



Population ecology of non-human primates and their conflict with humans in Lamo Forest and the surrounding fragmented forests of South-Central Ethiopia

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Received: 15 April 2025 / Revised: 31 January 2026 / Accepted: 24 April 2026 / Published online: 30 May 2026
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Abstract

Human-primate conflicts are a growing threat to conservation, particularly in low-income, densely populated regions like Ethiopia, where habitat fragmentation and crop raiding intensify tensions between expanding human populations and non-human primates. This study, conducted from January 2023 to August 2024 in Lamo Forest and surrounding fragmented forests of South-Central Ethiopia, aimed to investigate the population ecology of non-human primates and evaluate the dynamics of human-primate conflicts to inform coexistence strategies. The research used distance sampling techniques for primate density estimates and community surveys (individual interview and focus groups discussion) to assess human-primates conflict levels. The mean population density (individuals per km²) was 12.81 ± 3.4 for grivet monkeys, 11.76 ± 2.68 for Olive baboons, 10.06 ± 2.93 for mantled guereza, and 6.23 ± 0.9 for black colobus monkeys. Most respondents (48.1%, $n=165$) identified crop damage as the primary conflict cause and the least one was human attack (7.6%, $n=26$). The most damaged crops were *Zea mays* (29.7%, $n=102$) and *Musa acuminata* (17.8%, $n=61$). Over five years, total crop losses reached 18,373 kg, valued at US \$13,852.18, with an annual loss of \$2,770.44 per village, or \$8.08 per household. Livestock losses totaled \$139,814, averaging an annual loss of \$27,962.8, or \$81.52 per respondent. The primary strategy for preventing crop damage and livestock predation was physical guarding, employed by 35% of respondents ($n=120$), followed by chasing (28%) and fencing (16%). Future research must conduct longitudinal monitoring of primate population trends, community-led surveys to map conflict hotspots and assess economic impacts on farmers, and pilot testing of targeted interventions to foster peaceful coexistence.

Keywords Conservation · Crop raiding · Economic loss · Mitigation methods · Predation

Introduction

Ethiopia is home to highly diverse wildlife, comprising approximately 325 species across 52 families, including 57 endemic species (Bekele and Yalden, 2013). This biodiversity is distributed across strong altitudinal and climatic gradients, particularly within the Great Rift Valley, the Omo River Basin, and the western lowlands, which support unique

flora and fauna. However, wildlife habitats and biodiversity are increasingly threatened by poverty, rapid human population growth, agricultural expansion, livestock grazing, and sociopolitical instability, all of which contribute to habitat degradation, fragmentation, and loss (Reidinger and Miller, 2013; Bekele and Yalden, 2013).

Globally, anthropogenic pressures driven by long-term human population growth, agriculture, urbanization, and increasing resource demand have simplified ecosystems and altered ecological processes over millennia (Barnosky and Hadly, 2016). These pressures have intensified wildlife–human interactions, which range from beneficial to highly conflictual (Bhatia et al., 2020), and have contributed to widespread species declines and extinctions, resulting in substantial biodiversity loss (Surovell et al., 2016). Addressing these challenges requires coordinated

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collaboration among science, policy, and society to mitigate negative impacts and promote coexistence between humans and wildlife (Reidinger and Miller, 2013).

Primates are large, charismatic mammals widely distributed across tropical forests, with Africa hosting a particularly high diversity. Of the estimated 326–550 primates species worldwide, approximately 32% occur in Africa, which supports about 216 species and subspecies (Colin et al., 2006; Couvreur et al., 2021). Ethiopia alone harbors 13 non-human primate species distributed across diverse altitudinal zones (Bekele and Yalden, 2013). However, forest expansion–fragmentation cycles and increasing anthropogenic pressure have strongly shaped current primate distribution patterns (Lawes and Eeley, 2000). Across Africa, primates are especially vulnerable to habitat loss, degradation, and hunting, with nearly 60% of species facing extinction risk and 75% experiencing population declines (Estrada et al., 2017; Kifle and Bekele, 2021).

Human–primate conflict is increasingly common in areas where rural communities depend on agriculture and livestock and live in close proximity to natural forests (Kifle and Bekele, 2020b). Such conflicts have been widely documented across Africa, including Tanzania (Gillingham and Lee, 2003), Uganda (Hill and Wallace, 2012), Guinea-Bissau (Hockings and Sousa, 2013), Rwanda (McGuinness and Taylor, 2014), South Africa (Findlay, 2016), and Ethiopia (Kifle and Bekele, 2020b). In rural Ethiopia, conflicts are primarily driven by competition for resources such as food and habitat, with crop raiding, livestock predation, and habitat disturbance being the most common causes (Anshebo et al., 2025).

Several primate species, including vervet monkeys (*Chlorocebus pygerythrus*), grivet monkeys (*C. aethiops*), geladas (*Theropithecus gelada*), and olive baboons (*Papio anubis*), are known to raid crops and prey on livestock. These activities can result in losses of household income, experiencing annual financial losses (Kidane et al., 2024; Kifle and Bekele, 2020b). Denser primate populations in human-dominated landscapes strongly predict increased crop-foraging incursions, as proximity to farms amplifies the frequency of human primate encounters. Understanding primate population dynamics is therefore essential for effective conflict mitigation and conservation planning (Cavada et al., 2016; Anshebo et al., 2025).

Accurate estimates of primate population density provide critical baselines for monitoring population trends under conditions of habitat loss and fragmentation. Such data are necessary for designing proactive, evidence-based interventions, including community-managed buffer zones, habitat corridors, and targeted conflict mitigation strategies. In the absence of reliable ecological data, conservation efforts remain largely reactive and fail to account for the

direct relationship between primate abundance and conflict severity (Cavada et al., 2016; Anshebo et al., 2025). Despite this need, research on non-human primates and human–primate conflict in Ethiopia remains limited (Kifle and Bekele, 2020b).

Primate population density and species composition were assessed to provide ecological context for interpreting patterns of human primate conflict. In fragmented agricultural landscapes, the frequency and severity of crop raiding and livestock predation are shaped not only by human land-use practices but also by the abundance, habitat use, and spatial distribution of the primate species involved (Anshebo et al. 2025; Asaye, et al., 2024). Integrating ecological data with household- and village-level conflict surveys therefore allows for a more nuanced understanding of species-specific conflict patterns and spatial variation in economic losses, which is essential for developing targeted and effective mitigation strategies (Seoraj-Pillai and Pillay, 2016).

Lamo Forest and its surrounding fragmented habitats represent an important area for primate conservation; however, limited ecological information on primate populations in this landscape constrains understanding of both population status and conflict dynamics. Establishing baseline data on primate ecology alongside conflict patterns is thus critical for informed wildlife management in the region. Accordingly, this study focuses on four key components : (1) demographic characteristics of surveyed households, (2) types and extent of human–primate conflict, (3) primate species involved in conflict and their population density, and (4) existing conflict mitigation methods. Through this integrated approach, the study aims to assess human–primate conflict and estimate population sizes of four primate species in Lamo Forest and adjacent fragmented habitats of south-central Ethiopia.

Materials and methods

Description of the study area

The study was conducted in Lamo Forest and its surrounding fragmented forests (hereafter LSFF), located in Tembaro Special Woreda, south-central Ethiopia. LSFF lies between 07°12'30"–07°20'0" N and 37°28'30"–37°33'0" E, at elevations of 2100–2260 m a.s.l. (Fig. 1), within Sigazo and Farzano Kebeles. Covering 286 km² (22 km² forest and 264 km² farmland with fragmented forest), the area is about 405 km south of Addis Ababa. Tembaro Special Woreda borders Hadaro Tunto (south and east), Hadiya Zone (north), Dawuro (west), and Wolayita Zone (southeast). Formerly Omo Sheleko Woreda, it was renamed after the August 19, 2023, administrative restructuring that formed the Central

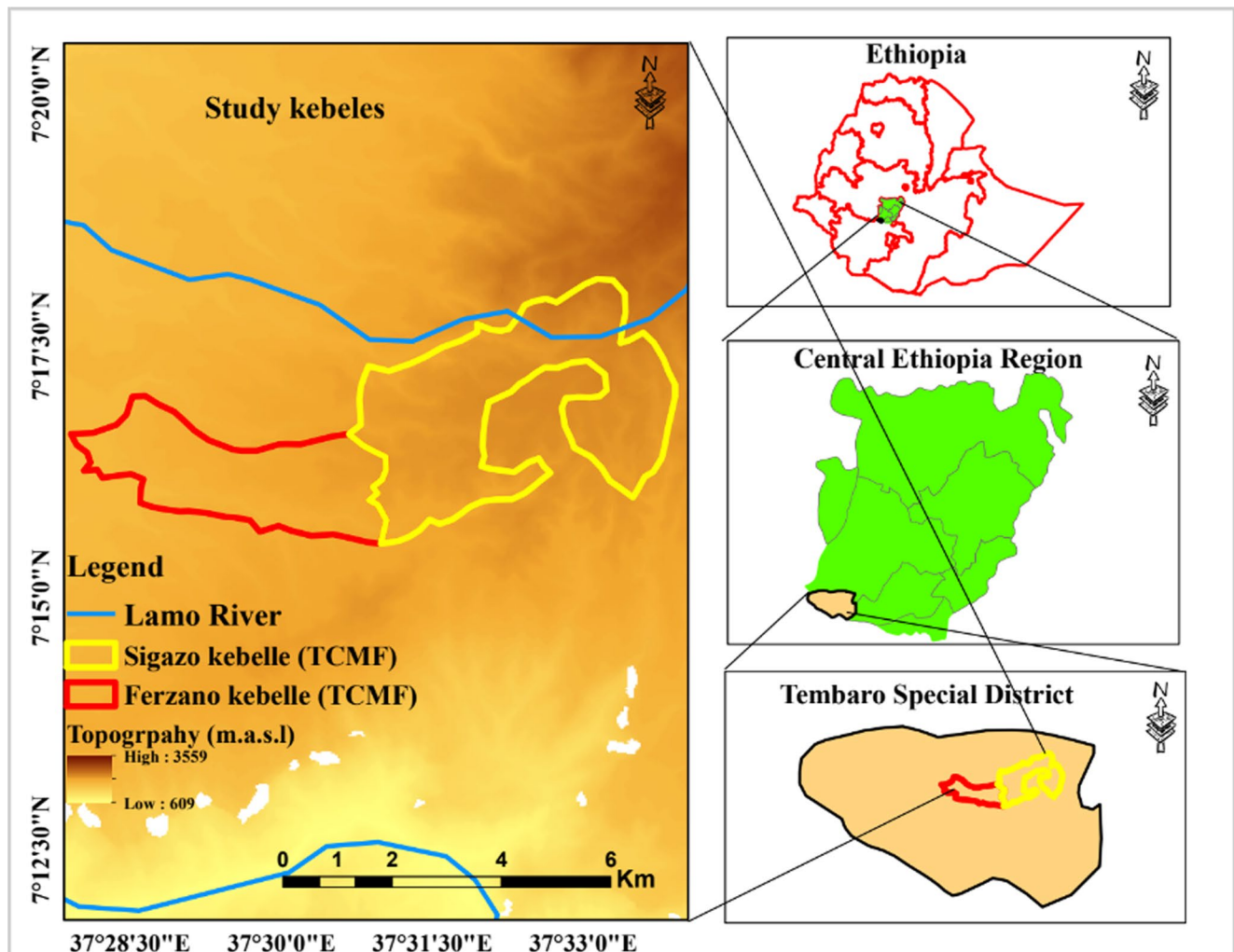


Fig. 1 Study area map

Ethiopia Regional State. The population practices traditional mixed farming, combining crop cultivation (annual and perennial) with livestock rearing. The region receives 900–1400 mm of annual rainfall, peaking June–September, with a dry season from March to May. Temperatures range from 22 to 30 °C (mean ~25 °C). Soils are primarily clay and loam, dominated by Alfisols. The area is drained by the Lamo, Gonjo, and Sana rivers, tributaries of the Omo River, which flows through a geologically active area with features like the Holido hot spring (Anshebo et al., 2025; Dobamo and Achiso, 2025).

The 2007 Census by the Central Statistical Agency (CSA) reported Tembaro Woreda's population as 480,573, with 235,334 men and 245,239 women. Of this, 45,615 (7.21%) are urban residents. The majority follow Protestantism (77.69%), while 14.9% are Ethiopian Orthodox Christians, 3.36% Catholic, 2.07% Muslim, and 1.17% practice traditional beliefs. The study area is characterized by fragmented, dense natural forests, mainly along the Omo

River. It hosts a variety of plant species, including *Croton macrostachyus*, *Strychnos spinosa*, *Albizia gumifera*, *Clematis longicauda*, *Prunus africana*, *Millettia ferruginea*, *Juniperus procera*, *Acacia bervispica*, *Combretum molle*, *Terminalia brownie*, *Syzygium guineense*, *Cordia africana*, *Allophylus abyssinicus*, *Olea europaea*, *Cupressus lusitanica*, *Ficus sycomorus*, *Ficus sur*, and *Ficus vasta* (Dobamo and Achiso, 2025; Hemade and Abebe, 2016).

The area hosts four primate species: the olive baboon (*Papio anubis*), grivet monkey (*Cercopithecus aethiops*), black colobus (*Colobus satanas*), and the Abyssinian black-and-white colobus or mantled guereza (*Colobus guereza*). It also supports a range of large and medium-sized mammals, including common duiker (*Sylvicapra grimmia*), bushbuck (*Tragelaphus scriptus*), Grant's gazelle (*Nanger granti*), Guenther's dikdik (*Madoqua guentheri*), hippopotamus (*Hippopotamus amphibius*), Nile crocodile (*Crocodylus niloticus*), porcupine (*Hystrix cristata*), hare (*Lepus timidus*), bush hyrax (*Heterohyrax brucei*), aardvark

(*Orycteropus afer*), and various predators such as golden and black-backed jackals (*Canis aureus*, *Lupulella mesomelas*), white-tailed mongoose (*Ichneumia albicauda*), lion (*Panthera leo*), leopard (*Panthera pardus*), serval (*Leptailurus serval*), honey badger (*Mellivora capensis*), caracal (*Caracal caracal*), African civet (*Civettictis civetta*), and spotted hyena (*Crocuta crocuta*) (Anshebo et al., 2025; Dobamo and Achiso, 2025). The area is also thought to harbor diverse bird, fish, reptile, and amphibian species. Some of these animals are known to damage crops and prey on livestock, although no studies currently assess their population density or conflict with local communities (Anshebo et al., 2025; Dobamo and Achiso, 2025; Tembaro Woreda Agricultural Office, 2019).

The population is primarily composed of the Tambaro ethnic group, with family farms ranging from 0.5 to 2.5 hectares. Limited land forces many to farm along forest edges using traditional methods that combine perennial and annual crops with livestock rearing. Most households rely on subsistence agriculture, making them vulnerable to crop-raiding and livestock predation by primates, which threaten local food security. Farmers follow a two-season planting cycle, starting in late March and again in August. Main crops include cereals like common beans (*Phaseolus vulgaris*), maize (*Zea mays*), teff (*Eragrostis tef*), faba beans (*Vicia faba*), peas (*Pisum sativum*), sorghum (*Sorghum bicolor*), wheat (*Triticum aestivum*), haricot beans (*Phaseolus vulgaris*), redkidney beans (*Phaseolus vulgaris*), and barley (*Hordeum vulgare*), along with cash crops such as coffee (*Coffea arabica*), ginger (*Zingiber officinale*), oats (*Avena sativa*), bananas (*Musa* spp.), taro (*Colocasia esculenta*), yams (*Dioscorea* spp.), false banana (*Ensete ventricosum*), potato (*Solanum tuberosum*), sweet potatoes (*Ipomoea batatas*), and fruits like avocado (*Persea americana*), papaya (*Carica papaya*), and mango (*Mangifera indica*). Stimulant crops like khat (*Catha edulis*) and tobacco (*Nicotiana tabacum*) are also cultivated. Common livestock includes cattle, sheep, goats, horses, mules, donkeys, and poultry (Tembaro Woreda Agricultural Office, 2019).

Methods

Data collection method for non-human primate population density

The population census of non-human primate species (hereafter referred to as primates) was conducted between January 2023 and August 2024 based on reconnaissance surveys. The study area was divided into forest and farmland habitats, and transect lines were established in each habitat,

following the methodology outlined by Buckland et al. (2010). A total of 15 line transects were established using a stratified random sampling approach to account for different topographies and habitat types. In some inaccessible areas, existing tracks and roads were used as transects. Of the 15 transects, six were located in forest (four 3 km long and two 4 km long) and nine in farmland (three 3 km long and six 4 km long), with consecutive transects spaced 500 m to 1 km apart to avoid double counting. Transect widths varied from 4 to 6 m on either side, depending on vegetation density, topography, and visibility conditions in each habitat.

Surveys were conducted twice daily, from 06:00am to 10:00 am and 14:00 pm to 18:00pm, aligning with primates' peak activity periods (Chagas and Ferrari, 2011). Transects were walked at 1 km/h with periodic stops to scan the forest, listen for vocalizations and movements in the canopy (Fashing and Cords, 2000), using natural markers and poles to demarcate lines. Each transect was systematically surveyed multiple times throughout both the dry (January–March) and wet (June–August) seasons, following the line-transect distance sampling methodology (Buckland et al., 2010), ensuring robust temporal and spatial coverage for accurate population estimates. Trained and experienced local personnel conducted the surveys at the same time during both seasons, ensuring a constant speed to maximize detection probability on both sides of the transects. Whenever primates (either individuals or groups) were sighted, data were recorded, including the GPS location, group size, estimated animal-observer distance, sighting angle, perpendicular distance from the transect to the first animal sighted, the height of the animal in the tree at the time of detection, and the dominant habitat type where the group was observed (Fashing and Cords, 2000; Chagas and Ferrari, 2011). Observations were made using normal vision, GPS, 7×35 binoculars, a Nikon 550 rangefinder, and a laser meter to estimate the animal-observer distance (r_i), calculated as the distance from the transect line to the geometric center of the group or individual. The laser meter was also used to determine the sighting angle (θ) between the transect line and the observed animal or group (Buckland et al., 2010). The survey followed a silent detection method to minimize disturbance to the primates.

Human-primate conflict

Data collection on human-primate conflict involved interviews with household through a questionnaire and focus group discussions. A preliminary assessment in September 2023 helped define the study's scope, including village selection and forest condition evaluation. Four of eight villages (Bada, Wamura, Kopate, Kotana, Elemeta, Muleta, Saruma,

and Mehal Farzano) were randomly chosen (Fenta, 2014). A total of 343 respondents were selected through multistage random sampling, with village sample sizes based on household proportions. Villages from Sigazo Kebele (Elmeta, Bada, Kopate) and Farzano Kebele (Kotana, Mehal Farzano) are located 0.5 to 1 km from the conserved forest edge. Household data were obtained from the district agriculture office, and sample sizes were calculated accordingly.

The questionnaire included both open- and closed-ended questions on human-primate conflict. It was pre-tested with 35 randomly selected individuals from five sampled villages, varying in age, sex, and background. Pre-testing helped refine the questionnaire format, assess time requirements, and improve the overall design. The total number of households across the five villages was 2,400, and final sample sizes were determined using Yamane's (1967) formula. Out of the total population of 2,400 households in the five villages (Elmeta, 508, Bada, 564, Kopate, 477, Kotana, 647, and Mehal Farzano, 204), 343 households were randomly selected for the survey.

$$n = \frac{N}{1 + N(e)^2}$$

Where: N = total population, n = required sample size.

e = precision level, set at $\pm 5\%$, with a 95% confidence interval and $p = 0.05$.

$$n = 2400 / 1 + 2400 (0.0025) \quad n = 2400 / 7 = 343.$$

Households were randomly selected by skipping one and interviewing the next (Feta, 2014). Interviews were conducted from January 2023 to August 2024 with 343 participants chosen from the villages. To avoid miscommunication, the questionnaire was written in English and translated into local language Tembarssa. The interviews were distributed randomly to household members on a first-come, first-served basis (Newmark et al., 1994). Both males and females of all ages participated as household representatives.

Fifteen local residents (three from each of the five villages) were trained to administer the questionnaires over a two-day session before data collection. The same translators and interview questions were used throughout both seasons to ensure consistency. Each interview lasted 35–45 min. Villages were categorized based on their distance from the forest: near (0–1 km), medium (1–2 km), and far (2–3 km). Structured questionnaires were used to assess human-primate conflict, and livestock losses were recorded to estimate the economic impact. Crop and livestock losses were valued based on market prices, though precise cost estimates for primate damage are challenging. Approximate costs were converted to US dollars using the exchange rate at the time of the study.

Focus group discussion

This approach aimed to gather data on the severity of conflict, benefits from primates, and recommendations for preventing future issues, while reinforcing questionnaire data. Two Focus Group Discussions (FGDs) were held in each study village, with 7 to 9 participants per group. Participants included village leaders, elders, religious leaders, a primary school teacher, and local government employees of both genders, who shared their experiences with human-primate conflict and provided insights on primates in the area. This information was triangulated with questionnaire responses to strengthen the findings. A guide checklist was prepared for the FGDs.

Data analysis

DISTANCE (Version 6.0, Release 2) Software was used for density and abundance estimation of primate population. Density of primate within the area surveyed (D_g) was estimated as:

$$D_g = \frac{nf(0)}{2L}$$

where ' L ' denotes the aggregate length of the transects, ' n ' is the number of primate individual observed and $f(0)$ is the probability density function of observed. Then, the perpendicular distance from the transect line to the animal is calculated as $x = ri \sin(\theta)$ (Buckland et al., 2010). Statistical Package for Social Sciences (SPSS) software version 21 was also used to compare the degree of conflict in different villages. Data analysis consisted of descriptive and inferential statistics. Descriptive statistics in the form of percentages and frequencies were used to analyze the demographic and socioeconomic profiles of the respondents. Chi-square test was used to determine the significant differences between villages with regard to crop damage by primate and techniques used in protecting against crop damage.

Results

Demographic Profile of the Respondents

Respondents' ages ranged from 18 to over 61 years. Among the participants, 21% ($n = 72$) were aged 18–30 years, 38% ($n = 130$) were between 31 and 45 years, 27% ($n = 93$) were 46–60 years, and 14% ($n = 48$) were older than 61 years. The study found that age and education significantly influenced respondents' attitudes toward primate conservation. Younger respondents (18–45 years) tended to have more

positive attitudes toward primate conservation compared to older respondents (Table 1). Regarding educational background, 15.5% of respondents were illiterate, 62.4% had completed primary education (grades 1–8), 16% had completed secondary education (grades 9–12), and 6.1% had higher education. Respondents with higher education levels generally expressed more positive attitudes toward primate conservation (Table 1).

In terms of overall attitudes, 53.3% of respondents had a negative view of primate conservation, 28.5% had a positive view, and 18.2% were neutral regarding the presence of primates in the study area. A significant difference was found in the attitudes of respondents toward primates ($\chi^2=19.2$, $df=2$, $p<0.05$). Result part section 1 Primate density, Section 2 Demographic Profile of the Respondents

Primate density estimation

The average population sizes in the study area were 1425.5 ± 412.94 for grivet monkeys, 678.5 ± 92.23 for black colobus, 1108.5 ± 311.3 for mantled guereza, and 1643 ± 397.2 for Anubis baboons. The mean population densities (individuals per km^2) were 12.81 ± 3.4 for grivet monkeys, 11.76 ± 2.68 for Anubis baboons, 10.06 ± 2.93 for mantled guereza, and 6.23 ± 0.9 for black colobus monkeys (Table 2). Minimum Akaike Information Criteria (AIC) values for each species were calculated using different models with different key functions (Figs. 2 and 3).

Human- primate conflict

Human–primate conflict around Lamo Forest was widely reported by surveyed households, primarily in the form of crop damage, with occasional livestock depredation and human casualties. Crop raiding was the most common conflict type, affecting a high proportion of respondents across all villages. *Papio anubis* and *Chlorocebus aethiops* were the species most frequently responsible for crop damage, which mainly affected maize and banana in fields located near forest edges. The majority of respondents 48.1% stated that crop damage was the most frequent reason for conflict between humans and primates, followed by livestock predation and crop damage 33.2%, livestock predation 11.1%, and human attack 7.6% as the main challenges facing the local community around the forest (Table 3). The difference in the consequences of conflict across the five study villages was statistically significant ($\chi^2=43.1$, $df=3$, $p<0.05$).

Primate species involved

Based on the respondent reports, four primate species were found to be engaged in crop-raiding activities. The most common crop raider that caused crop damage throughout all villages were the grivet monkeys (*Chlorocebus aethiops*) (46.1%, $n=158$), followed by Anubis baboon (*Papio anubis*) (37.9% $n=130$), black colobus monkey (*Colobus satanas*) (10%, $n=34$), and mantled guereza

Table 1 Sociodemographic statistics and respondents' response regarding primates in Lamo Forest and surrounding fragmented forests ($n=343$)

Categories	Respondents number & Percentage			Attitude of Respondents			
	Variable	No of Respondents	%	Negative	Positive	Neutral	
Sex	Male	213	62.1	131	52	30	
	Female	130	37.9	68	30	32	
Age	18–30	72	21	32	21	19	
	31–45	130	38	96	22	12	
	46–60	93	27	36	27	30	
	above 61	48	14	27	11	10	
Education	Illiterate	53	15.5	22	13	17	
	Literate	1–4	128	37.3	69	40	19
		5–8	86	25.1	27	36	23
		9–12	55	16.0	3	32	20
		above 12	21	6.1	2	14	5
Family size	1–5	171	49.9	101	41	29	
	6–10	111	32.3	73	21	17	
	Above 10	61	17.8	21	30	10	
Type of farming	Mixed farming	199	58	134	44	21	
	Crop cultivation	64	18.7	44	12	8	
	Livestock rearing	74	21.6	41	16	17	
	Other activities	6	1.7	1	3	2	
Farm Size in hectare	1–2.4.4	174	50.7	97	61	16	
	2.5–3.9	101	29.5	48	29	24	
	4 and above	68	19.8	24	30	14	
Percentage				53.3%	28.5%	18.2%	

Table 2 Density estimates of primate species in Lamo Forest and surrounding fragmented Forests

Primate species	Year	Parameter	Estimate	SE	%CV	95% CI	AIC	Model
Anubis baboon (<i>Papio anubis</i>)	2023	p	0.43	0.96	22.62	0.27–0.66	1112.41	UF/Cos
		ESW	25.89	5.86	22.62	16.63–40.33		
		D	9.61	2.34	24.39	5.97–15.46		
		N	1426	347.86	24.39	886.00–2294.0		
	2024	ESW	18.16	4.03	22.16	11.77–28.04	853.73	HR/Cos
		D	12.53	3.01	24.01	7.85–20.02		
		N	1860	446.53	24.01	1164.0–2971.0		
		ESW	18.16	4.03	22.16	11.77–28.04		
Griquet monkey (<i>Cercopithecus aethiops</i>)	2023	p	0.33	0.12	34.24	0.17–0.65	1062.33	NE/Cos
		ESW	20.38	6.98	34.24	10.53–39.45		
		D	11.53	4.09	35.44	5.83–22.79		
		N	1140	219.47	19.25	780.00–1667.0		
	2024	p	0.92	0.15	6.50	0.66–1.13	1243.47	NE/Sps
		ESW	3.78	0.62	16.5	2.72–5.25		
		D	14.09	2.71	19.25	9.64–20.61		
		N	1711	606.41	35.44	865.00–3381.0		
Black colobus monkey (<i>Colobus satanas</i>)	2023	p	0.33	0.29	8.88	0.28–0.39	1006.97	HR/Sps
		ESW	12.63	1.12	8.88	10.59–15.05		
		D	5.08	0.65	12.73	3.95–6.55		
		N	603	88.49	14.67	451.00–807.00		
	2024	P	0.58	0.74	12.65	0.45–0.75	994.89	NE/Cos
		ESW	35.35	4.47	12.65	27.53–45.38		
		D	7.37	1.15	15.61	5.42–10.02		
		N	754	96	12.73	586.00–971.00		
Mantled guereza (<i>Colobus guereza</i>)	2023	p	0.18	0.43	23.47	0.12–0.29	674.61	HR/Sps
		ESW	7.03	1.65	23.47	4.44–11.13		
		D	8.74	2.2	25.19	5.35–14.28		
		N	920	295.85	32.16	492.00–1722		
	2024	P	0.12	0.37	30.63	0.66–0.22	1012.36	HR/Sps
		ESW	4.9	1.5	30.63	2.69–8.93		
		D	11.38	3.66	32.16	6.08–21.29		
		N	1297	326.69	25.19	794.00–2119.0		

D= density, *N*= population, *ESW*=effective strip width, *P*=Detection probability, *%CV*=Percentage Coef. Variation, *CI*= Confidence Interval, *SE*= Standard Error, *HR/Sps*= Hazard Rate/Simple polynomials, *NE/Cos*=Negative Exponential/Cosines, *NE/SPs*=Negative Exponential/Simple polynomials, *HR/Sps*=Hazard Rate/Simple polynomials, *UF/Cos*=Uniform/Cosines

(*Colobus guereza*) (6%, $n=21$), which were reported as crop raiders in the study area. There was a significant difference in crop damage among crop raiders ($\chi^2 = 24.64$, $df=3$, $P<0.05$) (Fig. 4).

The respondents indicated that the major crops grown and damaged by primates were *Zea mays* (29.7%, $n=102$), followed by *Musa acuminata* (17.8%, $n=61$), *Phaseolus vulgaris* (9%, $n=31$), *Ipomoea batatas* (8.5%, $n=29$), *Eragrostis tef* (3.8%, $n=13$) and *Sorghum bicolor* (3.2%, $n=11$) were the least grown and damaged crop in the study area (Table 4). Different fruits and vegetables, including papaya, avocado, and mango, as well as onions and cabbage, were also grown in the study area, and damaged by primates. This situation may intensify the conflict issue.

Estimated economic loss of crops by primates

Over the past five-year period (2020–2024), the total estimated loss of various crop types was 18,373 kg, equating to an annual loss of 3,674.6 kg. The overall economic loss from crop damage in the study area amounted to US \$13,852.18 across five villages over the past five years. On average, the annual loss was US \$2,770.44, or US \$8.08 per household head each year. The frequency and severity of crop damage varied between villages, with the most intense conflict occurring within 0–1.5 km of the forest. These substantial economic losses highlight the need for targeted management strategies to mitigate human–primate conflict while supporting primate conservation in the study area (Table 5).

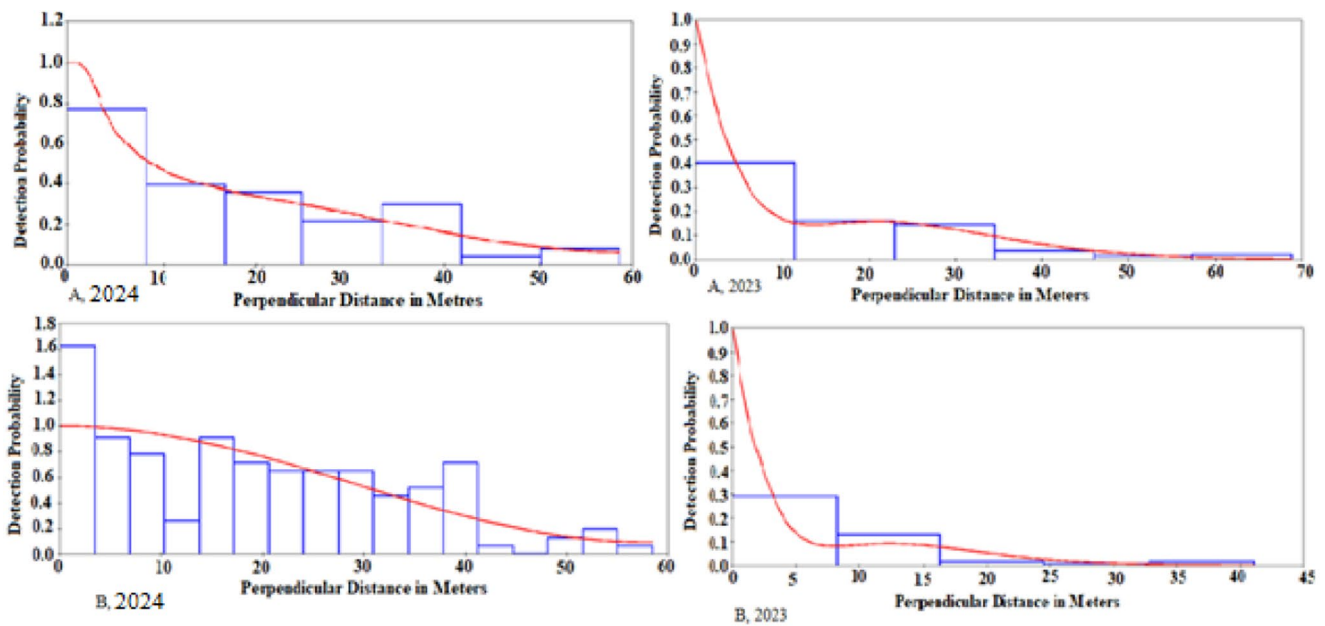


Fig. 2 Number of sightings of Anubis baboon (A) and Grivet monkey (B) at different distances from the transect centerline during two survey periods (2023 & 2024) in Lamo Forest and surrounding fragmented Forest

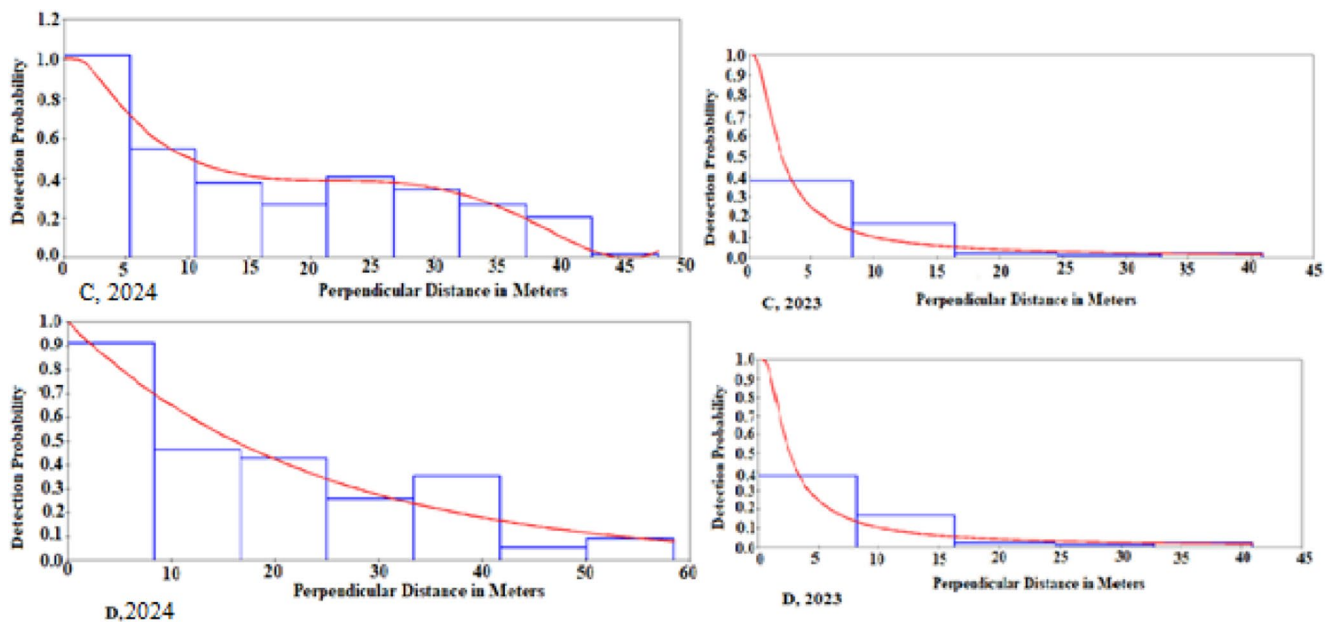


Fig. 3 Number of sightings of Black colobus (C) and Mantled guereza (D) at different distances from the transect centerline during two survey periods (2023 & 2024) in Lamo Forest and surrounding fragmented Forest

Small sized livestock loss by primates and its economic valuation

Over five past consecutive years (2020 to 2024), a total of 2,884 small-sized livestock were lost due to primates' attack, including 2,194 livestock and 690 eggs. Anubis baboons were responsible for more than half (69.5%, $n = 1,525$) of

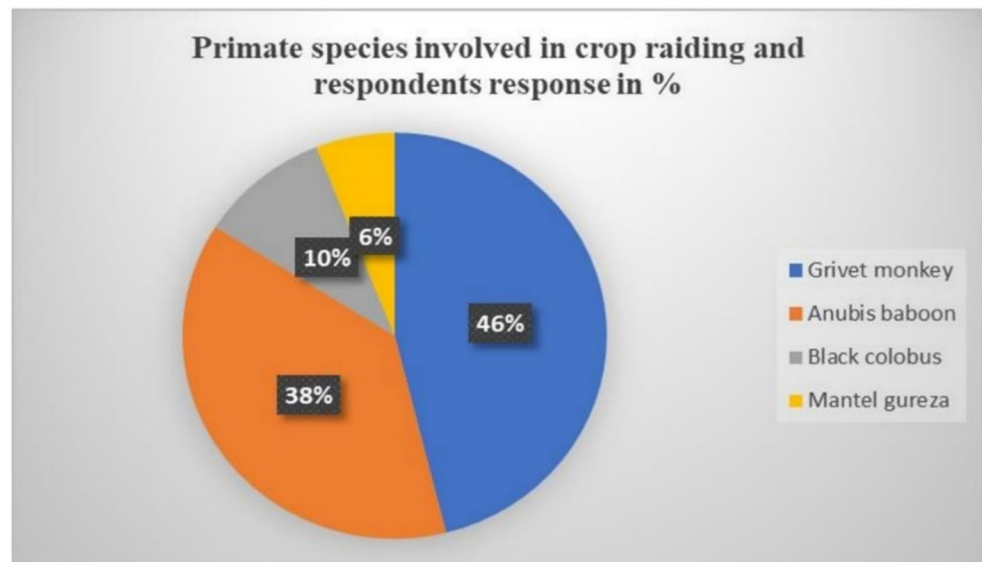
the livestock losses, followed by grivet monkeys (23.3%, $n = 511$) and black colobus monkeys (7.2%, $n = 158$). The majority of egg losses were caused by grivet monkeys (64.35%, $n = 444$), while Anubis baboons accounted for 35.65% ($n = 246$) of the egg losses (Table 6).

The overall cost of domestic animals' losses was 139,814US\$ within five years. An average annual economic

Table 3 Consequences of conflict between humans and primates in Lamo Forest and surrounding fragmented Forests

Villages	Consequences of conflict					Percentage (%)
	N	Crop damage	Livestock depredation	Livestock depredation & crop damage	Human casualties	
Bada,	108	58(53.7%)	9(8.3%)	34(31.5%)	7(6.5%)	31.5
Elmeta,	91	48(52.8%)	8(8.8%)	31(34%)	4(4.4%)	26.5
Kopate,	82	38(46.3%)	8(9.8%)	30(36.6%)	6(7.3%)	23.9
Kotana	32	11(34.3%)	7(21.9%)	10(31.3%)	4(12.5%)	9.3
Mehal Farzano	30	10(33.3%)	6(20%)	9(30%)	5(16.7%)	8.8
Total	343	48.1%	11.1%	33.2%	7.6%	100

The number in bracket represents percentage of respondents in each village

Fig. 4 Primate species involved in crop raiding in Lamo Forest and its surrounding fragmented forests**Table 4** The most frequently raided crops by primate and their rank ($n=343$) in Lamo Forest and surrounding fragmented forests

Crops types preferred by primate	Frequency	Percentage	Rank
Maize(<i>Zea mays</i>)	102	29.7	1
Banana (<i>Musa acuminata</i>)	61	17.8	2
Haricot beans (<i>Phaseolus vulgaris</i>)	31	9	3
Sweet potatoes (<i>Ipomoea batatas</i>)	29	8.5	4
Potato(<i>Solanum tuberosum</i>)	26	7.6	5
Wheat (<i>Triticum aestivum</i>)	22	6.4	6
Red kidney bean (<i>Phaseolus vulgaris</i>)	18	5.2	7
Pea (<i>Pisum sativum</i>)	16	4.7	8
Barely(<i>Hordeum vulgare</i>)	14	4.1	9
Teff (<i>Eragrostis tef</i>)	13	3.8	10
Sorghum (<i>Sorghum bicolor</i>)	11	3.2	11
Total	343	100	

loss of small livestock was 27, 962.8 US\$. The average annual loss incurred by each respondent due to primate's predation on their small animals was 81.52 US\$ (Table 7).

Mitigation methods practiced by local farmers

During the present study, respondents used different traditional methods to deter crop damage and livestock predation

by primate. About 120 (35%) of respondents guarded their crops throughout crop growing season and livestock predation, followed by chasing 96 (28%), 55 (16%) fencing, 45 (13%) scarecrow, 20 (6%) killing of animals and hung up and 7 (2%) of respondents were used smoking to repel the crop raiders from their farm (Fig. 5). The respondents did not use only one method alone; they combined and integrated traditional methods to prevent crop raiding.

Table 5 The estimated economic loss of different crop types caused by primates over the past five years (2020–2024) in Lamo Forest and the surrounding fragmented forests

Quanty (kg) in each village						Total loss in kg	Average Price per kg in US\$	Total loss in US\$
Crop type	Bada	Elmeta	Kopate	Kotana	Mehal Farzano			
Maize	843	683	443	120	130	2219	0.53	1176.07
Hb	600	463	436	221	164	1884	0.96	1808.64
Potato	787	646	531	189	191	2344	0.25	586
Wheat	674	533	411	368	317	2303	0.64	1473.92
Rkb	611	534	461	438	569	2613	0.98	2560.74
Peas	555	439	338	298	311	1941	0.99	1921.59
Barley	511	481	363	222	305	1882	0.97	1825.54
Teff	393	464	483	319	286	1945	1.1	2139.5
Sorghum	353	347	333	111	98	1242	0.29	360.18
TL kg	5327	4590	3799	2286	2371	18,373		13852.18
Percentage	28.99	24.99	20.68	12.44	12.90	100		

Rkb=Red kidney beans, *Hb*=Harricot beans, *TL Kg*=Total loss in kg

Table 6 The number of live-stock depredation by primates in LSFF over the past five years (2020–2024) ($n=343$)

Domestic animals	Predation by primate species				Total depredation
	Anubis baboon	Grivet monkey	Black colobus	Mantled guereza	
Poultry	381	489	103	0	973
Lamb	695	14	22	0	731
Immature goat	354	8	33	0	395
Calf of cow	95	0	0	0	95
Eggs	246	444	0	0	690
Total	1771	955	158	0	2884
Percentage (%)	61.4	33.1	5.5	0	100

Traditional methods used by respondents reveal statistically significant difference ($\chi^2=48.4$, $df=5$, $p<0.05$).

Discussions

Population density of primate

Understanding primate population trends is essential not only for ecological insight but also for managing human-primate interactions (Wang, 2010). In Ethiopia, primates are largely confined to small, isolated forest fragments amid agricultural fields, plantations, and settlements (Kifle & Bekele, 2020a; Kifle & Bekele, 2021). Even at low densities, they affect local livelihoods by raiding crops or competing for resources, making reliable population estimates critical for conflict management and conservation planning.

The density of Anubis baboons in this study was higher than that reported in Mono River, Togo (0.81 individuals/km²; Ségniabeto et al., 2018) and Kainji Lake National Park, Nigeria (0.04±0.00 individuals/km²; Ajayi et al., 2020), but lower than in Lake Manyara National Park, Tanzania (132.5 individuals/km²; Kifner et al., 2022). Grivet monkey density was much lower than in Arba Minch, Ethiopia (133.1 individuals/km²; Israel and Balakrishnan, 2016) and

Zegie Peninsula, Ethiopia (438.8 individuals/km²; Yitayih et al., 2021). Densities of black colobus and mantled guereza exceeded the mantled guereza group encounter rate (5.5 groups/km²) reported by Kifle and Bekele (2022) in Borena Sayint National Park, Ethiopia, but were lower than the average densities reported for Ethiopia, with black colobus at 8.3±1.20 and mantled guereza at 14.76±3.57 individuals/km² (Anshebo et al., 2025). As habitat shrinks, primates concentrate in smaller areas, leading to higher encounter rates. Fashing (2002) noted that *Colobus guereza* is resilient to habitat degradation, often achieving medium to high densities. Variations in primate densities may result from food scarcity and anthropogenic influences, with low densities associated with limited food sources near the forest.

Sociodemographic profile

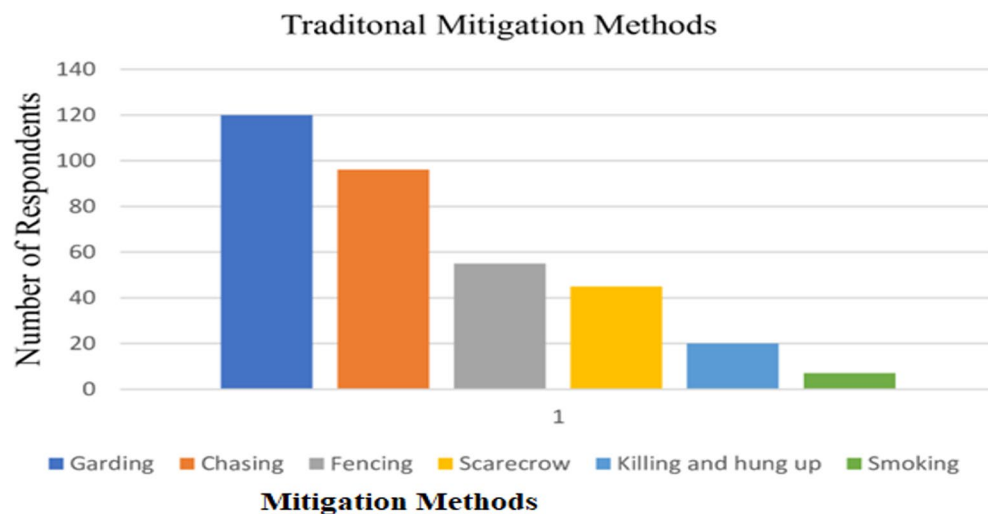
In the study area, socio-demographic factors like age, sex, and education influenced respondents' attitudes toward primate conservation. Those with higher education were more positive about conservation, while middle-aged individuals (31–45 years) showed greater awareness, likely due to a better understanding of wildlife importance (Hill, 2000). These findings align with Baker et al. (2014), who noted that formal education fosters more favorable conservation

Table 7 Economic loss due to domestic animals' depredation in the last five years (2020–2024) at LSFF

Livestock depredation in each village						Total kill	Average price per livestock in US\$	Total loss in US\$
Livestock type	Bada,	Elmeta,	Kopate,	Kotana	Mehal Farzano			
Poultry	261	224	199	149	140	973	8.7	8465.1
Lamb	205	180	140	102	104	731	90.81	66374.8
Immature goat	121	94	66	71	43	395	118.89	46961.6
Cdc	24	22	19	17	13	95	184.3	17508.5
Eggs	186	174	135	96	99	690	0.73	503.7
Total	797	694	559	435	399	2884		139,814
Percentage (%)	27.6	24.1	19.4	15.1	13.8	100		

Cdc = Calf of domestic cow

Average exchange rate of 1 US\$ amount is 53.57 Ethiopian birr during the study period

Fig. 5 Traditional mitigation methods used by the respondents to protect crop damage

attitudes and reduces negative perceptions as education levels rise.

In the study area, some respondents held positive views toward wild animals despite livestock losses from predation and crop damage, consistent with (Temesgen et al., 2025; Kidane et al., 2024; Hill and Wallace 2012). This contrasts with Eshete et al. (2018), who found that even minor livestock predation led to negative attitudes, hindering conservation. Those with positive views emphasized benefits such as tourism, environmental cleanliness, seed dispersal, pollination, and supplemental food sources during shortages, while negative attitudes focused on wild animals as crop raiders, livestock predators, and disease carriers (Temesgen et al., 2025; Kidane et al., 2024). Neutral respondents had no strong opinions, and those living farther from the forest tended to have more positive views. Focus group discussions revealed that people living closer to the forest often held negative views of primates, despite recognizing wildlife benefits like tourism, hunting, and recreation, especially during droughts when livestock are sent to the forest for fodder and water (Temesgen et al., 2025).

Human-primate conflict

Crop raiding and small livestock predation are among the most widespread drivers of human–primate conflict globally (Matseketsa et al., 2019), a pattern clearly reflected in the present study. In Lamo Forest and its surrounding fragmented landscapes, grivet monkeys and Anubis baboons were identified as the primary conflict species, causing substantial crop and livestock losses that directly threaten the food security and livelihoods of subsistence farmers (Kifle and Bekele, 2020b). The predominance of maize, haricot beans, wheat, and potatoes among damaged crops indicates a selective preference for high-energy and palatable crops, particularly those cultivated near forest edges. Similar crop preferences have been widely reported for primates across East Africa (Hill, 2000; Ango et al., 2017).

These findings have important implication for conflict mitigation policy. The concentration of damage near forest boundaries suggests that spatially targeted interventions such as buffer zones, strategic crop placement, and land-use zoning could substantially reduce conflict intensity,

as crop damage and raid frequency generally decline with increasing distance from forest edges (Mamo et al., 2021). However, in smallholder farming systems such as those in Tembaro Special Woreda, the adoption of buffer crops is constrained by limited land availability and heavy reliance on staple crops. Consequently, mitigation strategies must be context-specific, integrating ecological understanding with local socioeconomic realities (Rusoke and Orach-Meza, 2021). For example, cultivating less palatable or deterrent crops along forest margins while reserving interior fields for staple crops may reduce raiding without compromising household food security (Gatew and Azadge, 2025).

Although individual crop or livestock losses may appear minor, their cumulative economic impact is substantial. Farms located near forest edges experience repeated raids, where primates exploit dense vegetation, tree cover, and rocky terrain for concealment and escape (Gebo et al., 2022). Communities adjacent to protected and forested areas are therefore disproportionately affected (Ango et al., 2017). Grivet monkeys frequently consume stored or cultivated food and occasionally prey on small livestock (Ejigu and Bekele, 2010), while Anubis baboons are among the most destructive crop raiders and opportunistic livestock predators reported in southern Ethiopia and South Africa (Findlay, 2016; Alemayehu and Tekalign, 2022; Anshebo et al., 2025). The increasing intensity of crop damage observed in the study area mirrors broader regional trends associated with land-use change and habitat degradation (Leta, 2014).

The heightened vulnerability of farms near forests underscores the need for integrated landscape-level planning that balances conservation objectives with rural development. Evidence from Ethiopian and other African forest landscapes demonstrates that proximity to forest edges strongly predicts crop damage and conflict intensity, highlighting the importance of spatial planning in mitigation efforts (Kolinski and Milich, 2021; Anshebo et al., 2025). Enhancing forest resource availability through enrichment planting of native fruiting species may reduce primates' dependence on cultivated crops by improving natural food availability, while simultaneously supporting forest restoration goals (Anshebo et al., 2025). Equally important is community participation in decision-making and mitigation planning, which has been shown to improve conservation attitudes, increase local ownership, and enhance long-term effectiveness (Kolinski and Milich, 2021). Without integrated policy responses that combine ecological, socioeconomic, and participatory approaches, continued agricultural expansion and forest degradation are likely to intensify human–primate conflict, undermining both primate conservation and rural livelihoods (Gatew and Azadge, 2025).

Human–primate conflict in the study area is further driven by crop availability, seasonal scarcity of wild foods,

deforestation, and agricultural expansion (Hockings et al., 2015). Anubis baboons and grivet monkeys raid crops throughout the growing season, from germination to harvest, whereas colobus monkeys tend to target ripened crops. Maize and banana are particularly vulnerable due to their high palatability and ease of handling, resulting in significant financial losses for farmers (Warren, 2008). In addition to yield losses, farmers near forests incur substantial indirect costs through time-intensive crop guarding and reduced labor productivity (Ango et al., 2017). Addressing human–primate conflict therefore requires integrated mitigation approaches, including reinforced farm defenses, non-lethal deterrents, habitat restoration near agricultural landscapes, and community-led monitoring initiatives (Strum, 2010; Karki et al., 2024). Collectively, these strategies can reduce conflict intensity while supporting primate conservation and improving rural livelihoods (Naughton-Treves et al., 2005).

Estimated economic losses due to crop damage

Primates' crop-raiding is regarded as a serious issue in the current research area as it jeopardizes the food security of smallholder farmers' households. Over a five-year period, five villages reported an average crop loss of 18,373 kg, or US \$13,852.18, which would have a major impact on household income in the villages. Primates incurred an average of \$8.08 in annual economic losses per family, which is less than reports of Hariohay and Rskaf (2015) found that each household in the Kwakuchinja Wildlife Corridor lost nearly US\$154 as a result of crop damage, while Kwaslema et al. (2017), similar crop damage in Northern Tanzania's Kwakuchinja Wildlife Corridor cost each household about US\$154. According to our findings, the primary indicator of the extent of the financial loss resulting from primate agricultural damage is the distance to the forest. It was discovered that the area close to the forest had a greater economic loss than the area further from the forest. The Bada village faced the most crop and livestock loss. The focus group members also mentioned that local residents living close to the forest boundary were more likely to experience financial hardship as a result of animal depredation and crop raiding, similar researches conducted elsewhere in the globe (Ango et al., 2017; Hariohay and Rskaf, 2015).

Livestock predation by primates

Between 2020 and 2024, respondents reported the loss of 2,884 small livestock—including chickens, lambs, goats, and calves to primates such as Anubis baboons, grivet monkeys, and black colobus monkeys. These losses amounted to an average annual economic cost of US\$27,962.80, with a mean loss of US\$81.52 per household per year. Anubis baboons

were identified as the most problematic species, consistent with previous studies highlighting their role as key predators of eggs, birds, and small mammals (Allan et al., 2022; Kifle & Bekele, 2020a). Grivet monkeys primarily targeted chickens and eggs, particularly during the dry season, when reduced availability of natural foods and increased reliance on human refuse in nearby villages may intensify predatory behavior (Daszak et al., 2001; Yibelu et al., 2022).

The spatial distribution of livestock predation was strongly associated with village proximity to forested habitats. Villages located closer to Lamo Forest experienced significantly higher losses, reflecting primates' ability to exploit livestock in settlements while using forest cover as refuge. Habitat degradation, declining natural food availability, and inadequate livestock management practices further exacerbated predation pressure, making primates the primary predators of small livestock in the study area (Lindsey et al., 2017). Focus group discussions indicated that, in villages near the forest edge, primates caused greater cumulative economic losses than large carnivores such as hyenas, jackals, and leopards, although further observational studies are needed to validate these perceptions. Among the surveyed settlements, Bada village located closest to the forest reported the highest livestock losses, underscoring the importance of spatial factors in shaping patterns of human–primate conflict (Kifle and Bekele, 2020b).

Traditional mitigation methods

Although numerous mitigation strategies have been proposed to reduce human–primate conflict, relatively few have been systematically evaluated under smallholder farming conditions. Where tested, their effectiveness often varies according to cost, labor requirements, and local socio-economic context. For example, electric fencing has successfully reduced crop losses caused by Japanese macaques in Japan (Honda et al., 2009); however, its high installation and maintenance costs, along with limited access to electricity, render it largely impractical for subsistence farmers in developing regions. Similarly, physical barriers such as hedges and fences have produced mixed outcomes. Field trials in Uganda demonstrated that *jatropha* hedges reduced crop raiding by baboons and guenons by up to 85% when they obstructed access routes and visual cover to refuge areas, yet barbed-wire fencing has shown inconsistent effectiveness across sites (Hill and Wallace, 2012).

In the present study area, farmers primarily relied on traditional, labor-intensive methods such as guarding, chasing, and rudimentary fencing. Most respondents perceived active guarding particularly when combined with noise-making and collective action as the most effective and affordable option. However, empirical studies indicate that

guarding alone often provides only short-term deterrence and imposes substantial opportunity costs on households (Hill and Wallace, 2012). Other commonly recommended strategies include planting less palatable buffer crops or relocating preferred crops away from forest edges (Hockings and McLennan, 2012). In practice, however, land scarcity in smallholder systems severely limits the feasibility of buffer zones, as reallocating land may compromise household food security and income. Additionally, buffer crop selection must account for market value, labor demands, and household schedules (Riley and Priston, 2010). Importantly, primates may adapt over time by targeting alternative crops, underscoring the need for flexible, evidence-based mitigation approaches that prioritize reducing human–primate conflict rather than relying on static ecological assumptions.

Conclusions

This study surveyed the population ecology of non human primates in Lamo Forest and surrounding fragmented forests, focusing on their interactions with humans. Grivet monkeys and Anubis baboons were identified as the main drivers of human primate conflict, causing significant crop damage and small livestock losses, particularly near forest edges. These impacts threaten smallholder livelihoods and highlight the need for accurate primate population estimates to guide effective, spatially targeted management. Farmers currently rely on traditional mitigation methods, such as guarding and chasing, which provide some relief but are labor-intensive and costly. While strategies such as planting unpalatable crops, creating buffer zone, enhancing forest food availability, or implementing deterrents have been suggested, their effectiveness remains largely untested and requires future evaluation.

Integrating mitigation measures with local perceptions, cultural practices, and participatory planning is critical for designing socially acceptable and sustainable conservation approaches. Compensation or incentive-based schemes could reduce economic losses and foster coexistence, particularly if implemented transparently and accounting for both direct and indirect costs. Based on the findings, three targeted recommendations emerge to reduce human–primate conflict: (1) the development of community-based deterrent strategies to protect crops and livestock efficiently, (2) establishment of compensation schemes to offset losses and encourage tolerance, and (3) forest-edge land use planning, including planting less-palatable crops near forest boundaries and enhancing forest resources, to minimize crop raiding and promote coexistence. Further research is needed to test these interventions and evaluate their long-term effectiveness in balancing conservation goals with local livelihoods.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10344-026-02099-3>.

Acknowledgements We sincerely appreciate the support of the villagers living around the forest during our fieldwork. We also extend our heartfelt gratitude to the faculty members of Natural Sciences at Wolaita Sodo University for their valuable assistance in providing vehicles, which was instrumental in completing our work.

Author contributions Taye Dobamo conceptualized the study, prepared the methodology, validated the study, and wrote the original and final draft. Aberham Megaze and Abnet Woldesenbet supervised it, and reviewed the final draft of the paper.

Funding We declare that this research did not receive specific funding from any fundraising organizations.

Data availability Data is provided within the manuscript.

Declarations

Competing interests The authors declare no competing interests.

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References

- Ajayi SR, Ejidike BN, Ogunjemite BG, Olaniyi OE, Adeola AJ (2020) Population status of olive baboon *Papio anubis* (Lesson, 1827) in Kainji Lake National Park, Nigeria. *J Res For Wildl Environ* 12(2):270–276
- Alemayehu N, Tekalign W (2022) Prevalence of crop damage and crop-raiding animals in southern Ethiopia: the resolution of the conflict with the farmers. *GeoJournal* 87:845–859. <https://doi.org/10.1007/s10708-020-10287-0>
- Allan AT, LaBarge LR, Howlett C, Bailey AL, Jones B, Mason Z, Allan AT, Pinfield T, Schröder F, Whitaker A, White AF, Wilkinson H, Hill RA (2022) Patterns of predation and meat-eating by chacma baboons in an Afromontane environment. *Folia Primatol* 94(1):13–36. <https://doi.org/10.1163/14219980-bja10004>
- Ango TG, Orjesson LB, Senbeta F (2017) Crop raiding by wild mammals in Ethiopia: impacts on the livelihoods of small-holders in an agriculture forest mosaic landscape. *Oryx* 51(3):527–537. <https://doi.org/10.1017/S0030605316000028>
- Anshebo M, Megaze A, Dobamo T (2025) Investigating primate densities and human-primate conflict in Tembaro Community Conserved Forest, Omo River Basin, Ethiopia. *BMC Zool* 10(1):10. <https://doi.org/10.1186/s40850-025-00229>
- 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 Ecol Evol* 24(1):85
- Baker LR, Olubode OS, Tanimola AA, Garshelis DL (2014) Role of local culture, religion, and human attitudes in the conservation of sacred populations of a threatened ‘pest’ species. *Biodivers Conserv* 23:1895–1909. <https://doi.org/10.1007/s10531-014-0694-6>
- Barnosky AD, Hadly EA (2016) Tipping point for planet earth: how close are we to the edge? Thomas Dunne Books, New York
- Bekele A, Yalden DW (2013) The Mammals of Ethiopia and Eritrea. Addis Ababa University Press, Addis Ababa, Ethiopia
- Bhatia S, Redpath SM, Suryawanshi K, Mishra C (2020) Beyond conflict: exploring the spectrum of human-wildlife interactions and their underlying mechanisms. *Oryx* 54(5):621–628. <https://doi.org/10.1017/S003060531800159X>
- Buckland ST, Thomas L, Rexstad EA, Laake JL, Strindberg S, Hedley SL, Burnham KP (2010) Distance software: design and analysis of distance sampling surveys for estimating population size. *J Appl Ecol* 47(1):5–14. <https://doi.org/10.1111/j.1365-2664.2009.01737>
- Cavada N, Barelli C, Ciolli M, Rovero F (2016) Primates in human-modified and fragmented landscapes: the conservation relevance of modelling habitat and disturbance factors in density estimation. *PLoS One* 11(2):e0148289
- Chagas RRD, Ferrari SF (2011) Population parameters of the endangered titi monkey, *Callicebus coimbrai* Kobayashi and Langguth, 1999, in the fragmented landscape of southern Sergipe, Brazil. *Braz J Biol* 71:569–575. <https://doi.org/10.1590/s1519-69842011000400001>
- Colin A, Chapman MJ, Harriet A (2006) What hope for African primate diversity? *Afr J Ecol* 44:116–133. <https://doi.org/10.1111/j.1365-2028.2006.00636.x>
- Couvreur TL, Dauby G, Blach-Overgaard A, Deblauwe V, Dessein S, Droissart V, Sepulchre P (2021) Tectonics, climate and the diversification of the tropical African terrestrial flora and fauna. *Biol Rev* 96(1):16–51. <https://doi.org/10.1111/brev.12644>
- CSA, (2007). Southern Nations, Nationalities, and Peoples’ Region. en.wikipedia.org/wiki/Southern_Nation
- Daszak P, Cunningham AA, Hyatt AD (2001) Anthropogenic environmental change and the emergence of infectious diseases in wildlife. *Acta Trop* 78(2):103–116. [https://doi.org/10.1016/S0001-706X\(00\)00179-0](https://doi.org/10.1016/S0001-706X(00)00179-0)
- Dobamo T, Achiso Z (2025) The population ecology and habitat relationships of Grant’s gazelle (*Nanger granti* Brooke, 1872) in the Lamo Forest and the adjacent fragmented forests in South Central Ethiopia. *BMC Zool* 10(1):19
- Ejigu D, Bekele A (2010) Population structure, feeding ecology and human-grivet monkeys conflict at Bahir Dar University main campus, Bahir Dar. *Ethiop J Biol Sci* 9(1):35–47
- Eshete GI, Sillero-Zubiri C, Cieraad E, Musters CJM, De Snoo GR, De Jongh HH, Marino J (2018) Does livestock predation reflect in negative local perceptions of Ethiopian wolves in South Wollo? *Trop Ecol* 59(1):11–19
- Estrada A, Garber PA, Rylands AB, Roos C, Fernandez-Duque E (2017) Impending extinction crisis of the world’s primates: why primates matter. *Sci Adv* 3:e1600946. <https://doi.org/10.1126/sciadv.1600946>
- Fashing PJ (2002) Population status of black and white colobus monkeys (*Colobus guereza*) in Kakamega Forest, Kenya: are they really on the decline? *Afr Zool* 37(2):119–126. <https://doi.org/10.1080/15627020.2002.11657166>
- Fashing PJ, Cords M (2000) Diurnal primate densities and biomass in the Kakamega Forest: an evaluation of census methods and a comparison with other forests. *Am J Primatol* 50:139–152. <https://doi.org/10.1002>
- Fenta MM (2014) Human-wildlife conflicts: case study in Wondo Genet District, southern Ethiopia. *Agriculture, Forestry and Fisheries* 3(5):352–362. <https://doi.org/10.11648/j.aff.20140305.14>

- Findlay, L. (2016). *Human-primate conflict: An interdisciplinary evaluation of wildlife crop raiding on commercial crop farms in Limpopo Province, South Africa* (Doctoral dissertation, Durham University). Durham e-Theses. <http://etheses.dur.ac.uk/11872/>
- Gatew S, Azadze W (2025) Human-wildlife conflict and its socio-economic impacts in Northwest Ethiopia. *Discover Life* 55(1):14
- Gebo B, Takele S, Shibru S (2022) Knowledge, attitude and practice of the local people towards human-carnivore co-existence in Faragosa-Fura Land Scape, Gamo Zone, Southern Ethiopia. *Wildl Biol* 2022(2):1–10. <https://doi.org/10.1002/wlb3.01018>
- Gillingham S, Lee PC (2003) People and protected areas: a study of local perceptions of wildlife crop-damage conflict in an area bordering the Selous Game Reserve, Tanzania. *Oryx* 37(3):316–325. <https://doi.org/10.1017/S0030605303000577>
- Hariohay KM, Roskaf E (2015) Wildlife-induced damage to crops and livestock loss and how they affect human attitudes in the Kwakuchinja Wildlife Corridor in northern Tanzania. *Environ Nat Resour Res* 5(3):72–79. <https://doi.org/10.5539/enr.v5n3p72>
- Hemede MB, Abebe W (2016) Floristic composition and vegetation structure of woody species in Lammo Natural Forest in Tembaro Woreda, Kambata-Tembaro Zone, southern Ethiopia. *Am J Agric For* 4(2):49–55. <https://doi.org/10.11648/j.ajaf.20160402.16>
- Hill CM, Wallace GE (2012) Crop protection and conflict mitigation: reducing the costs of living alongside non-human primates. *Biodivers Conserv* 21:2569–2587. <https://doi.org/10.1007/s10531-012-0318-y>
- Hill CM (2000) Conflict of interest between people and baboons: crop raiding in Uganda. *Int J Primatol* 21(2):299–315. <https://doi.org/10.1023/A:1005481605637>
- Hockings KJ, McLennan MR (2012) From forest to farm: a systematic review of cultivar feeding by chimpanzees—management implications for wildlife in anthropogenic landscapes. *PLoS One* 7(4):e33391. <https://doi.org/10.1371/journal.pone.0033391>
- Hockings KJ, Sousa C (2013) Human-chimpanzee sympatry and interactions in Cantanhez National Park, Guinea-Bissau: current research and future directions. *Primate Conserv* 26:57–65. <https://doi.org/10.1896/052.026.0104>
- Hockings KJ, McLennan MR, Carvalho S, Ancrenaz M, Bobe R, Byrne RW, Hill CM (2015) Apes in the Anthropocene: flexibility and survival. *Trends Ecol Evol* 30(4):215–222. <https://doi.org/10.1016/j.tree.2015.02.002>
- Honda T, Miyagawa Y, Ueda H, Inoue M (2009) Effectiveness of newly-designed electric fences in reducing crop damage by medium and large mammals. *Mamm Stud* 34:13–17. <https://doi.org/10.3106/041.034.0103>
- Israel PM, Balakrishnan M (2016) The effect of habitat on density, feeding behaviour and activity of Heller's vervet monkey (*Chlorocebus pygerythrus arenarius*, Heller, 1913): a case study in Arba Minch forest, Ethiopia. *Res J Chem Environ* 4(3):24–3. <https://doi.org/10.11648/j.ijnrem.20160103.12>
- Karki, S., Dahal, A., & Sharma, S. (2024). *Pattern and correlates of human-primate conflict: An insight for its mitigation—A case study of Nilkantha Municipality of Dhading District, Nepal*. ESS Open Archive. <https://doi.org/10.22541/essoar.56256090>
- Kidane EE, Kiros S, Berhe A, Girma Z (2024) Human-wildlife conflict and community perceptions towards wildlife conservation in and around Kafta-Sheraro National Park, northern Ethiopia. *Glob Ecol Conserv* 54:e03072. <https://doi.org/10.1016/j.gecco.2024.e03072>
- Kifle Z, Bekele A (2020b) Human-hamadryas baboon (*Papio hamadryas*) conflict in the Wonchit Valley, South Wollo, Ethiopia. *African Journal of Ecology of Ecology*. 58:786–795. <https://doi.org/10.1111/aje.12816>
- Kifle Z, Bekele A (2021) Human-olive baboon (*Papio anubis*) conflict in the human-modified landscape, Wollo, Ethiopia. *Glob Ecol Conserv* 31:e01820. <https://doi.org/10.1016/j.gecco.2021.e01820>
- Kifle Z, Bekele A (2022) Effect of human disturbance on the group size and population structure of geladas (*Theropithecus gelada*) in and surrounding area of Borena Sayint National Park, Ethiopia. *Glob Ecol Conserv* 40:e02307. <https://doi.org/10.1016/j.gecco.2022.e02307>
- Kifle Z, Bekele A (2020a) Human-Gelada conflict and attitude of the local community toward the conservation of the southern gelada (*Theropithecus gelada obscurus*) around Borena Saynt National Park, Ethiopia. *Environ Manage* 65(3):399–409. <https://doi.org/10.1007/s00267-019-01246-8>
- Kifner C, Paci'encia FMD, Henrich G et al (2022) Road-based line distance surveys overestimate densities of olive baboons. *PLoS One* 17(2):e0263314. <https://doi.org/10.1371/journal.pone.0263314>
- Kolinski L, Milich KM (2021) Human-wildlife conflict mitigation impacts community perceptions around Kibale National Park, Uganda. *Diversity* 13(4):145. <https://doi.org/10.3390/d13040145>
- Kwaslema MH, Robert D, Jafari RK, Eivn R (2017) Assessing crop and livestock losses along the Rungwa-Katavi wildlife corridor, southwestern Tanzania. *Int J Biodivers Conserv* 9(8):273–283. <https://doi.org/10.5897/IJBC2017.1116>
- Lawes MJ, Eeley HAC (2000) Are local patterns of anthropoid primate diversity related to patterns of diversity at a larger scale? *J Biogeogr* 27(6):1421–1435
- Leta, G. (2014). Assessment of human-wild animal conflict and management strategies in Gera District, southwestern Ethiopia. Jimma University <http://10.140.5.162/handle/123456789/2113>
- Lindsey PA, Petracca LS, Funston PJ, Bauer H, Dickman A, Everatt K, Flyman M, Henschel P, Hinks AE, Kasiki S, Loveridge A, Macdonald DW, Mandisodza R, Mgoola W, Miller SM, Nazerali S, Siegel L, Uisebn K, Hunter LTB (2017) The performance of African protected areas for lions and their prey. *Biol Conserv* 209:137e–1149. <https://doi.org/10.1016/j.biocon.2017.01.011>
- Mamo A, Lemessa D, Diriba OH, Hunde D (2021) Pattern of crop raiding by wild large mammals and the resultant impacts vary with distances from forests in southwest Ethiopia. *Ecol Evol* 11(7):3203–3209. <https://doi.org/10.1002/ece3.7258>
- Matseketsa G, Never M, Edson G, Davidson MK, Gladman C (2019) An assessment of human-wildlife conflicts in local communities bordering the western part of Save Valley Conservancy, Zimbabwe. *Glob Ecol Conserv* 20:1–10. <https://doi.org/10.1016/j.gecco.2019.e00737>
- McGuinness S, Taylor D (2014) Farmers' perceptions and actions to decrease crop raiding by forest-dwelling primates around a Rwandan forest fragment. *Hum Dimens Wildl* 19(2):179–190. <https://doi.org/10.1080/10871209.2014.853330>
- Naughton-Treves, L., & Treves, A. (2005). Socio-ecological factors shaping local support for wildlife: Crop-raiding by elephants and other wildlife in Africa. In R. Woodroffe, S. Thirgood, & A. Rabinowitz (Eds.), *People and wildlife: Conflict or coexistence?* (pp. 252–277). Cambridge University Press.
- Newmark WD, Manyanza DN, Gamassa DM, Sariko HI (1994) The conflict between wildlife and local people living adjacent to protected areas in Tanzania: Human density as a predictor. *Conserv Biol* 8(1):249–255. <https://doi.org/10.1046/j.1523-1739.1994.08010249>
- Reidinger, R. F., & Miller, J. E. (2013). *Wildlife damage management: Prevention, problem solving, and conflict resolution*. Johns Hopkins University Press.
- Riley EP, Priston NEC (2010) Macaques in farms and folklore: exploring the human-nonhuman primate interface in Sulawesi, Indonesia. *Am J Primatol* 72(10):848–854. <https://doi.org/10.1002/ajp.20798>
- Rusoke, T., & Orach-Meza, F. L. (2021). Buffer crops as a mitigation measure against crop damage by wildlife: A case of farmers bordering Kibale National Park, western Uganda.

- Ségniagbeto GH, Atsri KH, Delagnon A, Elikplim AK, Gbetey AK, Amori G, Luiselli L (2018) Local distribution and density estimates of primates in the Transboundary Reserve of the Mono River, Togo (West Africa). *Revue d'Ecologie. Terre et Vie* 73(3):363–374.
- Seoraj-Pillai N, Pillay N (2016) A meta-analysis of human–wildlife conflict: South African and global perspectives. *Sustainability (Basel)* 9(1):34
- Strum SC (2010) The development of primate raiding: implications for management and conservation. *Int J Primatol* 31(1):133–156. <https://doi.org/10.1007/s10764-009-9387-5>
- Surovell TA, Pelton SR, Anderson-Sprecher R, Myers AD (2016) Test of Martin's overkill hypothesis using radiocarbon dates on extinct megafauna. *Proc Natl Acad Sci U S A* 113(4):886–891. <https://doi.org/10.1073/pnas.1504020112>
- Tembaro Woreda Agricultural office (2019). The assessment of fauna and flora in the district conducted by different experts.
- Temesgen Z, Biru Y, Mekonnen AG, 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>
- Wang SW (2010) Estimating population densities and biomass of ungulates in the temperate ecosystem of Bhutan. *Oryx* 44(3):376–382. <https://doi.org/10.1017/S0030605310000487>
- Warren Y (2008) Crop-raiding baboons (*Papio anubis*) and defensive farmers: a West African perspective. *West Afr J Appl Ecol* 14:23–28. <https://doi.org/10.4314/wajae.v14i1.44705>
- Yamane T (1967) *Statistics, an Introductory Analysis*. New York University, New York, NY, USA
- Yibelu, Y., Esubalew, A., & Misganaw, M. (2022). *Diurnal activity budget and feeding activity of grivet monkeys (Chlorocebus aethiops) in Zegie Peninsula, Northern Ethiopia* (Preprint). Research Square. <https://doi.org/10.21203/rs.3.rs-1669156/v1>
- Yitayih Y, Ejigu D, Mola M (2021) Population size and human-grivet monkeys (*Chlorocebus aethiops*) conflict in Zegie Peninsula, Bahir Dar, Ethiopia. *BMC Zool* 6:2021. <https://doi.org/10.1186/s40850-021-00066-w>

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