International Journal of Ecology and Environmental Sciences 51: 377-401, 2025
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2025.0738

Navigating Human Wildlife Co-existence in the Vicinity of Malampuzha Dam, Kerala, India

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ABSTRACT

Human-wildlife conflict (HWC) typically arises when human activities harm wildlife and vice versa. In the Akathethera and Malampuzha I Panchayats, HWC has escalated since 2015, particularly following 2020. A significant increase in built-up areas by 100%, alongside a decrease in forest cover by 1.509% and a reduction in mixed tree cover by 9.09%, indicate habitat fragmentation and encroachment on wildlife habitats between 2013 and 2025. Households cultivate approximately three crops annually, facing depredation from at least two different animal species. The broader range of crops cultivated tends to attract more animals, evidenced by a correlation of 0.518. It is reported that the average annual economic loss due to crop damage amounts to IRS 58,550.59 per household. There have been 618 reported livestock deaths, mostly involving poultry and guard dogs. Leopards are responsible for the most attacks, with the average loss per household estimated at IRS 36168.42 between 2015 and 2025. Additionally, there have been 28 recorded cases of human injury and two fatalities, primarily due to attacks by elephants, wild boars, and snakes, with an average economic loss of IRS 8,911.76 per incident during the same period. Elephants, wild boars, and monkeys account for much of the property damage, particularly in the form of fence destruction, resulting in an average loss of IRS 26,546.51 per household from 2015 to 2024. Heat density and conflict probability maps indicate that the southern part of the study area is the most vulnerable. Only 27.49% of households have registered for compensation. Given the high incidence of crop damage, livestock losses, property destruction, and human injury and fatalities, there is growing animosity towards wildlife conservation. This situation necessitates a comprehensive and practical framework to promote wildlife conservation and human safety.

Key words: Human-wildlife conflict (HWC), Livestock kills, Human injury, Economic loss, Heat density, Conflict probability

INTRODUCTION

Human-wildlife conflict (HWC) arises when human activities adversely impact wildlife and, conversely, when wildlife negatively affects human communities (König et al. 2020, Anonymous 2025a). India is notably rich in biodiversity, being one of the 17 most megadiverse countries globally (Anonymous 2009, Balasubramanian 2017). It harbours 75 to 80% of all documented species within just 2.4% of the world's land area (Anonymous 2022b). It encompasses a network of 1,022 Protected Areas (PAs) (Anonymous 2023b, 2024b). However, it is also home to nearly 18% of the global human population (Sikdar and Mukhopadhyay 2016, Anonymous 2023a), leading to an increase in resource-based conflicts (Blondel 2012, Ghosh 2019, Sharma et al. 2021, Nandi 2024) as the habitats of wildlife and human settlements overlap, resulting in heightened instances of conflict (Pandey et al. 2017, Mahanti and Kumar 2018). This situation severely compromises conservation efforts (Ogra and Badola 2008, Anonymous 2023d). Furthermore, protected animals often inhabit areas beyond designated PAs (Barua et al. 2013), compelling humans to adapt to wildlife (Ogra and Badola 2008, Pooley et al. 2021). In India, the number of deaths and injuries resulting from animal attacks rose by over 19% from 2021 to

2022 (Anonymous 2022a). The transformation of landscapes into agricultural land, urbanisation, and the degradation of wildlife habitats further exacerbate HWC (Kattan et al. 2004, Albarracín and Aliaga-Rossel 2018, Coogan et al. 2019), leading to significant repercussions for both humans and wildlife (Mmbaga et al. 2017, Billah et al. 2021). These actions violate wildlife conservation principles and escalate tensions and conflicts (Anonymous 2021, 2022c). Ultimately, these conflicts result in crop damage and the injury or death of humans and livestock (Mahanti and Kumar 2018, Mekonen 2020). Crop raids and livestock predation jeopardise households' livelihoods and economic stability (Mulonga et al. 2003, Mekonen 2020), in addition to posing risks to human welfare, safety, and social costs (Anonymous 2022c).

The human-wildlife conflict (HWC) in Kerala, India, is widespread and severe. In March 2024, it was designated as a State-Specific Disaster (Philip 2024) which prompted this research to shed light on the issues and challenges faced by both humans and wildlife and reveal the ground truth. In the last five years, crop damage amounting to 217.4 crore IRS has been reported (Anonymous 2025b). The highest number of HWC incidents have been documented in Wayanad, Palakkad, and Idukki (Anonymous 2025b). To address this growing issue, the Ministry of Environment, Forest and Climate Change has increased financial assistance to Kerala by 8.99% from 2019-20 to 2023-24, raising the funding from 845.026 lakh IRS to 921.036 lakh IRS. This support is part of centrally sponsored schemes to develop wildlife habitats for wildlife protection and mitigate HWC while revising relief rates for ex-gratia payments (Anonymous 2024a). The selected study area, Akathethera and Malampuzha I Panchayaths in the Palakkad district is particularly affected by HWC. Residents regularly experience crop raiding, livestock deaths, property destruction, and even human fatalities and injuries. Since 2015, the number of HWC incidents has surged, a trend exacerbated by the COVID-19 lockdown of 2020-21, which allowed wildlife greater access to human habitats. The local population faces significant economic losses, compounded by a cumbersome compensation filing process and delays in the disbursement of funds. This study aims to illuminate the struggles of the residents while revealing the harsh realities of the current situation. By conducting land use and land cover (LULC) change detection analysis, conflict probability mapping, and heat density mapping, the research highlights the causes and extent of HWC. Ultimately, the study seeks to discuss the economic losses endured by residents and wildlife and to propose potential solutions for protecting the interests of both humans and wildlife. Lying at the Kerala-Tamil Nadu border and the lap of Malampuzha dam, the chosen study area, Akathethera and Malampuzha I Panchayaths of Palakkad district, is riddled with HWC. Crop raiding, livestock deaths, property destruction, human deaths and injuries are part of the daily lives of the residents. The residents face significant economic losses and lack of prompt compensation dispersal. By performing LULC change detection analysis, conflict probability mapping, and heat density mapping, an attempt has been made to highlight the reasons for and extent of HWC. The study sheds light on the economic losses and the plight of the residents and the wildlife and strives to formulate possible solutions to safeguard the interests of both humans and wildlife.

STUDY AREA

Akathethera and Malampuzha I Panchayats are situated in the Palakkad district of Kerala, India, at coordinates ranging from 76°37'30" to 76°46'30" E longitude and 10°48'30" to 10°55'30" N latitude (Fig. 1). Akathethera is designated as a Census Town and is governed by the Akathethera Panchayat, with a population of 28592 individuals, comprising 13862 males and 14730 females. In contrast, the Malampuzha Panchayat oversees Malampuzha I, which has a population of 14479 individuals (comprised of 7,133 males and 7,346 females) (Anonymous 2011, 2025c). The study area encompasses 113.85 km² and features diverse vegetation types, including wet evergreen forest, moist deciduous forest, forest plantations, and savannah grassland (Sivaram et al. 2013). The proximity of Akathethera and Malampuzha to the renowned Malampuzha dam attracts tourists and recreational enthusiasts. The questionnaire survey was conducted in populated locations (Fig. 2).

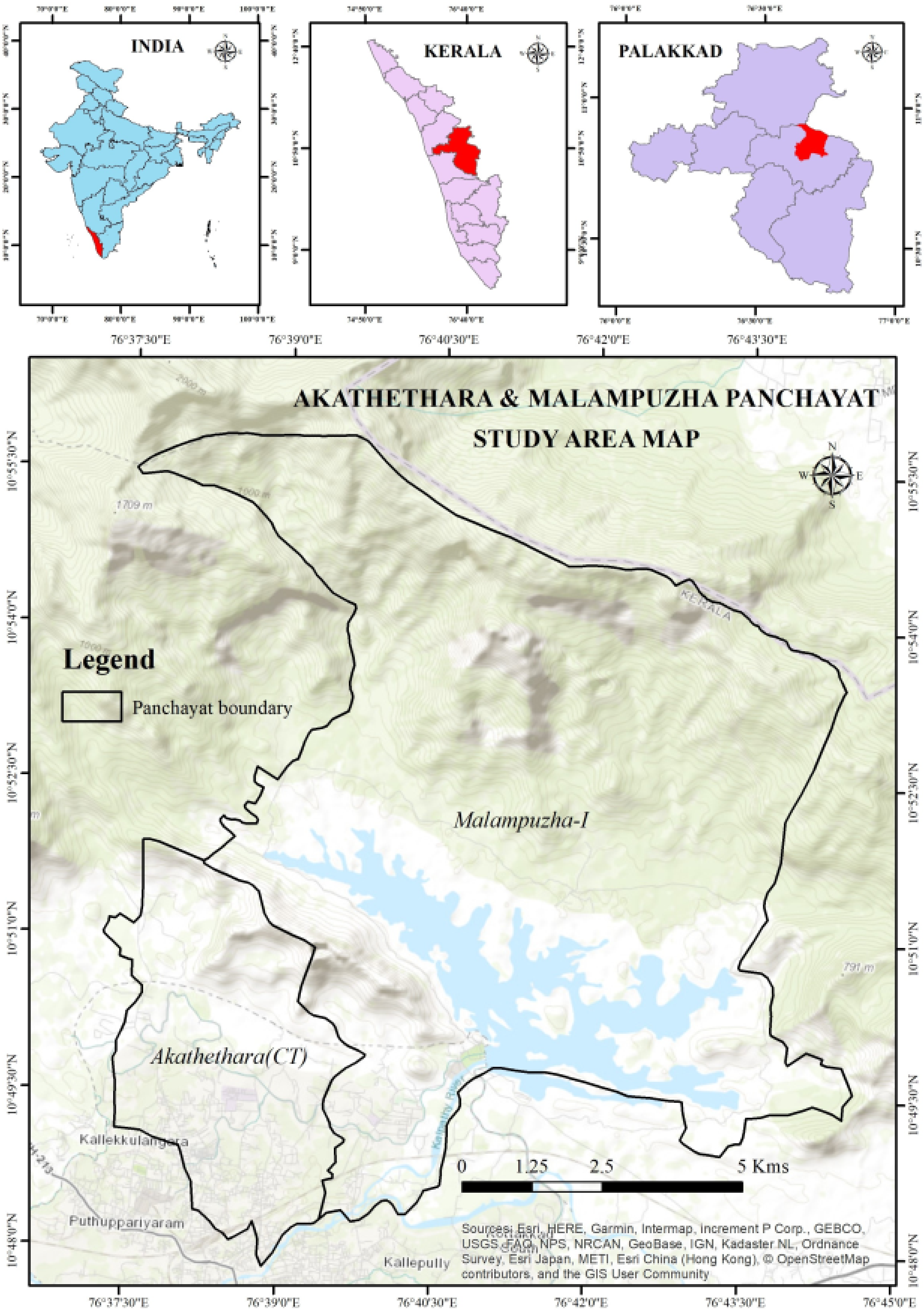

Figure 1. Location of study area

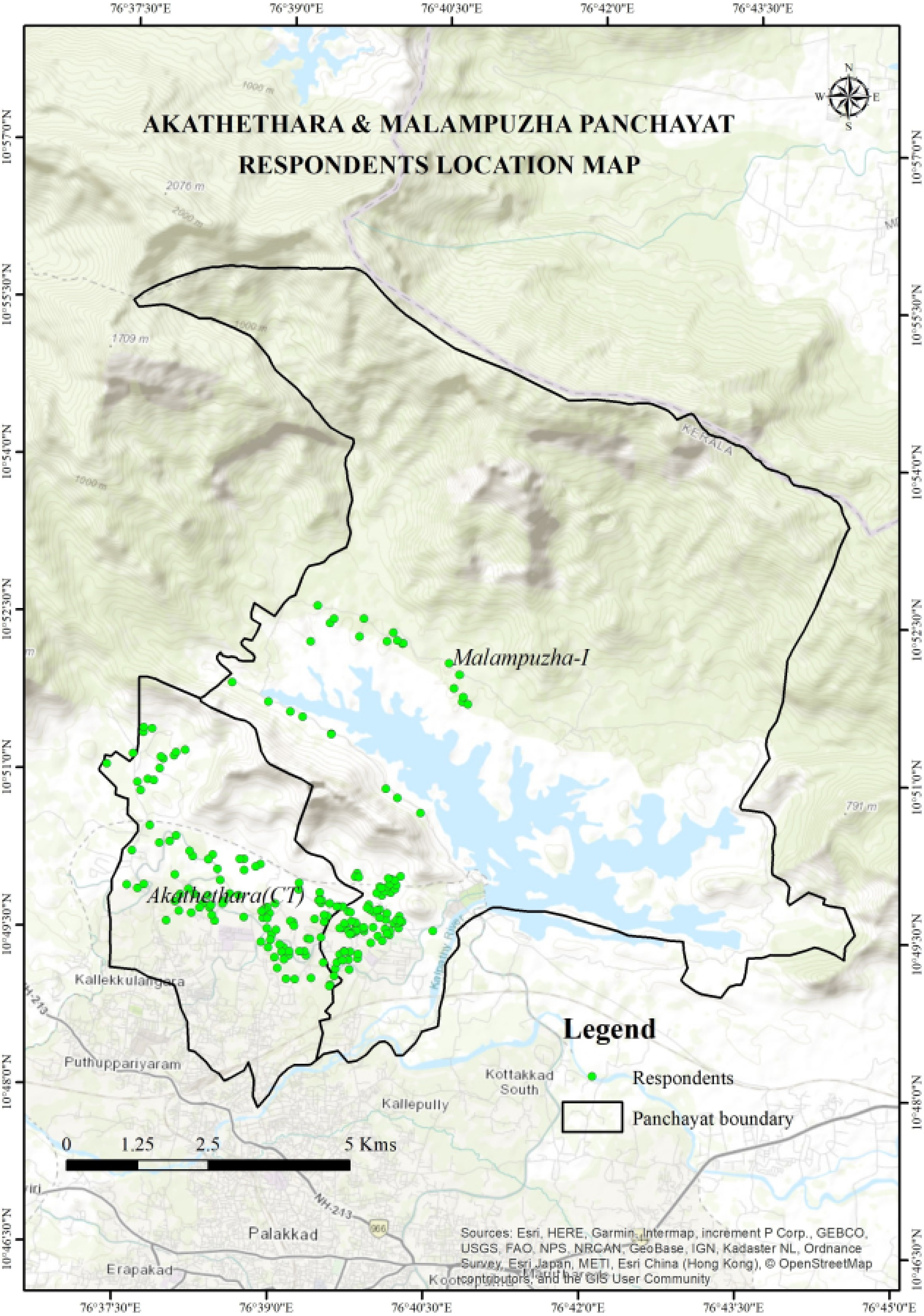

Figure 2. Respondents' location

MATERIAL AND METHODS

Primary sources and methods used

A household questionnaire survey was conducted in the Akathethera and Malampuzha I Panchayaths of Kerala, which comprised 10571 households (Anonymous 2011, 2025c) between June and July of 2024. A sample size of 371 was determined using equations 1 and 2. The survey, administered in the local language, focused on the respondents' socio-economic status of the respondents, type of household, type of fencing of the household, and agricultural land or kitchen garden, types of cultivated crops, and livestock raised, etc. Information was gathered on wildlife incidents affecting crops, livestock mortality, property damage, human injuries, and fatalities. Discussions with residents included details on economic losses, compensation received, and strategies employed to prevent wildlife attacks. Utilising Global Positioning System technology (Fig. 2), location points for 210 respondents were collected during the survey, which were subsequently visualised as heat density maps using QGIS 3.34 software. Additionally, the correlation between household crop types and the frequency of wildlife attacks on those crops was calculated and illustrated using Jamovi 2.6 software.

Calculation of sample size for infinite population (Cochran 1977):

$$S= Z^2*p*(1-p)/m^2 \ldots\ldots\ldots\ldots\text{eq.1}$$

Where: S= sample size for infinite population, Z = Z score at 95% Confidence, which is 1.960, p = population proportion (assumed at 50% or 0.5) and m = margin of error at 5% or 0.05.

Calculation of sample size for 10751 households (Cochran 1977):

$$\text{Sample size}= (S)/1+ [(S-1)/\text{population}]\ldots\text{eq.2}$$

Where: S = sample size for infinite population calculated in eq.1 and population = 10571 households.

Secondary sources and methods used

The field and questionnaire survey indicated a significant increase in human-wildlife conflict (HWC) since 2015, and this trend continues to rise even today. Changes in land use and land cover (LULC) may contribute to the escalation of HWC. Therefore, LULC changes prior to 2015 and up to 2025 were analysed to investigate this. Due to the unavailability of cloud free satellite imagery for 2014, cloud-free LANDSAT 8 (OLI) imagery from 2013 was utilised (Table 1). Satellite images from the autumn-winter months (November-February) were obtained from the United States Geological Survey. Supervised classification was performed using the Maximum Likelihood Classification (Nad et al. 2022) in ERDAS Imagine, with training samples collected randomly (Nad et al. 2022). The images were categorised into seven major classes, and the outputs were evaluated for accuracy. One hundred eighteen random points were selected from the images and validated against Google Earth Pro imagery corresponding to the same date as the data acquisition. The Kappa test was applied using equation 3 (Billah et al. 2021).

$$K = (N\Sigma^{r}_{i"1} X_{ii} \Sigma^{r}_{i"1} (X_{i+)} (X_{+i}))/(N^2 \Sigma^{r}_{i"1} (X_{i+})(X_{+i})) \ldots\ldots\text{eq.3}$$

Where, N is the total number of samples in the matrix, r is the number of rows in the matrix, X_i = the number in row i and column i, X_{+i} is the total for row i, and X_{i+} is column i.

For detecting land use and land cover (LULC) changes between 2013 and 2025, the study employed Post-Classification Change Detection, following the method outlined by El-Hattab (2016). This process involved converting raster images to vector format using ArcGIS software and applying the intersect option in the Geoprocessing tool. The identified changes were then categorised and analysed within a conversion matrix. The research utilised spatial analysis to develop heat density maps based on data collected from questionnaires and respondents' locations. This was achieved using the Spatial Analyst Tool in ArcMap 10.2. A conflict probability map was also created by integrating settlement density, proximity to historical conflict locations, and a surface resistance layer derived from the LULC data. This integration was facilitated by a weighted overlay analysis (Table 2), ultimately producing the final conflict probability map. All datasets were standardised and converted to raster format using ArcMap 10.2. Settlement density was calculated using the Kernel Density tool from the Spatial Analyst Tool based on the locations of surveyed

Table 1. Details of satellite imageries

Satellite imagery	Date of image acquisition	Year	Path/Row	Resolution
Landsat 8 (OLI)	07-11-2013	2013	144/052	30 m
Landsat 8 (OLI)	08-01-2025	2025	144/053	30 m

households. The resulting raster was reclassified into five categories - Very Low, Low, Moderate, High, and Very High - using the Reclassify tool with the Natural Breaks (Jenks) method. A proximity raster was generated using the Euclidean Distance tool from the Spatial Analyst Tool to assess proximity based on reported animal attack locations. This raster was also reclassified into five categories with Natural Breaks, where lower values indicated a higher probability of conflict. LULC data was converted to raster format for the Surface Resistance layer using the Polygon to Raster tool from the Conversion Tool, assigning resistance values based on expected animal movement behaviour. Reclassification for the surface was performed using the Reclassify tool, categorising it into five resistance levels. The Weighted Overlay tool from the Spatial Analyst Tools combined the three reclassified raster layers. Weights were assigned to each factor based on their relative influence on conflict probability: Settlement Index (50%), Proximity to Conflict Locations (30%), and Surface Resistance (20%). The final output raster classified conflict probability into five levels: Very Low, Low, Moderate, High, and Very High.

RESULTS

The accuracy assessment for Land Use and Land Cover (LULC) in 2013 (Fig. 3) and 2025 (Fig. 4) was assessed using the Kappa coefficient and overall accuracy percentage metrics. The overall Kappa accuracy for LULC in 2013 is 95.76%, whereas for 2025, it is 88.98%. Specifically, the Kappa coefficient for 2013 is 0.94, and for 2025, it is 0.86, which affirms the reliability of the LULC findings as a Kappa coefficient greater than 0.8 is generally acceptable (Akpoti et al. 2016, Shivakumar and Rajashekararadhy 2019). The analysis of LULC change between 2013 and 2025 (Table 3) revealed agriculture area has declined from 3.52 to 3.39 km² (a decrease of 3.69%), while bare rock/soil also diminished from 14.38 to 12.35 km² (a reduction of 14.11%). Conversely, the area under built-up has doubled from 1.18 to 2.36 km² (an increase of 100%), while the forested area decreased from 55.65 to 54.81 km² (a decline of 1.509%) between 2013 and 2025. The most significant reduction, at -9.09%, is observed in area under mixed trees, which decreased from 8.69 to 7.90 km². Meanwhile, plantation area increased from 15.1 to 15.59 km² (a rise of 3.24%), and also the area under water bodies from 15.32 to 17.45 km² (an increase of 13.60%) during the assessment period (Fig. 5).

Between 2013 and 2025 (Table 4), agriculture area has been converted into plantation and built up while bare rock/soil area was converted into built-up and water body. On the other hand forest area is degreaded into bare rock/soil, built-up and plantation,

Table 2. Details of weighted overlay analysis

Settlement Index Reclassification			Proximity to Conflict Locations			Surface Resistance Reclassification		
Density range	Reclassified value	Conflict probability	Distance (m)	Reclassified value	Conflict probability	LULC Class	Reclassified value	Conflict probability
0 - 4	1	Very low	0 - 652	5	Very high	Water body	1	Very low
04-11	2	Low	652 - 1518	4	High	Forest	2	Low
11-22	3	Moderate	1518 - 2432	3	Moderate	Agriculture/ Plantation/ Mixed tree	3	Moderate
22 - 38	4	High	2432 - 3415	2	Low	Bare rock/soil	4	High
38 - 66	5	Very high	3415 - 5129	1	Very low	Built-up	5	Very high

while 0.12% of forest land is degraded into bare rock/soil, 0.07% is converted into built up and 1.49% into plantation. The most evident change is the conversion of 11.16% mixed tree cover in to built-up area. While 0.19% of plantation is converted into agriculture, 0.92% into built-up and 0.66% into mixed tree cover; a minor 0.26% area is degraded into bare rock/soil (Fig. 5).

Crop damage

The study area is recognised for its agricultural productivity, with a diverse range of crops and fruits being cultivated, including paddy, coconut, rubber, jackfruit, areca nut, pepper, banana, mango, tubers, sweet potato, pineapple, cashew, ginger, cardamom, Chinese potato, turmeric, and various vegetables. Approximately 55.25% (n=205) of households are involved in agricultural activities, including full-scale farming or cultivating food crops in kitchen gardens. Among the households growing food crops, 72.68% (n=149) own agricultural land, while the remaining 27.31% (n=56) cultivate crops within their household boundaries. The average size of agricultural plots is 0.68 acres, and each household grows about three different crops annually. Specifically, 14.6% (n=30) of households grow at least one crop, 26.8% (n=55) cultivate at least two crops, 34.1% (n=70) grow at least three crops, 15.6% (n=32) manage four crops, 7.3% (n=15) grow five crops, while 1% (n=2) engage in cultivating six crops, and 0.5% (n=1) grow at least seven crops in a given year. Of the households (n=205) growing crops, a striking 97.07% (n=199) report experiencing annual crop damage due to wildlife. On average, crops within these households are affected by at least two types of wildlife. Only 2.9% (n=6) of the households surveyed reported no crop damage, while 16.1% (n=33) indicated that at least one animal had caused damage to their crops. Furthermore, 35.6% (n=73) reported damage from at least two different animals, 28.3% (n=58)

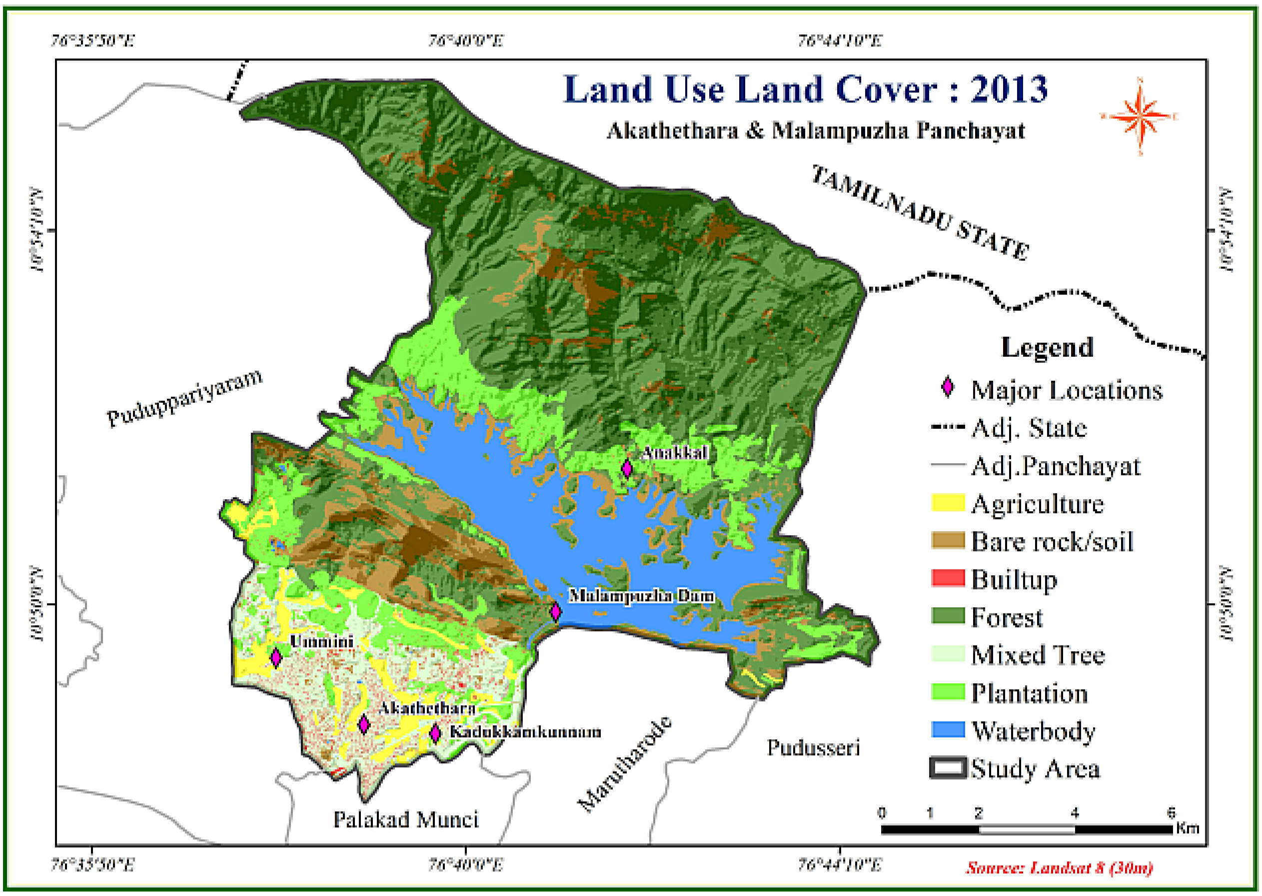

Figure 3. LULC classification for 2013

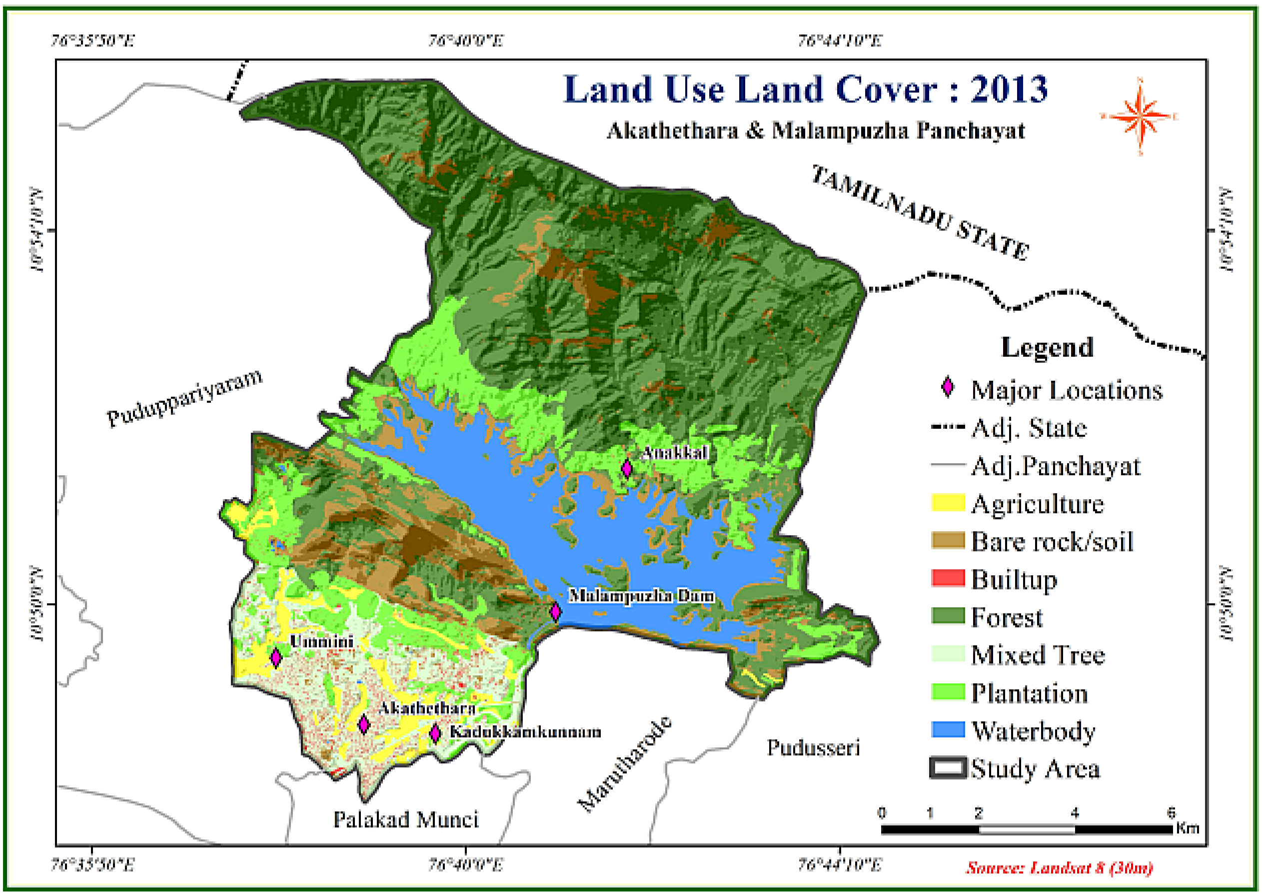

Figure 4. LULC classification for 2025

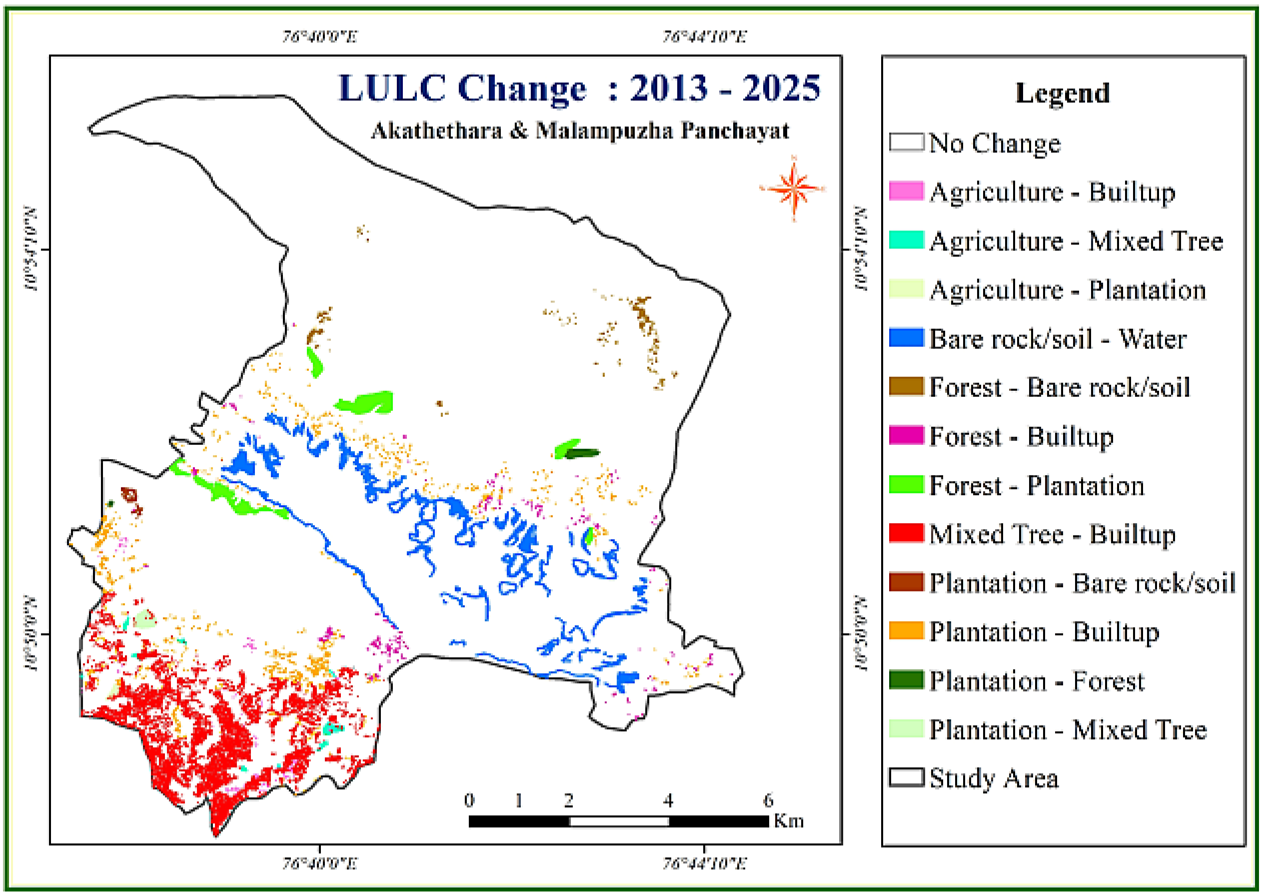

Figure 5. LULC change detection 2013-2025

Table 3. Land use land Cover (2013 and 2025)

LULC categories	Area: 2013		Area: 2025		Change
	km²	%	km²	%	(%)
Agriculture	3.52	3.09	3.39	2.98	-3.6932
Bare rock/soil	14.38	12.63	12.35	10.85	-14.117
Built up	1.18	1.04	2.36	2.07	100
Forest	55.65	48.88	54.81	48.14	-1.5094
Mixed Tree	8.69	7.64	7.9	6.94	-9.0909
Plantation	15.1	13.27	15.59	13.69	3.24503
Waterbody	15.32	13.46	17.45	15.33	13.9034
Total	**113.85**	**100**	**113.85**	**100**	

experienced damage from three animals, 12.2% (n=25) faced damage from four species, and 4.9% reported damage due to at least five different animals. Wild boars are responsible for the maximum damage to crops. About 156 households reported attacks from wild boars, 128 from elephants, 105 from monkeys, and 60 from peacocks. Additionally, 33 households experienced damage caused by giant squirrels and 16 faced damage from deer. A positive correlation of 0.518 was identified between the number of crops grown per household and the incidence of wildlife damage (Fig. 8). In terms of timing, 4% (n=8) of households reported damage occurring during the day, 30.2% (n=60) at night, and 65.8% (n=131) experienced damage at both times. It was observed that monkeys, peacocks, and giant squirrels primarily damage crops during daylight hours, while elephants and wild boars tend to cause damage mainly at night. Furthermore, 7.04% (n=14) of households experienced seasonal damage, such as harm to paddy during the harvesting and ripening seasons, whereas 92.96% (n=185) dealt with damage year-round. Monkeys and squirrels primarily affect fruit trees, while elephants damage paddy, coconut, and various fruits. Wild boars target vegetables, tubers, and other crops. Individual instances of crop damage can be found in Table 5.

Livestock and guard dog deaths

31.19% (n=138) of households surveyed owned livestock and guard dogs between 2015 and 2024, and 94.2% (n=130) reported incidents of wildlife attacks resulting in casualties. On average, each affected household (n=130) suffered five livestock or guard dog deaths during this period. In total, these households experienced 618 individual livestock deaths (Table 5), which included 45 milch animals, 100 goats, 369 poultry, and 104 dog fatalities. Among the households, 100 reported attacks from at least one predator, 22 encountered at least two predators, seven faced attacks by at least three predators, and one household experienced attacks from as many as four different predators (Figs. 9, 10). More specifically, 71 households were affected solely by leopard attacks on livestock (Table 6), 15 experienced only mongoose attacks, and five dealt with mongoose and fox attacks. In comparison, four households experienced combined attacks from mongoose, fox, and wild cat. Additionally, four households faced attacks from mongoose and wild cats, four reported wild cat attacks, and three dealt with python attacks, among others.

Leopards, tigers, and wolves are known to kill livestock such as milch animals, goats, poultry, and

Table 4. LULC change detection (2013-2025)

	Agriculture	Bare rock/ soil	Built-up	Forest	Mixed tree	Plantation	Water body	Total 2013
Agriculture	3.37	0.00	0.02	0.00	0.09	0.03	0.00	**3.52**
Bare rock/soil	0.00	12.24	0.01	0.00	0.00	0.00	2.13	**14.38**
Built up	0.00	0.00	1.18	0.00	0.00	0.00	0.00	**1.18**
Forest	0.00	0.07	0.04	54.72	0.00	0.83	0.00	**55.65**
Mixed tree	0.00	0.00	0.97	0.00	7.71	0.02	0.00	**8.69**
Plantation	0.03	0.04	0.14	0.09	0.10	14.71	0.00	**15.10**
Water body	0.00	0.00	0.00	0.00	0.00	0.00	15.32	**15.32**
Total 2025	**3.40**	**12.35**	**2.36**	**54.81**	**7.90**	**15.59**	**17.45**	**113.85**

Table 5. Details of damages reported due to human-wild life conflict

Crops damaged (annual individual cases)	**Cases**	**Crops damaged (annual individual cases)**	**Cases**
Coconut	132	Mango	25
Banana	64	Pepper	24
Rubber	62	Cashew	7
Tubers	60	Chinese potato	3
Paddy	58	Papaya	3
Vegetables	44	Pineapple	2
Jackfruit	36	Turmeric	1
Areca nut	26	Ginger, coffee, cardamom	1
Livestock killed (2015-2024 individual deaths)	**Cases**	**Property damaged (2015-2024)**	**Cases**
Poultry	369	Fence only	114
Dogs	104	Roof only	36
Goats	100	Fence and roof	11
Cows	42	Fence and house wall	5
Buffalow	3	Gate only	2
Human injury and death	**Cases**	House walls only	2
(2015-2024)		Farm shed only	1
Human injury	28	Gate and fence	1
Death	2		

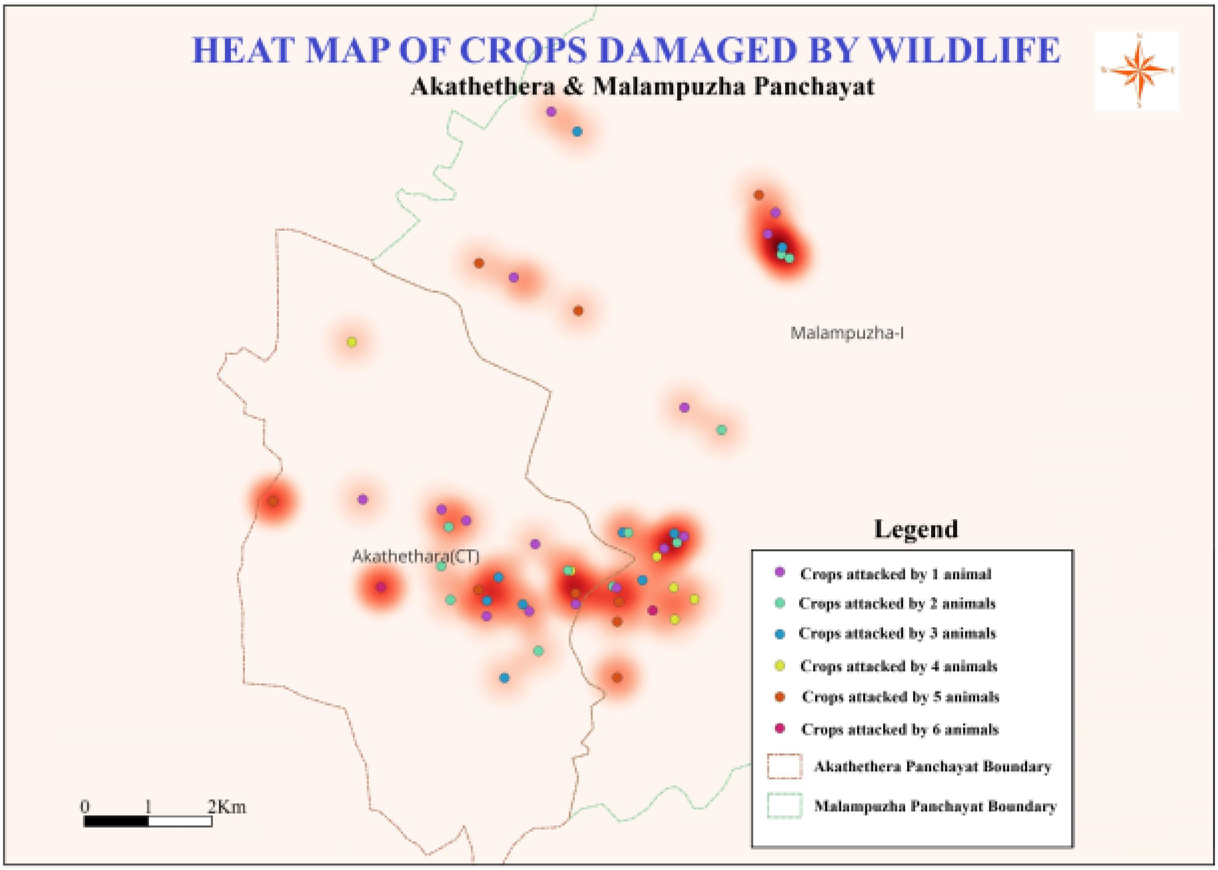

Figure 6. Heat map of crops damaged by wildlife

Figure 7. An elephant damaged the wall of the banana plantation

dogs, while mongooses primarily prey on poultry. Foxes, pythons, and wild cats also target poultry. Leopards, tigers, and wolves focus their attacks on guard dogs. Regarding the timing of these incidents, 17.7% (n=23) of the 130 households surveyed have reported experiencing daytime attacks, whereas a significant 69.2% (n=90) encountered attacks during the evening or night time, and 13.1% (n=17) of households experienced both day and night attacks. Regarding seasonality, 18.5% (n=24) of households reported that attacks primarily occurred in the summer, while 81.5% (n=106) noted that attacks happened throughout the year and were generally unpredictable.

Property damage

Among the 371 surveyed households, 46.36% (n=172) reported property damage caused by wildlife between 2015 and 2024 (Fig. 11). Within this group, 0.58% (n=1) experienced damage to their farm shed (Fig. 12). The majority, 66.28% (n=114), reported damage solely to fences, while 2.91% (n=5) faced damage to both their fences and house walls, and 6.4% (n=11) encountered damage to their fences and roofs. Furthermore, 1.16% (n=2) of households reported damage to their gates, while another 1.16% (n=2) experienced damage only to house walls. An

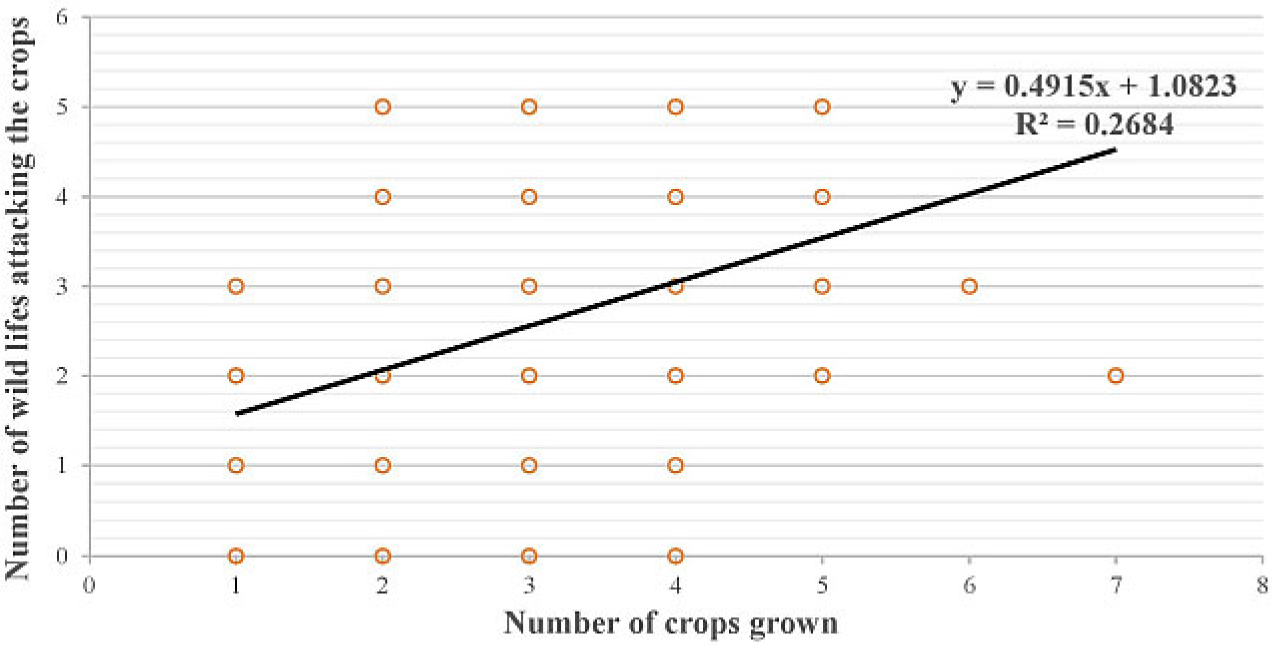

Figure 8. Correlation between the number of crops grown and the number of wildlife attacking the crops

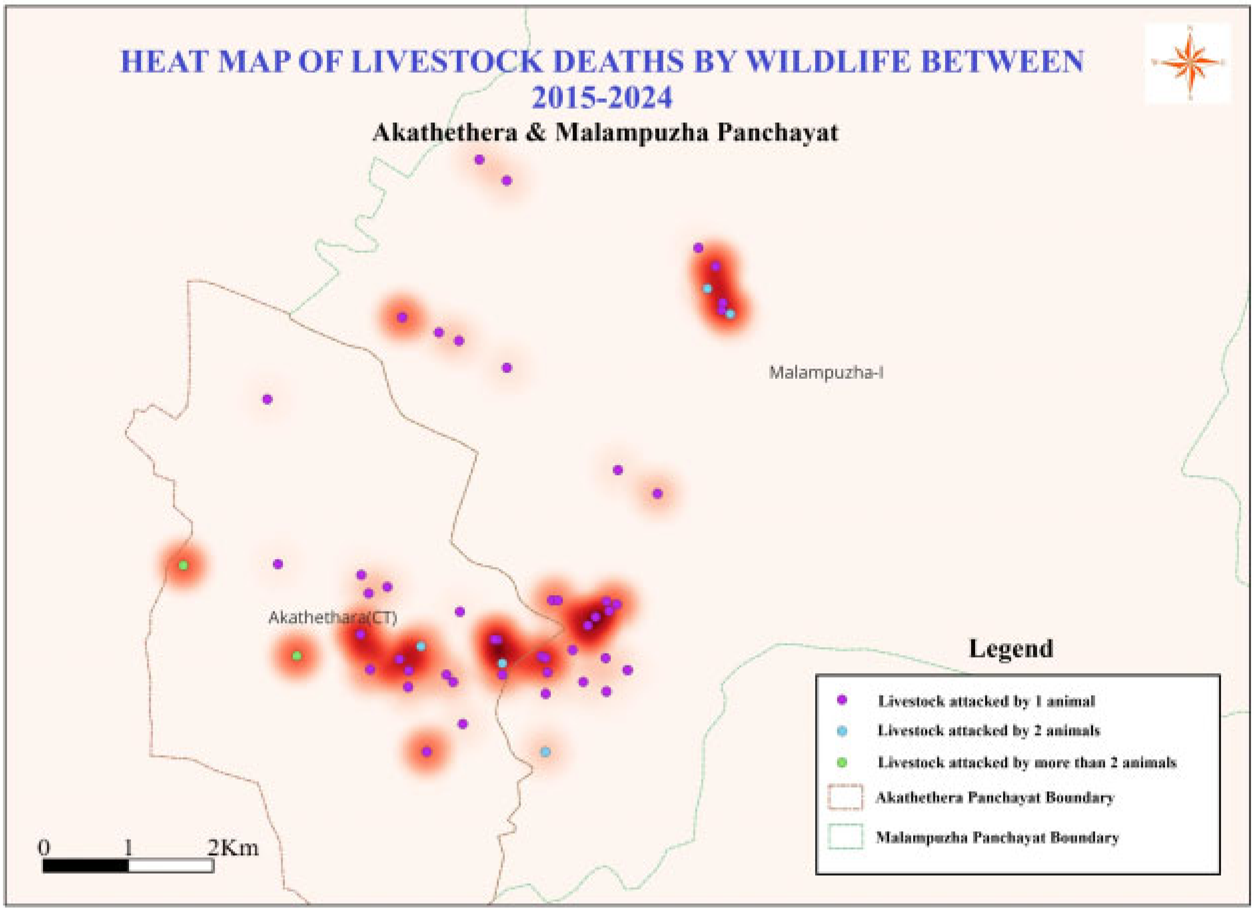

Figure 9. Heat map of livestock deaths by wildlife between 2015 and 2024

Figure 10. Milch animal death caused by wildlife attack

additional 0.58% (n=1) reported combined damage to their gates and fences, and 20.93% (n=36) experienced damage exclusively to their roofs. Of the surveyed households, 83.14% (n=143) witnessed attacks from at least one type of wildlife, with 14.53% (n=25) experiencing attacks from at least two species and 2.33% (n=4) from three or more. Notably, among the 172 households affected, 31.98% (n=55) reported being attacked exclusively by elephants (Table 7, Fig. 12), while 31.40% (n=54) experienced attacks from wild boars, and 18.60% (n=32) reported only monkey attacks. Additionally, 6.98% (n=12) experienced attacks from both elephants and wild boars, while 6.40% (n=11) faced combined attacks from wild boars and monkeys, among others (Table 7, Fig. 13).Elephants and wild boars are known to damage the fences of residences, but only elephants inflict damage on house walls. Monkeys and peacocks are primarily responsible for damaging roofs. A significant majority, 90.1% (n=155) of households, perceive property damage as unpredictable, while

Table 6. Details of predators responsible for livestock deaths

Predator/s	No. of households reporting attacks
Leopard only	71
Mongoose only	15
Mongoose and fox	5
Leopard and mongoose	4
Mongoose, fox and wild cat	4
Mongoose and wild cat	4
Wild cat only	4
Snake only	3
Leopard, mongoose and fox	3
Tiger only	3
Wolf only	2
Fox only	2
Mongoose and vulture	2
Unknown animal	2
Mongoose and wild dog	1
Mongoose and snake	1
Mongoose, fox ,wild dog, wild cat	1
Leopard and tiger	1
Fox and wildcat	1
Elephant only	1

9.9% (n=17) have experienced seasonal attacks, particularly during the summer. In terms of timing, 18.02% (n=31) of households reported wildlife attacks primarily occurring during the day, 73.26% (n=126) experienced assaults at night, and only 8.72% (n=15) faced attacks during both day and night. Monkeys and peacocks typically cause damage to dwellings in daylight, whereas elephants and wild boars are more active at night. The prevalence of property damage is extensive in the study area (Fig. 14).

Human injury and deaths

Injuries sustained by individuals in the study areas have unfortunately resulted in fatalities. The field survey indicated that injuries occur while collecting forest products, working in various plantations, travelling, or during attacks at their homes. Out of the surveyed households (n=371), 7.27% (n=27) collect forest products. Seven individuals from different households have encountered attacks while visiting the forest. Specifically, honeybee attacks affected two households, while two others experienced snake bites and another two faced attacks from elephants. Additionally, 1 respondent's livestock was killed due to a leopard attack between 2015 and 2024. Those grazing livestock in the forest have faced attack on themselves and on their animals. These wildlife conflicts occurred during daytime hours and were described as unpredictable and not seasonal. Furthermore, within the surveyed households, 6.199% (n=23) sustained injuries within their villages from 2015 to 2024, leading to the tragic loss of lives for members of two households (Fig. 15). From the 23 households affected, seven members were injured in encounters with elephants, including three incidents involving the notorious PTF elephant known for attacking humans, which resulted in 2 fatalities. Additionally, two households reported experiencing honeybee attacks in the summer, while seven households faced snake bites near their residences, predominantly during the monsoon season. Lastly, seven households encountered wild boar attacks while travelling by motorcycle in the village at night.

Table 7. Details of wildlife responsible for property damage

Type of attack	No. of households reporting attacks	%
Elephant only	55	31.98
Wild boar only	54	31.40
Monkey only	32	18.60
Peacock only	1	0.58
Leopard only	1	0.58
Elephant and leopard	1	0.58
Wild boar and monkey	11	6.40
Elephant and wild boar	12	6.98
Monkey and peacock	1	0.58
Elephant and monkey	1	0.58
Elephant, wild boar and monkey	2	1.16
Elephant, wild boar, squirrel and monkey	1	0.58

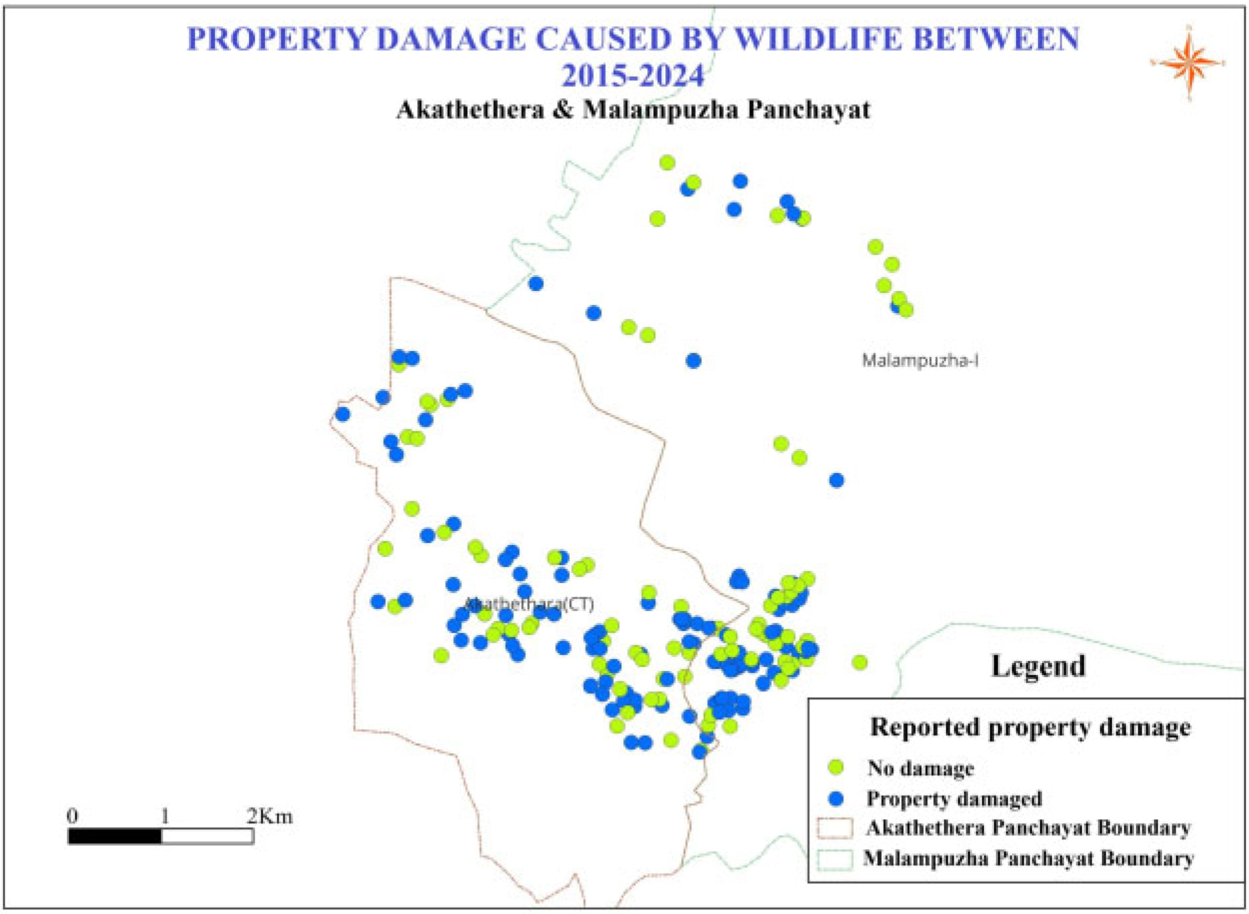

Figure 11. Property damage caused by wildlife between 2015 and 2024

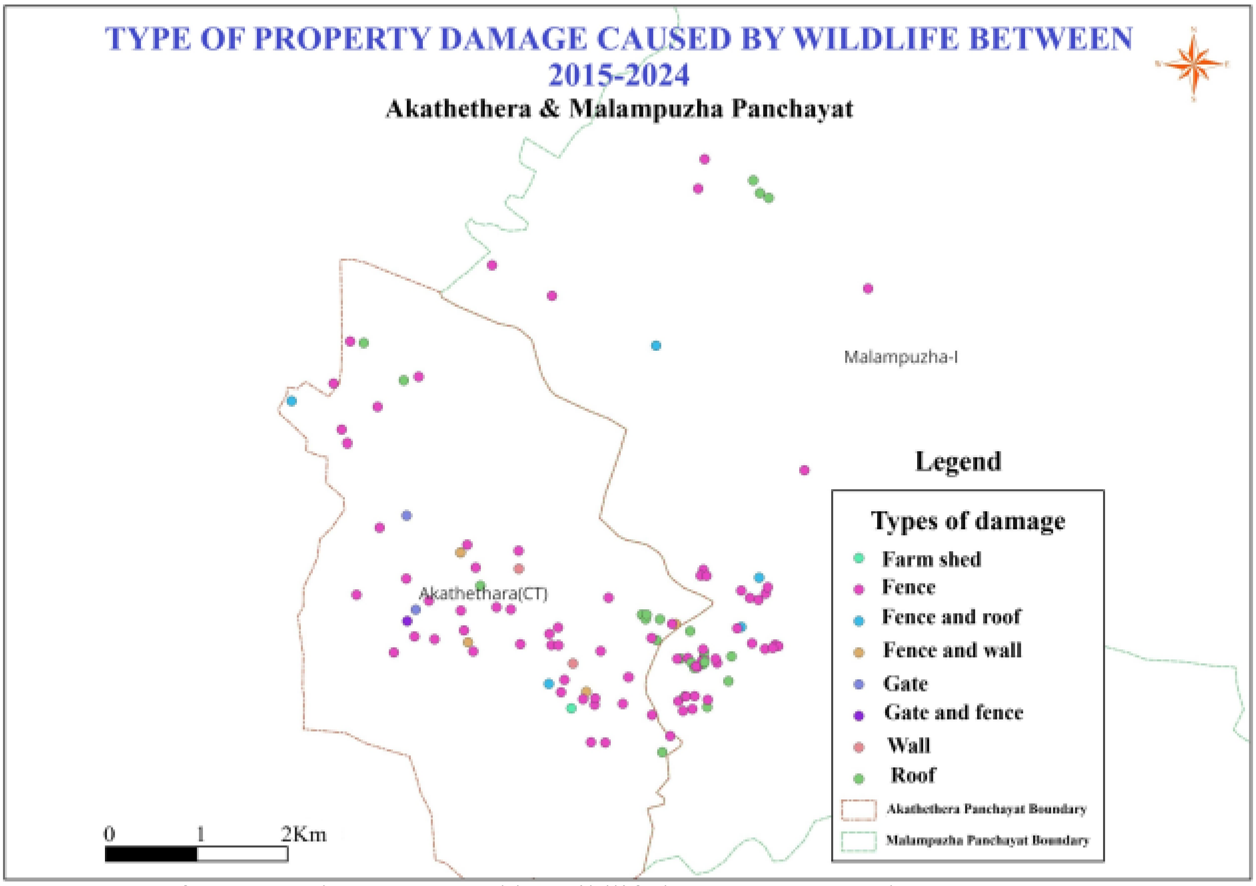

Figure 12. Type of property damage caused by wildlife between 2015 and 2024

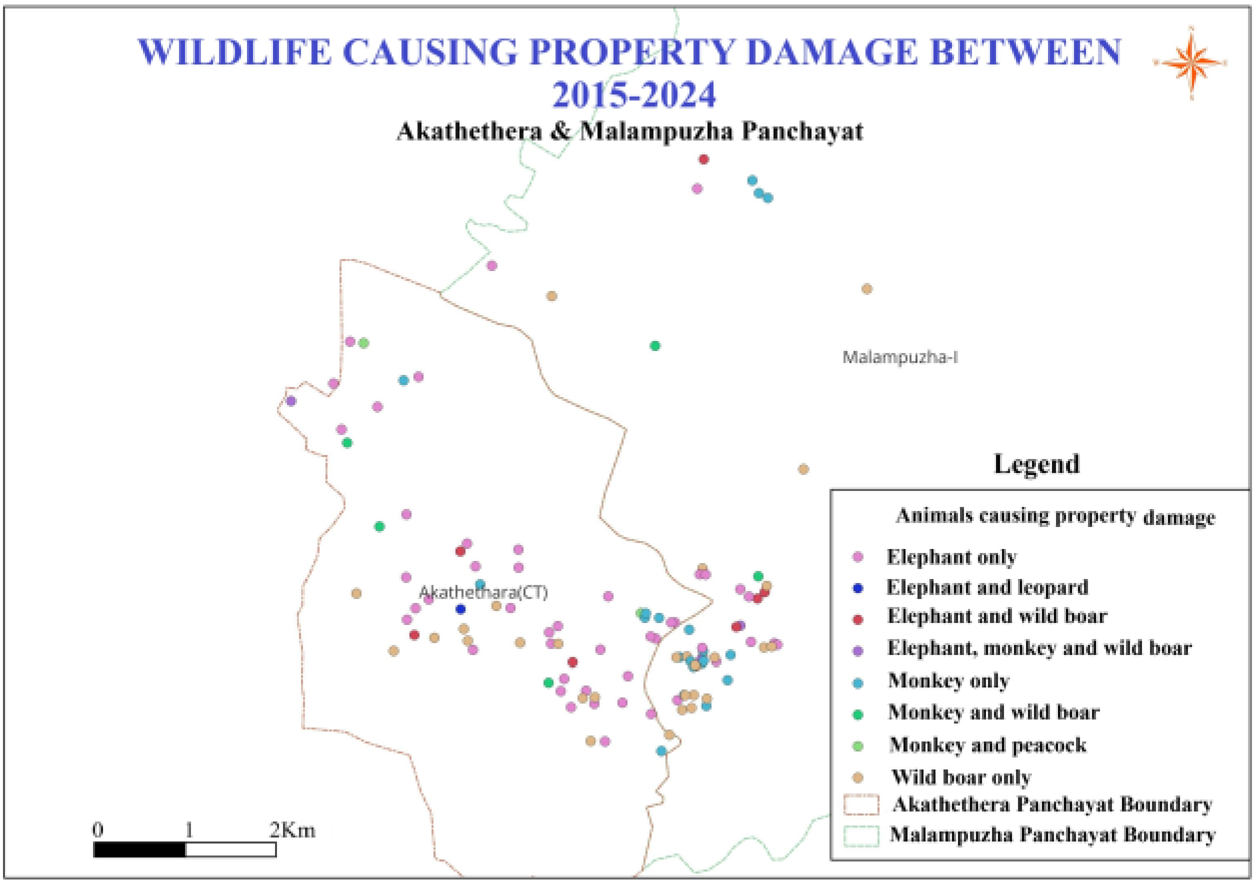

Figure 13. Wildlife causing property damage between 2015 and 2024

Figure 14. (a) Roof damage, (b) Fence damage, (c) Gate damage

Economic losses, compensation and grievances

Making sounds, using firecrackers and airguns, and clanging utensils together are among the most effective methods for deterring wildlife. Since animals often use night time cover to raid human dwellings, bright flashing lights can also be highly effective. Many households rely on guard dogs for protection against wildlife. However, in the event of predatory attacks, residents feel their options are limited to using guard dogs and contacting the Forest Department for assistance. Additionally, some households employ fire and smoke to drive wildlife away. According to certain residents, attacks can sometimes escalate to violence, making prevention methods ineffective. In these instances, household members seek shelter and attempt to protect themselves. When attacks result in significant losses, the Forest Department is called to evaluate the damages. Out of 27 households reporting injuries and fatalities, 17 experienced economic losses, primarily due to bodily injury and vehicle damage. Four households did not calculate their economic losses despite suffering injuries, while two did not incur medical expenses but faced funeral costs due to fatalities (funeral costs unknown). The remaining four households reported no economic losses. On average, the 17 households that did incur losses faced an economic impact of IRS 8,911.76 per wildlife attack. Among the 27 household members who suffered physical injuries, only 11 households (40.74%) filed claims for compensation with the authorities. Of these, only three households (18.18%), which included two that experienced fatalities and one with significant disabilities, received compensation (IRS 200000 for major disability, IRS 500000, and IRS 100000 for the deaths).

Of the 199 households that reported annual crop damage, only 42.71% (n=85) assessed their annual economic losses, while the remainder did not. The

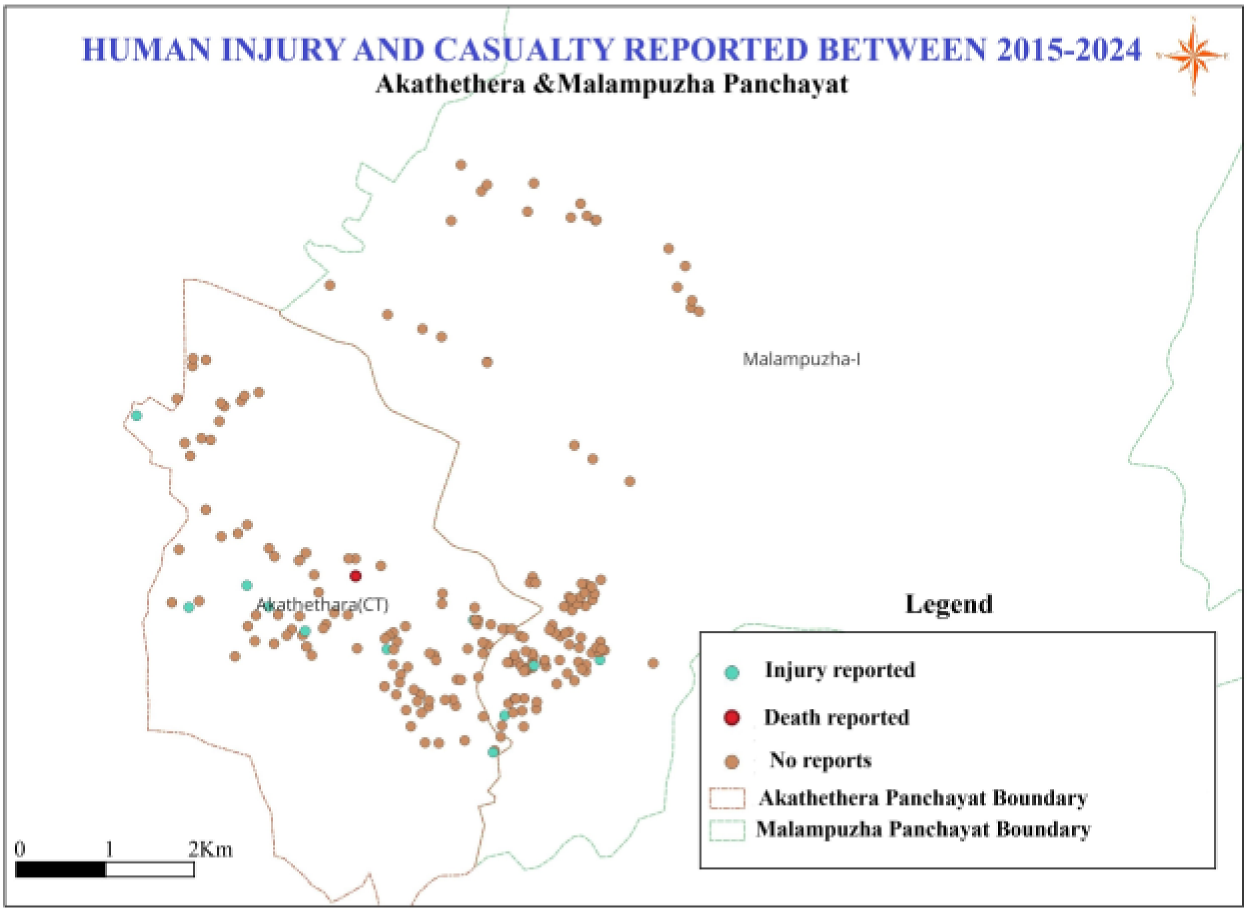

Figure 15. Human injury and death caused by wildlife between 2015 and 2024 Note: Location of only one death incident was recorded

average economic loss attributed to crop damage was reportedly IRS 58550.59. Among these households, only 53 submitted reports of their crop damage to the authorities for compensation, and just three received compensation of 75.22% less than their actual claims. All households expressed dissatisfaction with the compensation received. The loss resulting from the death of a milch animal, a goat, and poultry was valued at IRS 50000-55000, 10000, and 500, respectively. Notably, the losses from guard dog fatalities are unfortunately not acknowledged as economic losses. Between 2015 and 2024, 73.07% (n=95 out of 130 households reporting livestock kills) calculated their economic losses due to predation, while 8.46% (n=11) did not. The remaining 18.47% (n=24) of reported losses are unaccounted for, as they are due to guard dog deaths. The average loss experienced by each household from livestock deaths during this period was approximately Rupees 36,168.42. Of the households that calculated their losses, only 54.73% (n=52 out of 95) reported these losses to authorities for compensation. Among those, merely 30.188% (n=16) received compensation, which was, on average, 62.80% below their actual claims. From 2015 to 2024, 172 surveyed households experienced property damage, with only 25% (n=43) quantifying their economic losses, leaving the rest 128 unaccounted for. The average loss per household due to property damage during this time frame was IRS 26,546.51. Only 44.18% of those affected applied for compensation, and a mere one household (5.26%) received assistance through the Government's fence rebuilding initiative.

Significant reasons for the lack of reporting include the ineligibility for compensation (where minor injuries, snake bite incidents, poultry deaths, and minor property damages are not eligible), the time-consuming or cumbersome filing process, and delays in receiving compensation. Respondents experiencing annual losses of up to IRS 500000 chose not to report these losses due to one or a combination of the aforementioned reasons.

Human-wildlife conflict probability mapping

The study utilised spatial analysis to create a conflict probability map by integrating factors such as settlement density (Fig. 16), proximity to historical conflict locations (Fig. 17), and surface resistance derived from Land Use and Land Cover (LULC) data (Fig. 18). A weighted overlay analysis was then conducted to produce the final conflict probability map. The map categorises HWC probability zones into very high, high, medium, low, and very low, represented by dark green, light green, dark yellow, brown, and purple, respectively (Fig. 19). Areas of very high HWC probability are found in regions with high human inhabitation and significant livestock kills near the Malampuzha dam. In contrast, the regions to the north of the dam fall within the low to moderate conflict probability zones, as habitation is minimal and human-wildlife conflict arises primarily from livestock grazing and plantation activities. The southern part of the dam is characterised by highlands, which are largely devoid of human activities, thus exhibiting a low conflict probability. Conversely, the areas with high and very high HWC probability are located in the extreme south of the Malampuzha dam, where human habitation and livestock housing are most concentrated. These high-probability areas also overlap with regions experiencing the most significant LULC changes. All these findings corroborate the results obtained from fieldwork and questionnaire surveys, further validating the HWC probability map.

DISCUSSION

The region primarily comprises low-income households that supplement their income through livestock rearing. Findings indicate that 19.9% of respondents are illiterate, only 38% have completed high school, and the average annual income is a modest IRS 91142.85. Consequently, the economic repercussions from crop damage, livestock losses, property damage, injuries, and fatalities significantly impact these households. Wildlife attacks have surged since 2015, particularly following the COVID-19 pandemic of 2020-21, with incidents involving elephants, wild boars, and leopards being the most prevalent. The fragmentation of natural habitats and the encroachment on wildlife migration routes (Anonymous 2022d) are observed. The decline of forested areas between 2013 and 2025, alongside the conversion of mixed tree cover into built-up environments and plantations, suggests a reduction

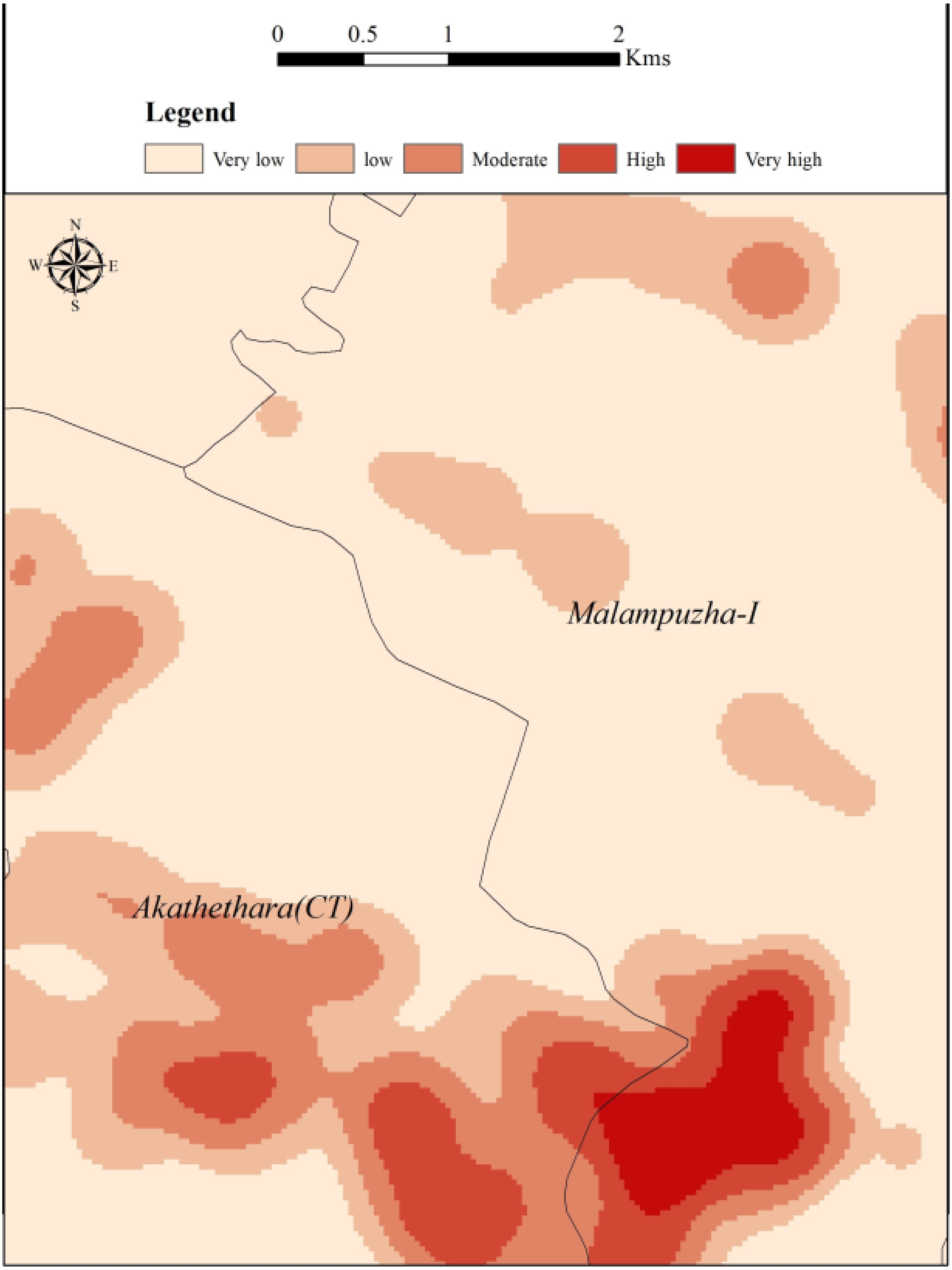

Figure 16. Settlement index map

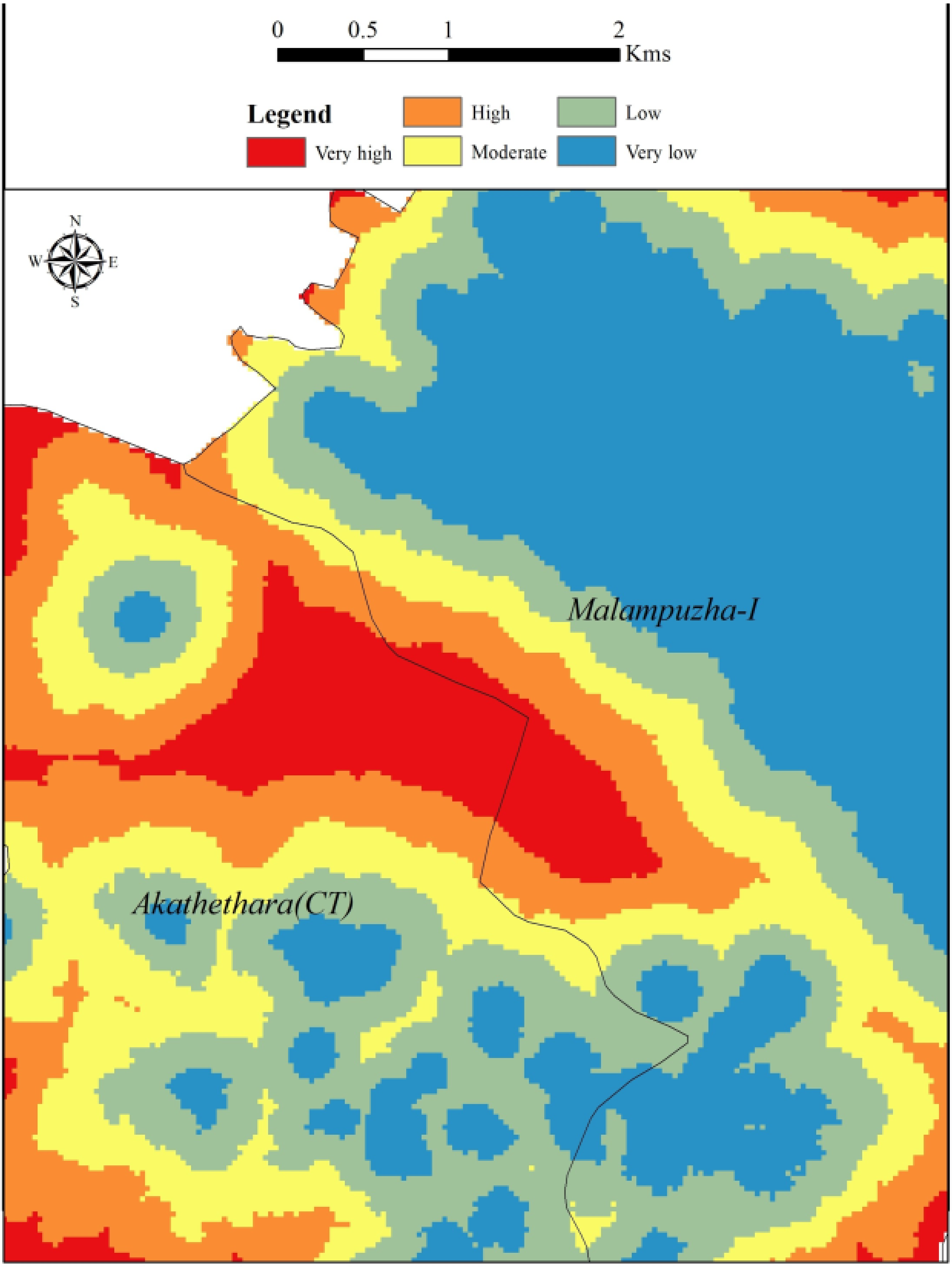

Figure 17. Proximity to conflict location map

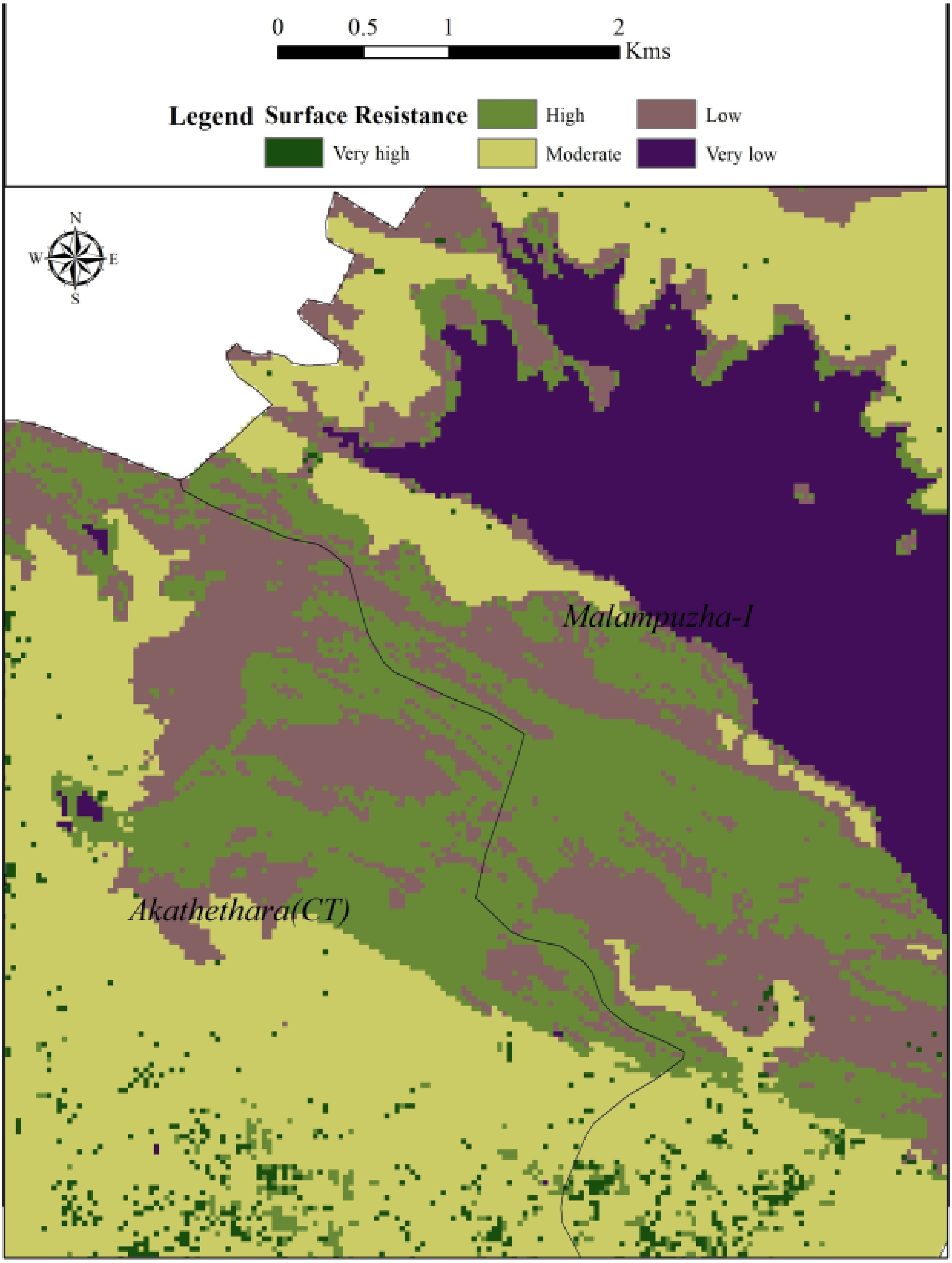

Figure 18. Surface Resistance Map

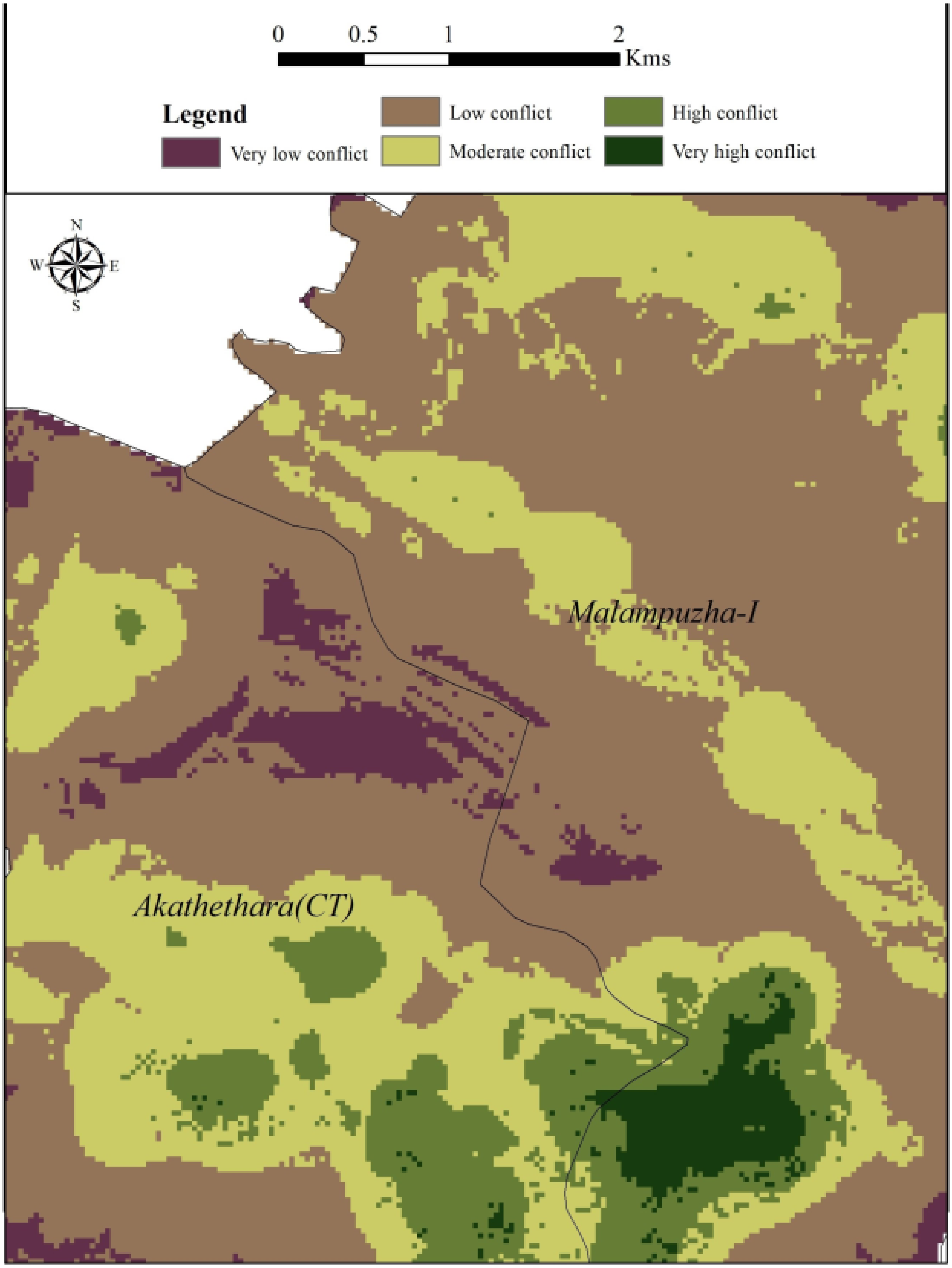

Figure 19. Human-wildlife conflict probability

in wildlife habitats. The easy availability of food sources, such as bananas, jackfruit, and coconut plantations, creates artificial food sources (Griffin and Ciuti 2023) and water sources in/around the villages attract wildlife. Since the population is concentrated in the southern part of the study area, sedentary agriculture is practised, leading to the highest incidences of crop raids in this region. Additionally, livestock with limited escape routes in the villages make them easy targets for older or inexperienced predators (Anonymous 2022d), who might not survive under normal circumstances. This situation poses risks, as livestock are often kept close to homes. Food availability for weaker predators helps sustain and increase their populations, resulting in increased livestock attacks and human fatalities. Climate change and human activities such as livestock grazing, plantations, and illegal activities, limit food options and drive herbivores and pollinator species toward human settlements, attracting predators as forests become devoid of prey. Establishing teak plantations has led to monoculture and marijuana cultivation, further constraining food availability for wildlife. Additionally, the considerable increase in wildlife populations, particularly among prolific breeders like wild boars, poses a significant challenge (Anonymous 2022d). Respondents are concerned that the Wildlife Protection Act 1972 complicates any efforts to control wildlife populations. Frequent flooding during the monsoon season exacerbates the food scarcity in forests, compelling animals to search for sustenance within human areas. Over the past two to five years, there has been a notable rise in attacks by peacocks and monkeys, highlighting the decline of pollinator species which are critical to the forest ecosystem. Furthermore, the number of human injuries and casualties in Akathethera Panchayat has increased significantly.

The southern portion of the study area experiences a significantly high concentration of property damage, primarily due to elephant attacks. Most households (85.98%) have implemented fencing to mitigate property losses. Research shows that concrete and plant-based fencing (bio-fencing) are the most effective in protecting against wildlife intrusions. However, only 35.60% of agricultural fields and plantations are fenced. Among these, concrete fencing is the most effective, averaging only two animal attacks on agricultural land, while metal fencing ranks second, with an average of three animal attacks on crops. Residents face considerable frustration due to delayed payments and, in some cases, ineligibility for compensation. Only 27.49% of households have reported for compensation claims, including crop damage, livestock losses, property damage, and human injuries or fatalities. Additionally, many residents are unaware of the compensation rates or government schemes available to assist victims of animal attacks.

The mapping of human-wildlife conflict (HWC) probability aligns with the major conflicts reported by respondents, indicating that most land use and land cover (LULC) changes occur in the southern sections of the study area, which are particularly susceptible to conflicts due to agriculture and habitation. To enhance the accuracy of conflict probability mapping, conducting a larger survey of the study area would be beneficial. A more precise delineation of HWC through extensive field surveys could pave the way for practical solutions that relieve residents, fostering a new co-adaptation and peaceful coexistence (Anonymous 2023b).

Due to the growing inconvenience caused by wildlife attacks, there is increasing animosity towards wildlife conservation efforts. Residents have suggested drastic measures, such as culling, poaching, and allowing the free ownership of air guns and other weapons, as ways to prevent these conflicts. Implementing the Gadgil Committee Report is essential to achieve peaceful coexistence between humans and wildlife. The Western Ghats should be designated as an ‘Ecologically Sensitive Area,’ adopting an agroecological zoning approach and a bottom-up decision-making process. Reviving traditional knowledge, such as using Attappady Dolichos beans and bio-fencing with lemon, neem, or chillies around plantations, agricultural fields, or homes, is vital. There is a need for revisions in elephant trench designs and for strengthening and repairing fences around hotspots identified through accurate Human-Wildlife Conflict (HWC) probability mapping. Prioritising curbing illegal activities, unauthorised plantations, and grazing within forested areas is necessary. Additionally, installing bright street lights around residential areas and selectively castrating prolific breeders should be undertaken. Protecting migratory routes and conserving forests will help ensure ample food and water sources for wildlife. It is also important to implement AI-assisted early warning systems with automatic sirens at a considerable distance from villages and develop movement prediction models. Establishing a buffer (zone devoid of vegetation around each village and enforcing strict land-use regulations are critical steps. Involving NGOs and self-help groups in producing and distributing dung cakes with chillies and capacity-building programs that educate residents on accessing government portals and applying for eligible schemes should be prioritised. Promoting livestock insurance, such as the Livestock Insurance Scheme, and crop insurance, like the Pradhan Mantri Fasal Beema Yojana, needs to be strengthened. Prompt compensation with revised rates should be provided for losses.

CONCLUSIONS

The Human-Wildlife Conflict (HWC) in the study area has escalated over the years, with evidence suggesting that such conflicts are often under-reported. Residents face a persistent threat of danger, leading many to abandon livestock farming and consequently jeopardise their livelihoods. Given that the Malampuzha Dam attracts tourists, HWC also poses risks to visitors. The situation has resulted in considerable economic losses and detrimental effects on public health, leaving residents increasingly helpless. Barriers such as ineligibility for compensation in instances of poultry deaths, a cumbersome claims process, and delays in compensation exacerbate the challenges, discouraging victims from reporting incidents or accurately assessing their losses. The HWC in this region stems from a complex interplay of ecological factors, administrative shortcomings, and socio-economic impacts, highlighting the urgent need for coordinated action and collaboration among all key stakeholders.

ACKNOWLEDGEMENTS

We acknowledge Arya R and Sreevisal G (Team SARF) for helping with the maps. We also thank the Panchayat officials of Akathethera and Malampuzha I and all the respondents for their cooperation and help. We thank the respective institutions to which the authors belong for providing research facilities. The conception, design, analysis and interpretation and writing of manuscript were handled by the first author and second author; collection of data (sampling) was handled by the third author and fourth author, use of software and partial preparation of maps were done by the second author and third author. Overall supervision and editing were carried out by the fifth author. This work was supported by the University Grants Commission, India [the first author is the recipient of SJSGC Fellowship, F.No. 82-7/2022(SA-III), ID: UGCES-GE-WES-F-SJSGC-9213.

Authors' contributions: All authors contributed equally.

Conflict of interest: The authors declare no conflict of interest.

REFERENCES

Akpoti, K., Antwi, E.O. and Kabo-bah, A T. 2016. Impacts of rainfall variability, land use and land cover change on stream flow of the Black Volta Basin, West Africa. Hydrology, 3, 1-24. https://doi.org/10.3390/hydrology 3030026

Albarracín, V. and Aliaga-Rossel, E. 2018. Bearly Guilty: Understanding Human–Andean Bear Conflict Regarding Crop Losses. Ethnobiology Letters, 9, 323-332. https://doi.org/10.14237/ebl.9.2.2018.1300

Anonymous. 2009. India's Fourth National Report to the Convention on Biological Diversity. Ministry of Environment and Forests, Government of India, New Delhi.

Anonymous. 2011. District Census Handbook, Palakkad District, Census of India, Government of India. 270 pages.

Anonymous. 2021. Human-Wildlife Conflict. UNDRR. https://www.undrr.org/understanding-disaster-risk/terminology/hips/bi0007 (accessed on 2.2.2025)

Anonymous. 2022a. Crime in India, 2022. NCRB, Ministry of Home Affairs, Government of India, New Delhi. 476 pages.

Anonymous. 2022b. India, Naturally! India's Living Biodiversity – A People's Resource. Fourth edition. Ministry of Environment Forest and Climate Change and UNDP, New Delhi. 103 pages.

Anonymous. 2022c. Human-wildlife conflict. IUCN, Gland, Switzerland. https://iucn.org/resources/issues-brief/human-wildlife-conflict#:~:text=Human%2Dwildlife%20 conflicts%20have%20severe,protected%2 0areas%2C%2 0wildlife%20and%20biodiversity (accessed on 30.1.2025)

Anonymous. 2022d. Project Proposal for Management of Human-Wildlife Conflict. Kerala Forest Department, Trivendrum. https://forest.kerala.gov.in/images/Department%20News/2022/proposal.pdf (accessed on 8.1.2025)

Anonymous. 2023a. India's National Plan (Nap) To Combat Desertification and Land Degradation Through Forestry Interventions. Ministry of Environment, Forests and Climate Change, Government of India, New Delhi. 107 pages.

Anonymous. 2023b. About Us. National Wildlife Database Cell. https://wii.gov.in/nwdc_aboutus (accessed on 1.2.2025)

Anonymous. 2023c. IUCN SSC guidelines on human-wildlife conflict and coexistence. First Edition. IUCN, Gland, Switzerland. 216 pages.

Anonymous. 2023d. Human Wildlife Conflict Mitigation. Indo-German Biodiversity Programme. https://indo-germanbiodiversity.com/projects-human+wildlife+conflict+mitigation.html (accessed on 2.2.2025)

Anonymous. 2024a. Compensation for Wild Animals Attacks. Press Information Bureau (PIB), New Delhi. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2002607 (accessed on 1.2.2025)

Anonymous. 2024b. Global Nature Conservation Index. Press Information Bureau (PIB), New Delhi. https://pib.gov.in/PressReleseDetailm.aspx?PRID=2078360andreg=3andlang=1 (Accessed on 1.2.2025)

Anonymous. 2025a. What is human-wildlife conflict and why is it more than just a conservation concern? WWF. https://www.worldwildlife.org/stories/what-is-human-wildlife-conflict-and-why-is-it-more-than-just-a-conservation-concern (accessed on 1.2.2025)

Anonymous. 2025b. Spotlight. The Hindu www.thehindu.com (accessed on 21.2.2025).

Anonymous. 2025c. Palakkad District Population Data. Department of Panchayats. https://dop.lsgkerala.gov.in/en/nod/1052 (accessed on 29.5.2024)

Balasubramanian, A. 2017. Biodiversity Profile of India. Mysore, Karnataka, India. http://dx.doi.org/10.13140/RG.2.2.10664.57601

Barua, M., Bhagwat, S. A. and Jadav, S. 2013. The hidden dimensions of human–wildlife conflict: Health impacts, opportunity and transaction costs. Biological Conservation, 157, 309-316. https://doi.org/10.1016/j.biocon.2012.07.014

Billah, M. M., Rahman, M. M., Abedin, J. and Akter, H. 2021. Land cover change and its impact on human–elephant conflict: A case from Fashiakhali forest reserve in Bangladesh. SN Applied Science, 3, 1-18. https://doi.org/10.1007/s42452-021-04625-1

Blondel, A. 2012. Climate Change Fuelling Resource-Based Conflicts in the Asia-Pacific. Asia-Pacific Human Development Report Background Papers Series 2012/12, UNDP. 96 pages. https://www.undp.org/sites/g/files/zskgke326/files/migration/asia_pacific_rbap/RBAP-HDR-2012-APHDR-TBP-12.pdf

Cochran, W.G. 1977. Sampling Techniques (3rd ed.). John Wiley and Sons, New York. 448 pages.

Coogan, S.C., Alders, R., Kock, R., Raubenheimer, D. and Mor, S.M. 2019. A clash of appetites: food-related dimensions of human–animal conflict. Pp. 259-288. In: Walton, M. (Ed.), One Planet, One Health. Sydney University Press, Sydney. https://open.sydneyuniversitypress.com.au/files/9781743325384.pdf

El-Hattab, M.M. 2016. Applying post classification change detection technique to monitor an Egyptian coastal zone. The Egyptian Journal of Remote Sensing and Space Sciences, 19, 23-36. http://dx.doi.org/10.1016/j.ejrs.2016.02.002

Ghosh, S. 2019. With increasing human encroachment, wild animals have nowhere to go. https://www.newslaundry.com/2019/02/07/with-increasing-human-encroachment-wild-animals-have-nowhere-to-go (accessed on 30.1.2025)

Griffin, L. and Ciuti, S. 2023. Should we feed wildlife? A call for further research into this recreational activity. Conservation Science and Practice, 5, e12958. https://doi.org/10.1111/csp2.12958

Kattan, G., Hernández, O. L., Goldstein, I., Rojas, V., Murillo, O., Gómez, C., Restrepo, H. and Cuesta, F. 2004. Range fragmentation of the spectacled bear *Tremarctos ornatus* in the northern Andes. Oryx, 38, 1-10. https://doi.org/10.1017/S0030605304000298

König, H.J., Kiffner, C., Kramer-Schadt, S., Fürst, C., Keuling, O. and Ford, A.T. 2020. Human–wildlife coexistence in a changing world. Conservation Biology, 34, 786-794. https://doi.org/10.1111/cobi.13513

Mahanti, P. and Kumar, S. 2018. Human wildlife conflict: A case study in Kerala. Journal of Biodiversity and Conservation, 1, 1-12. https://aprfjournal.in/PDF/2018/vol-1_issue-2/Human-Wildlife-Conflict-A-Case-Study-in-Kerala-India-India.pdf

Mekonen, S. 2020. Coexistence between human and wildlife: the nature, causes and mitigations of human wildlife conflict around Bale Mountains National. BMC Ecology, 20, 1-9. https://doi.org/10.1186/s12898-020-00319-1

Mmbaga, N.E., Munishi, L.K. and Treydte, A.C. 2017. How dynamics and drivers of land use/land cover change impact elephant conservation and agricultural livelihood development in Rombo, Tanzania. Journal of Land Use Science, 12, 168-181. https://doi.org/10.1080/1747423X.2017.1313324

Mulonga, S., Suich, H. and Murphy, C. 2003. The conflict continues: Human wildlife conflict and livelihoods in Caprivi. DEA Research Discussion Paper, 1-33, Ministry of Environment, Forestry and Tourism, Government of Namibia, Windhoek, Namibia.

Nad, C., Roy, R. and Roy, T. B. 2022. Human elephant conflict in changing land-use land-cover scenario in and adjoining region of Buxa tiger reserve, India. Environmental Challenges, 7, 1-11. https://doi.org/10.1016/j.envc.2021.100384

Nandi, S. 2024. Understanding Human-Wildlife Conflict in India. WildlifeSOS, New Delhi. https://wildlifesos.org/

understanding-human-wildlife-conflict-in-india/#:~:text=This%20population%20density%20is%20putting,%2C%20livelihoods%2C%20and%20even%20life (accessed on 1.2.2025)

Ogra, M. and Badola, R. 2008. Compensating human-wildlife conflict in protected area communities: Ground-level perspectives from Uttarakhand, India. Human Ecology, 36, 717-729. https://doi.org/10.1007/s10745-008-9189-y

Pandey, A., Oberoi, A., Sharma, A. and Bhardawaj, A. 2017. Analysis of human–wildlife conflict management. Engineering Sciences International Research Journal, 5, 63-65.

Philip, S. 2024. Kerala declares man-animal conflict a state-specific disaster: What changes with this? Indian Express. https://indianexpress.com/article/explained/kerala-man-animal-conflict-state-specific-disaster-explained-9201527 (accessed on 7.1.25)

Pooley, S., Bhatia, S. and Vasava, A. 2021. Rethinking the study of human–wildlife coexistence. Conservation Biology, 35, 784-793. https://doi.org/10.1111/cobi.13653

Sharma, P., Chettri, N. and Wangchuk, K. 2021. Human-wildlife conflict in the roof of the world: Understanding multidimensional perspectives through a systematic review. Ecology and Evolution, 11, 11569-11586. https://doi.org/10.1002/ece3.7980

Shivakumar, B.R. and Rajashekararadhy, S.V. 2019. Spatiotemporal variability in spate irrigation systems in Khirthar National Range, Sindh, Pakistan (case study). Acta Geophysica, 1-11. https://doi.org/10.1007/s11600-019-00392-1

Sikdar, C. and Mukhopadhyay, K. 2016. Impact of population on carbon emission: Lessons from India. Asia-Pacific Development Journal, 23, 105-132. https://unescap.org/sites/default/files/chapter%205.pdf

Sivaram, M., Jayson, E.A. and Ramachandran, K.K. 2013. Population Estimation of Major Mammals in the forests of Kerala - 2011. Kerala Forests and Wildlife Department, Kerala Forest Research Institute, Periyar Tiger Conservation Foundation and World Wide Fund for Nature–India. Thiruvananthapuram. 120 pages.

Received: 28th February 2025
Accepted: 29th May 2025