanta National Park, Nepal. https://doi.org/10.1371/journal.pone.0282654

R Core Team (2025) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Ranjan V, Badol R, Hussain S, DhakatePM (2025) Assessing the implications of habitat trans formations on human-large carnivore interactions outside protected areas. Scientific Reports 15: 28784. https://doi.org/10.1038/s41598-025-13808-4

Reed MS (2008) Stakeholder participation for environmental management: A literature review. Biological Conservation 141(10): 2417–2431. https://doi.org/10.1016/j.biocon.2008.07.014

Robert V (2019) Generalized Linear Models 1. Statistics for Linguists: An Introduction Using R. Routledge, New York, 198–217. https://doi.org/10.4324/9781315165547-12

Rothman-Ostrow P, Gilbert W, Rushton J (2020) Tropical livestock units: Re-evaluating a methodology. Frontiers in Veterinary Science 7: 556788. https://doi.org/10.3389/fvets.2020.556788

Salerno J, Aguirre AA, Aguirre LF, Bonacic C, Bosco-Lauth A, Breck SW, Gitonga PN, GoldsteinT, Gonzalez MN, Hoag DLK, Mayo C, Mizia J, Raynor EJ, Ritten J, Sherman TJ, Shockley K, Sukumar R, Thekaekara T, Titcomb G, Crooks KR (2025) Transdisci plinary research priorities for a One Health approach to human–wildlife coexi stence. BioScience 2025: biaf026. https://doi.org/10.1093/biosci/biaf026

Scheyvens R (1999) Ecotourism and the empowerment of local communities. Tourism Management 20(2): 245–249. https://doi.org/10.1016/S0261-5177(98)00069-7

Sebsibe I (2022) Humans-livestock predators conflict in the Central and Eastern Part of Bale Mountains National Park, Ethiopia. BMC Ecology and Evolution 22: 113. https://doi.org/10.1186/s12862-022-02065-y

Shanko G, Tona B (2022) Human-Terrestrial Wildlife Conflict in Ethiopia: A Systematic Review. Scientific World Journal 2022: 2612716. https://doi.org/10.1155/2022/2612716

Shibru S, Tolcha A, Melese M, Ayechew B, Tsegaye G, Gatew S (2024) Perceptions of farmers towards carnivores in an Ethiopian protected area. African Journal of Ecology 62(1): e13218. https://doi.org/10.1111/aje.13218

Stahl P, Ruette S, Gros L (2002) Predation on free-ranging poultry by mammalian and avian predators: field loss estimates in a French rural area. Mammal Review 32(3): 227–234. https://doi.org/10.1046/j.1365-2907.2002.00110.x

Storch I, Cristescu B, Fabiano E (2025) Human–wildlife conflict and coexistence in the African context. Wildlife Biology 2025(1): e01432. https://doi.org/10.1002/wlb3.01432

Syamsia (2016) Executive Summary. South African Medical Journal 101(2003): 16.

Temesgen Z, Biru Y, Gibru A, Hundie K (2025) Human–wildlife conflict and local community attitudes towards wildlife conservation in Konta Special District, southwest Ethiopia. BioRisk 23: 63–77. https://doi.org/10.3897/biorisk.23.163073

Tessema ME, Ashenafi ZT, Lilieholm RJ, LeaderWilliams N (2007) Community Attitudes towards Wildlife Conservation in Ethiopia. In: George Wright Society Conference, 287–292.

Thorn M, Green M, Scott D, Marnewick K (2013) Characteristics and determinants of human-carnivore conflict in South African farmland. Biodiversity and Conservation 22(8): 1715–1730. https://doi.org/10.1007/s10531-013-0508-2

Torres-Romero EJ, Eppley TM, Ripple WJ, Newsome TM, Krofel M, Carter NH, Ordiz A, De OliveiraTG, Selva N, Penteriani V (2025) Ecology Global scale assessment of the human-induced extinction crisis of terrestrial carnivores. Science Advances 11(29): eadq2853. https://doi.org/10.1126/sciadv.adq2853

van Eeden LM, Crowther MS, Dickman CR, Macdonald DW, Ripple WJ, Ritchie EG, Newsome TM (2018) Managing conflict between large carnivores and livestock. Conservation Biology 32(1): 26–34. https://doi.org/10.1111/cobi.12959

Weldearegay EM, Awas T (2021) Ethnobotanical study in and around Sirso Natural Forest of Melokoza District, Gamo Goffa Zone, Southern Ethiopia. Ethnobotany Research and Applications 22: 1–24. https://doi.org/10.32859/era.22.27.1-24

Williams ST, Maree N, Taylor P, Belmain SR, Keith M, Swanepoel H (2018) Predation by small mammalian carnivores in rural agro-ecosystems: An undervalued ecosystem service? Ecosystem Services 30: 362–371. https://doi.org/10.1016/j.ecoser.2017.12.006

Yerbury RM, Lukey SJ (2021) Human–animal interactions: Expressions of wellbeing through a "nature language." Animals 11(4): 950. https://doi.org/10.3390/ani11040950

Yirga G, Freckleton RP, Beckerman AP (2025) War-Induced behavioral change in spotted hyena (*Crocuta crocuta*) populations in Tigray, Northern Ethiopia. Ecology and Evolution 15(2): e70920. https://doi.org/10.1002/ece3.70920

Yokamo S, Tsalla T, Oyka E, Wotro W (2018) Identification and prioritization of major agricultural production and productivity constraints: The case of Melokoza District. Journal of Biology, Agriculture and Healthcare 11(5): 38–43.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

The research received ethical approval from Arba Minch University under permit number Bio778/16, as well as authorization from the Melekoza District Forest and Environment Development Office, referenced by number 13/685/78, prior to data collection. Participants were briefed on the study's objectives, and their confidentiality was guaranteed before interviews were conducted.

Artificial Intelligence (AI) use

The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI.
No AI tools were used in the preparation of this manuscript.

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Author contributions

Matewos Masne Mazga: conception and design of the study, collection of raw data, analysis and interpretation of data, and drafting of the manuscript. Serekebirhan Takele: statistical expertise and advice, critical revision of the article for intellectual content, administrative and technical support, and approval of the final manuscript. Berhanu Gebo: statistical expertise and advice, critical revision of the article for intellectual content, administrative and technical support, and approval of the final manuscript.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Supplementary material 1

Raw data used for analysis

Authors: Matewos Masne, Serekebirhan Takele, Berhanu Gebo

Data type: xlsx

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