भारतीय वन्यजीव संस्थान
Wildlife Institute of India

HUMAN ELEPHANT CONFLICT IN THE STATE OF KERALAM

INDIA (2008 - 2025)

TRENDS, CHALLENGES & INSIGHTS

Final Project Report
TR-0044-2026

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Citation: Bilal Habib, Anukul Nath, Athira N. G., Anshuman Gogoi, Mukesh Chand, Kalpana Roy, Aju Mathew George, Vaibhav C. Mathur, Parag Nigam, Gobind Sagar Bhardwaj, Ramesh Kumar Pandey (2026): Human-elephant conflict in the State of Keralam, India (2008 - 2025): Trends, Challenges and Insights. Wildlife Institute of India & Project Elephant Division, Ministry of Environment, Forest and Climate Change, Government of India. Pp. 84. TR-0044-2026.

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Acknowledgements

We express our sincere gratitude to the Project Elephant Division of the Ministry of Environment, Forest and Climate Change (MoEFCC) for their financial assistance and necessary approvals for this study. Our heartfelt thanks go to the Principal Chief Conservator of Forests (PCCF) and Chief Wildlife Warden, Government of Keralam, for granting the permits essential to our work. We are also indebted to the staff of the Keralam Forest Department for providing access to their official records, which were invaluable to our research.

Additionally, we appreciate the support from the staff of the Project Elephant Division at MoEFCC and the Elephant Cell at the Wildlife Institute of India. Lastly, we extend our thanks to the Director, Dean, and Registrar of the Wildlife Institute of India for their unwavering support throughout this research endeavour.

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Photo: Maitreyee Bhave

EXECUTIVE SUMMARY

Human-elephant conflict (HEC) in Keralam has emerged as a major conservation and management challenge, resulting in substantial losses of both human and elephant lives. Rapid land-use changes, habitat fragmentation, expanding agriculture and plantations, and the development of roads, railways, and other infrastructure have intensified interactions between humans and elephants, increasing the frequency of conflict. This report examines the spatial and temporal patterns of elephant mortality and human-elephant conflict in Keralam during 2008-2025, identifies major conflict hotspots and the factors driving conflict, and proposes evidence-based mitigation strategies to promote long-term coexistence between people and elephants. To assess conflict patterns, the study integrates spatial analysis, field observations, and ecological assessments using forest department records, field surveys, and geospatial datasets. Relationships between landscape characteristics, anthropogenic factors, elephant mortality, and human casualties were evaluated to identify priority areas for conservation and conflict mitigation.

The Landscape in Numbers

2,785
Wild Elephants (SAIEE-2025)

18 YEARS
Study Duration (2008–2025)

36 *Forest Divisions Covered*

TOTAL AREA
38,863 KM²

Priority Areas and Management Implications

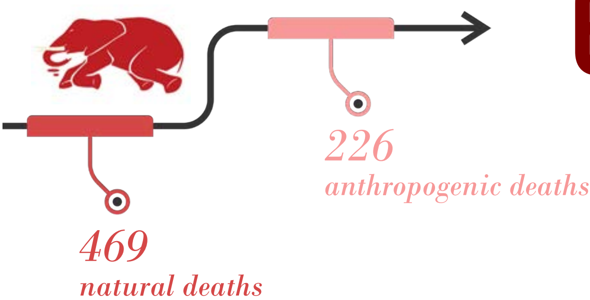
Elephant mortality and human casualties were concentrated in a limited number of landscapes, particularly Nilambur, Mannarkkad, Munnar & Palakkad. These areas should receive priority attention.

The principals recommended actions are:

1. Strengthen barrier infrastructure through scientific placement, maintenance, and GIS-based monitoring.
2. Reduce electrocution by removing illegal fencing, improving power infrastructure, and promoting safe solar fencing.
3. Prevent train collisions using AI/DAS detection systems and wildlife crossing structures.
4. Enhance early warning systems through GPS tracking, AI surveillance, and community alert networks.
5. Strengthen Rapid Response Teams (RRTs) for timely response and conflict management.
6. Restore elephant habitats by improving forests, water sources, and ecological corridors.
7. Protect elephant corridors and maintain landscape connectivity through coordinated land-use planning.
8. Expand long-term monitoring of elephant movements to support evidence-based management.
9. Strengthen community participation through awareness, timely compensation, and improved crop protection measures.

Reducing conflict in Keralam requires coordinated action and targeted interventions in hotspot landscapes to improve human safety and reduce elephant deaths.

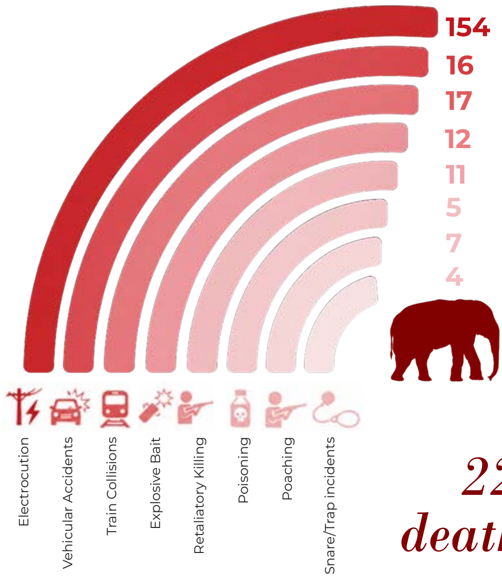
Elephant
MORTALITIES



695

Anthropogenic
DEATHS

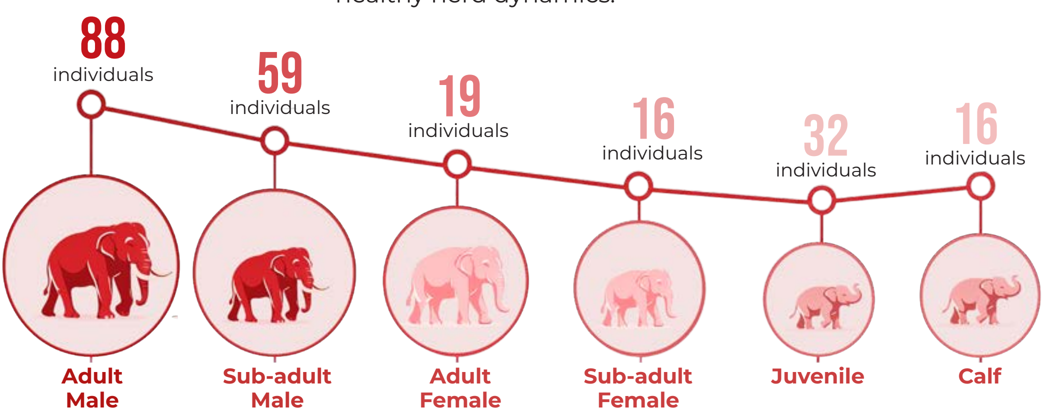
Over the past 18 years, 695 elephants have died in Keralam, with 226 deaths attributed to various anthropogenic activities and 469 resulting from natural causes.



226 deaths

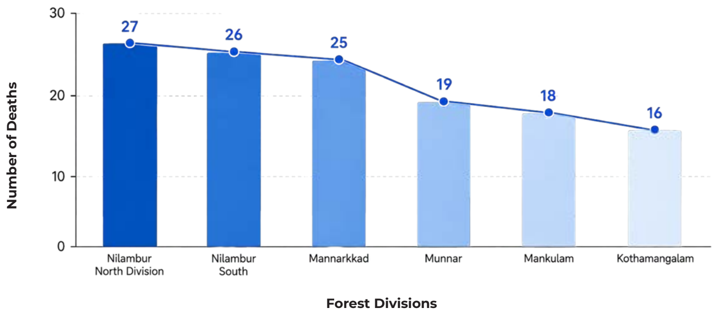
Age-Class
DEMOGRAPHY

Adult males, the ecological keystones of elephant populations, are the most affected by anthropogenic mortality factors, particularly electrocution and vehicular accident. This can threaten the long-term stability of elephant populations in the area, as males play a crucial role in social structures, gene flow, and maintaining healthy herd dynamics.



Spatial Distribution of
ANTHROPOGENIC ELEPHANT MORTALITY

These divisions were also identified as major elephant-mortality hotspots.



These regions experience high levels of HEC, highlighting the need for targeted mitigation strategies.

Human-elephant conflict affected 214 villages, with Ranni being the most impacted, recording incidents of 169 cases. Munnar Division followed with 144 cases, while Munnar Wildlife and Nilambur North each reported conflicts in 138 and 108 cases respectively.

Human Fatalities
AND INJURIES

581
Human fatalities

1,200
Human injuries

Seasonal analysis revealed that the monsoon season accounted for the highest number of conflict incidents, followed by the post-monsoon, pre-monsoon, and winter seasons. Male victims were significantly more numerous than female victims across all seasons

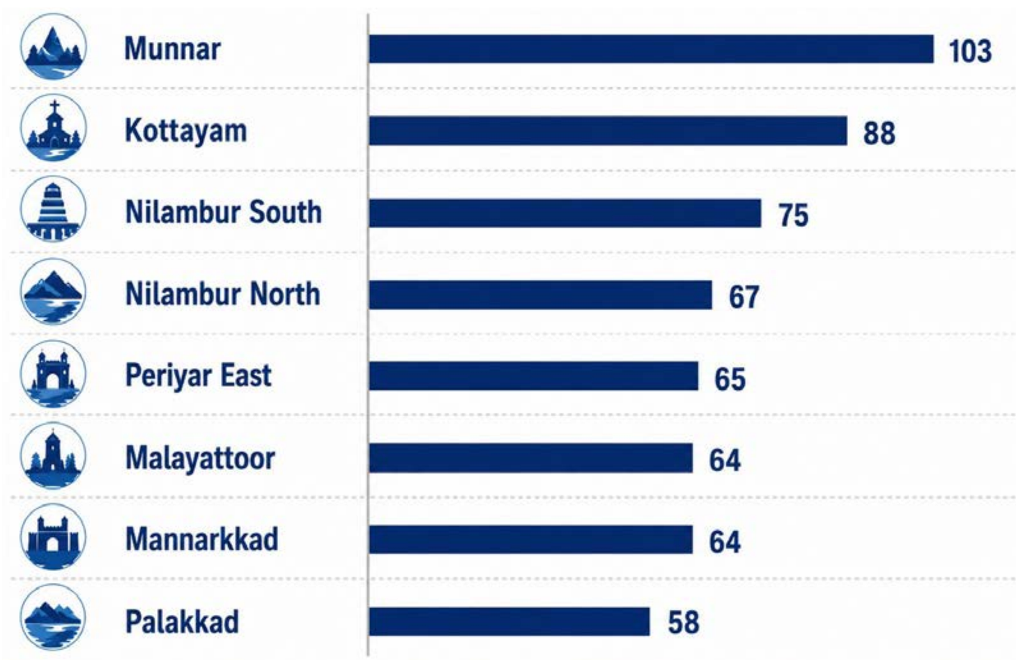


Photo: Jerrin Tomy

INTRODUCTION

Human-wildlife conflict (HWC) has become one of the most significant challenges to biodiversity conservation, driven by the increasing spatial overlap between expanding human land use and wildlife habitats in an increasingly human modified world. Globally, land-use change including deforestation, agricultural expansion, infrastructure development, and urbanisation has fragmented natural ecosystems and compressed wildlife into smaller, isolated patches. These processes have intensified interactions between humans and wildlife, often resulting in negative outcomes for both. Among such interactions, human-elephant conflict (HEC) is particularly acute due to the ecological and behavioural characteristics of elephants. As large-bodied, wide-ranging megaherbivores, the Asian elephant requires extensive and heterogeneous habitats to meet its nutritional and social needs. However, habitat loss and fragmentation have increasingly confined elephant populations, forcing them into closer proximity with human settlements. This has led to a range of conflict outcomes, including crop depredation, property damage, and human and elephant mortality (Sukumar, 2003; Fernando et al., 2005). Importantly, these interactions are shaped not only by ecological factors but also by human land-use patterns, livelihoods, and socio-cultural contexts, underscoring the socio-ecological nature of HWC (Desai & Riddle, 2015). Consequently, there is increasing recognition that HEC should not be viewed solely as a conservation problem but as a coexistence challenge requiring context-dependent management strategies tailored to ecological, social and economic settings (Pandey et al., 2026b). In Asia, HEC is especially pronounced because elephants persist in highly modified, multi-use landscapes. The Asian elephant now occupies less than a tenth of its historical range, with fragmented populations distributed across South and Southeast Asia (Fernando et al., 2005). Unlike many African systems, Asian elephants frequently inhabit landscapes interspersed with agriculture, plantations, and dense human settlements, resulting in persistent spatial and temporal overlap with people (Sukumar, 1989; Goswami et al., 2014; Rameshan et al., 2014).

India represents the global stronghold for the Asian elephant, harbouring nearly 60% of the global population. Recognising its ecological and cultural significance, the Government of India launched Project Elephant in 1992 to strengthen habitat protection, secure elephant corridors, mitigate conflict, and promote long-term conservation across elephant landscapes (Pandey et al., 2026c). However, rapid economic development and demographic expansion have significantly altered the landscape, leading to habitat degradation, fragmentation, and loss of connectivity. Linear infrastructure such as roads, railways, and transmission lines further disrupts elephant movement and increases mortality risks. These changes have modified traditional ranging patterns and intensified conflict in human-dominated areas (Sukumar, 2003; Goswami et al., 2014; Anoop et al., 2023). Despite the establishment of Elephant Reserves under Project Elephant, many reserves encompass a mosaic of forests, agriculture, settlements, and other land uses. Ongoing land-use changes and expanding infrastructure have contributed to habitat degradation and reduced functional connectivity across elephant landscapes (Pandey et al., 2025a). Maintaining functional elephant corridors has therefore emerged as a critical conservation priority for facilitating seasonal movements, gene flow, and landscape connectivity while reducing conflict in human-dominated landscapes (Pandey et al., 2024a). Notably, empirical evidence indicates that conflict intensity is more strongly influenced by landscape configuration and resource distribution than by elephant density alone (Goswami et al., 2015; Gubbi, 2012). Recent landscape-scale analyses from India further demonstrate that environmental and anthropogenic variables jointly shape the spatial distribution of HEC across diverse elephant landscapes (Pandey et al., 2026a). Studies from southern India highlight the importance of landscape-level drivers in shaping conflict dynamics. In Karnataka, conflict intensity has been linked to proximity to forests, cropping patterns, and the cultivation of high-value crops such as banana, sugarcane, and maize, which provide high caloric returns (Gubbi, 2012). Similarly, research from the Nilgiri landscape demonstrates that habitat fragmentation and disruption of movement corridors strongly influence elephant movement and the spatial distribution of conflict events (Bhaskaran et al., 2010; Rameshan et al., 2014).

The Western Ghats constitute a critical region for elephant conservation. This globally recognised biodiversity hotspot supports a substantial proportion of the Asian elephant population and contains some of the largest remaining contiguous forest tracts. Kerala, located along the southwestern slopes of the Western Ghats, supports an estimated population of around 2,785 elephants (Qureshi et al., 2025), forming part of the larger Nilgiri Biosphere Reserve population (Sukumar, 2003; Vineetha et al., 2024; Rameshan et al., 2014). Elephant habitats in this region span approximately 39,000-40,000 km^2, extending beyond protected areas into reserve forests, plantations, and agricultural lands (Vineetha et al., 2024; Anoop et al., 2023). Despite relatively high forest cover, increasing anthropogenic pressures have fragmented habitats and constrained movement, contributing to elevated levels of HEC. The state is characterised by high biodiversity with one of the highest human population densities in India, resulting in frequent human-elephant interactions. Forests cover approximately 27.83% of the state but are interspersed with agriculture, plantations, and settlements, creating a highly permeable interface between wildlife habitats and human livelihoods.

Ecologically, *Keralam* comprises a mosaic of tropical evergreen, semi-evergreen, moist deciduous, and montane ecosystems, providing year-round access to water and forage. However, these natural habitats are embedded within landscapes dominated by plantations and agriculture. Crops such as banana, coconut, and rubber are highly attractive to elephants due to their high nutritional value (Madhusudan, 2003; Nair & Jayson, 2021), increasing the likelihood of crop raiding and property damage. The proximity of high-value crops to forest edges further amplifies conflict risk. Empirical studies from *Keralam* reinforce these patterns. In the Nilambur landscape, conflict incidence has been linked to forest interface and livestock presence (Rohini et al., 2016). In Malappuram district, elephants are estimated to cause annual crop losses exceeding INR 5 million, primarily affecting plantation crops such as plantain, rubber, areca nut, and coconut (Nair & Jayson, 2021). At broader scales, district-level analyses identify Wayanad, Palakkad, and Kannur as persistent conflict hotspots (Sengupta et al., 2020), with crop depredation accounting for the majority of incidents (Shajna et al., 2025).

Seasonality further influences HEC dynamics. Monsoonal cycles affect vegetation productivity, water availability, and agricultural patterns, thereby shaping elephant movement and foraging behavior. Conflict often peaks during crop maturation stages, when fields offer high-energy food resources. Studies from the Western Ghats indicate that seasonality and proximity to forest boundaries are key determinants of conflict occurrence (Anoop et al., 2023; Münster & Münster, 2012; Pavithra et al., 2025). Beyond ecological drivers, HEC in *Keralam* is deeply embedded in socio-economic and cultural contexts. Rural livelihoods depend heavily on agriculture and plantations, making households particularly vulnerable to crop losses. At the same time, elephants hold significant cultural and religious value, especially in temple festivals and rituals. This dual perception-of elephants as both revered symbols and sources of economic loss-creates complex and often conflicting attitudes toward conservation. HEC in *Keralam* manifests in multiple forms, including crop damage, property destruction, human injury and mortality, and elephant deaths due to electrocution, train collisions, and retaliatory actions (Ramakumar, 2021; Anoop et al., 2025). These outcomes highlight the bidirectional nature of conflict and the shared costs borne by humans and wildlife. Across India, elephant conservation has progressively shifted from protected area-based management towards landscape-level approaches that integrate elephant reserves, habitat connectivity, corridor conservation, and community participation. Achieving long-term coexistence requires adaptive, context-specific strategies that balance elephant conservation with human livelihoods (Pandey et al., 2024b; Pandey et al., 2026b). Recent advances in spatial modelling have improved understanding of HEC patterns, demonstrating that conflict is spatially structured and predictable based on environmental and anthropogenic variables (Vineetha et al., 2024; Pavithra et al., 2025; Sengupta et al., 2020). However, despite the implementation of mitigation measures such as electric fencing, trenches, and compensation schemes, conflict persists. This suggests that site-specific interventions alone are insufficient. There is growing consensus that effective management requires integrated, landscape-level approaches that address underlying drivers, including habitat fragmentation, corridor degradation, and land-use patterns. Such strategies must combine ecological restoration, land-use planning, early warning systems, corridor conservation, and community participation to achieve long-term coexistence (Anoop et al., 2023; Rameshan et al., 2014; Vineetha et al., 2024; Pandey et al., 2024b; Pandey et al., 2026b).

Building on this context, the present study examines long-term patterns in *Keralam* using data spanning 2008-2025. By integrating spatial and temporal analyses of conflict incidents with environmental and anthropogenic variables, this study aims to identify key drivers, seasonal trends, and geographic hotspots of conflict across the state. The findings are intended to contribute to a more nuanced, landscape-level understanding of HEC and to inform evidence-based mitigation and management strategies.

1. How have the causes and spatial distribution of human fatalities and elephant mortality changed across *Keralam* between 2008 and 2025?

2. Are the age, sex, and other demographic characteristics of deceased elephants associated with specific causes of mortality, particularly anthropogenic causes?

3. Are changes in land use and land cover between 2008 and 2025 associated with the spatial and temporal patterns of human and elephant mortality?

Photo: Reji Chandran.

Photo: Maitreyee Bhave

STUDY AREA

The study was conducted in the state of Keralam, located along the southwestern coast of India between approximately 8°18'N to 12°48'N latitude and 74°52'E to 77°22'E longitude, covering an area of ~38,863 km². The state of Keralam is located along the Malabar Coast in peninsular India. Although its geographical extent consists of only 1.18% of the land area of the country, it is one of the top three states of the country in terms of the density of its elephant population (Gubbi *et al.* 2014). The state is bounded by the Arabian Sea to the west and the Western Ghats to the east, and shares interstate boundaries with Tamil Nadu and Karnataka. Keralam forms part of the Western Ghats biodiversity hotspot, one of the most species-rich and ecologically significant regions globally (Myers *et al.*, 2000). The terrain is characterized by a steep elevational gradient from coastal plains to montane forests exceeding 2,600 m, resulting in diverse vegetation types including tropical wet evergreen, semi-evergreen, moist deciduous, and montane shola-grassland systems (Champion & Seth, 1968).

Keralam has one of the highest forest cover proportions in India, with approximately 22,059 km² (~27.83% of the state's geographical area) under forest (FSI, 2023). These forests are largely contiguous along the Western Ghats and form part of the larger Nilgiri-Eastern Ghats-Anamalai landscape, which supports one of the largest populations of the Asian elephant globally (MoEFCC, 2017). Major protected areas such as Wayanad Wildlife Sanctuary, Periyar Tiger Reserve, and Silent Valley National Park are interconnected through forest corridors that facilitate elephant movement across Keralam, Tamil Nadu, and Karnataka (Project Elephant, 2010)

Based on rainfall characteristics and cloud formation, there are four seasons in Keralam. South West monsoon (locally known as Kalavarsham): June - September; North- East monsoon (locally known as Thulavarsham): October - November; Winter (December- February) and

Pre- Monsoon Summer (March - May) and Winter (December - February) and Summer (March - May). This high and relatively stable rainfall supports dense vegetation and year-round availability of forage and water, distinguishing Keralam from more seasonal dry forest landscapes in central and eastern India. However, seasonal variation still influences elephant movement, particularly in relation to crop availability and water distribution. About 45 species of edible and commercial plants are regularly destroyed by wild animals in the State. These plants include paddy, coconut, arecanut, rubber, banana, plantain, tapioca, sweet potato, coffee, oil palm, pepper, cardamom, ginger, jackfruit, mulberry, mango, and pineapple (Nair and Jayson 2021). These crops, particularly banana, coconut, and jackfruit, are highly palatable to elephants and contribute significantly to HEC (Sukumar, 2003; Gubbi, 2012).

Keralam is one of the most densely populated states in India, with a population exceeding 33 million and high rural-urban connectivity (Government of India, 2011). Human settlements are widely distributed, often extending into forest fringes and valley systems. Agriculture is a dominant land use, with cropping patterns characterized by plantation crops such as rubber, coconut, tea, and coffee, alongside paddy cultivation in lowland areas. Human-elephant interactions in Keralam occur primarily along forest-agriculture interfaces, where elephants move between protected areas and surrounding landscapes. Unlike eastern India, where migratory dynamics dominate, elephant populations in Keralam are largely resident but exhibit seasonal ranging behavior within a relatively contiguous forest network (Baskaran *et al.,* 2018). However, increasing fragmentation due to infrastructure development, plantation expansion, and human encroachment has constrained movement pathways and intensified conflict in several regions, particularly in Wayanad, Palakkad, and Idukki districts (Kumar *et al.,* 2010). The Palakkad Gap, a major break in the Western Ghats, serves as a critical corridor for elephant movement but is also a hotspot of conflict due to high human activity.

Photo: Reji Chandran.

METHODS

Collection of Elephant Mortality and Human Fatality Records

Information on Human-Elephant Conflict (HEC) incidents was compiled from all 36 Forest Divisions of Keralam covering the period 2008 to 2025. The dataset included detailed records of elephant mortality due to both natural and anthropogenic causes and human fatalities and injuries caused by wild elephants, along with associated variables such as division name, village name, date of incident, gender of the victim, and contextual notes provided by field staff. All data were obtained directly from the Keralam Forest Department, and divisional authorities cross-verified the entries to ensure completeness and accuracy. Only officially documented and field-confirmed cases were included in the final dataset to maintain data reliability for spatial-temporal analysis.

Categorisation of Datasets

A total of 695 elephant mortality and HEC incidents with 581 human fatality cases and 1200 human injury cases were recorded across the major elephant-bearing forest divisions of the state. These were categorized into human-induced causes and natural causes, following the classification system used by the Keralam Forest Department.

Each elephant mortality cases were classified based on mentioned details of each incident in the data as the year of incident, season: Summer (March- May), Monsoon (June- September); two monsoon period: Southwest monsoon (June-September) Northeast Monsson (October- November), and winter (December-February), age demography of elephant, reason due to which elephant has

Table 1.1(a): *Elephant age categories followed Arivazhagan and Sukumar (2008).*

Age Group	Age Range
Calves	0-1
Juveniles/Yearlings	1-5
Sub- adults (Males& Females)	6-15
Adults (Males & Females)	16+

died, place of occurrence, division wise distribution of the incidents.Elephant age categories followed Arivazhagan and Sukumar (2008), as mentioned in Table 1.1(a). For elephant deaths, causes of death were categorised as outlined in Table 1.1(b).

The HEC incidents included details of human death/ injuries, place of occurrence, age, and sex. This data was further classified based on the year in which the incidents happened, age and sex of the deceased person, and season.

To examine the relationship between cause of death and elephant demography, a chi-square test was performed using R (version 4.3.1) to test the significance of associations between mortality categories and age groups. For HEC incidents, a chi-square test was performed for season vs. sex.

Table 1.1(b): *Flowchart Illustrating the Categorization of Elephant Mortality Factors in* Keralam.

Categories	**Sub-categories**
Natural	Natural causes, Accidental
Poisoning	Retaliatory killing
Poaching	Poaching
Electrocution	Electrocution
Human-made infrastructure/ anthropogenic stress	Linear infrastructure, Entrapment in drains/ canals, Train Hit etc
Human-made infrastructure/ anthropogenic stress	Linear infrastructure, Entrapment in drains/ canals, Train Hit etc

Land Use and Land Cover LULC Change Analysis

LULC analysis was conducted for Keralam over 21 years to examine how landscape transformation has influenced patterns of elephant mortality. Satellite-based LULC maps were generated at five-year intervals (2005, 2010, 2015, 2020, and 2025). Google Earth Engine (GEE) was used for image preprocessing, classification, and temporal comparison. ArcGIS Pro was used for subsetting the Keralam study area, raster dataset compilation, fragmentation analysis, distance calculations (e.g., distance to settlements, plantations, water bodies, roads), and map preparation. Landsat imagery was classified using a Random Forest (RF) classifier from the "smileRandomForest" library, with six spectral bands (blue, green, red, near-infrared, and two shortwave infrared bands). The spatial resolution was maintained at 30 m, and data were projected to UTM Zone 43N for Keralam. Eight major LULC categories were mapped: (1) Forest, (2) Waterbodies, (3) Barren/open land, (4) Cropland, (5) Settlements, (6) Scrub land, (7) Grassland, (8) Plantations (Rubber,tea, coffee, coconut, and spices). Temporal LULC changes across the 21-year period were analyzed to quantify habitat loss, fragmentation, and expansion of human-modified land uses. Particular emphasis was placed on areas showing increases in agriculture, settlements, and plantations, as these transitions are closely linked to conflict-prone zones and elephant movement pathways in Keralam (Figure 1.1).

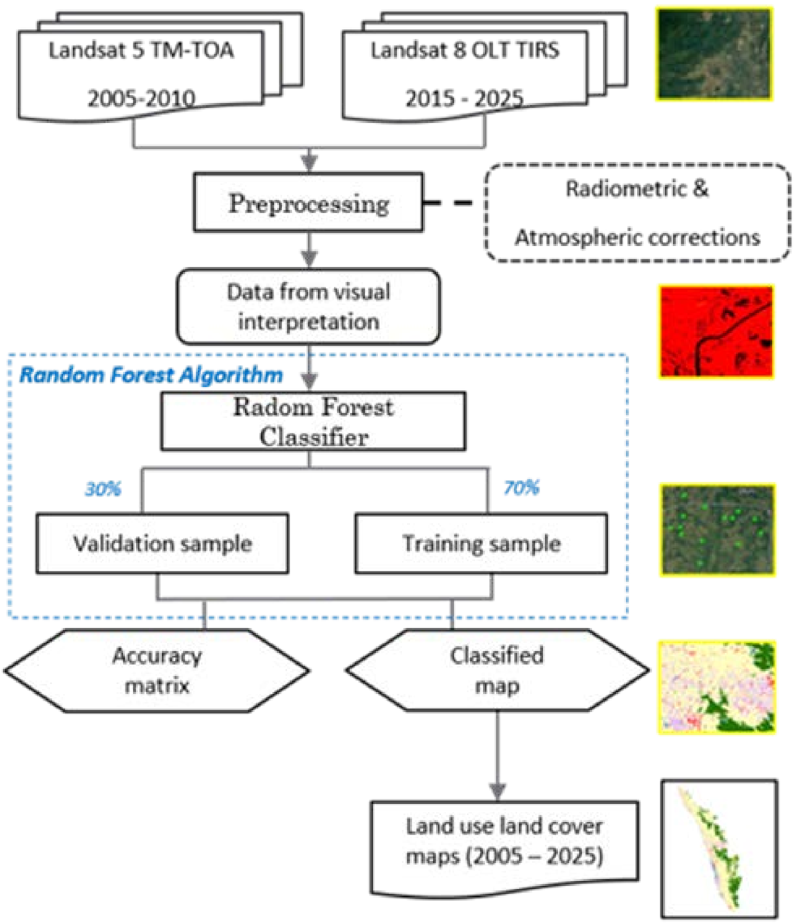


Table 1.1: *Land Use Land Cover classification methodology flowchart for the state of* Keralam

LULC layers for Keralam for 2008 and 2025 were used to calculate the fragmentation metrics Largest Patch Index (LPI) and Edge Density (ED). A 7 km × 7 km fishnet grid was overlaid on the fragmentation layers, and LPI and ED values were reclassified into five classes: Very Low, Low, Medium, High, and Very High. For LPI, higher classes indicate larger and more continuous forest patches, whereas lower classes indicate greater fragmentation. Conversely, higher ED classes represent greater forest fragmentation due to increased edge density, while lower classes indicate more compact and less fragmented forest landscapes. The proportion of each fragmentation class within every 7 km × 7 km grid was calculated and summarized as percentages to compare changes in forest fragmentation between 2008 and 2025 and to assess changes in forest landscape dynamics across Keralam.

Spatial Distribution of Elephant Mortality and Human Mortalities & Injuries

Elephant mortality incidents in Keralam were georeferenced using GPS coordinates and systematically mapped to examine their spatial distribution patterns across the state. A heat map was generated using R (version 4.3.1) to investigate the relationship between mortality frequency and geographic location. Kernel Density Estimation (KDE) was applied to identify zones with elevated mortality intensity, enabling the visualization of spatial hotspots where elephant mortalities and human mortalities & injuries were disproportionately concentrated. Administrative boundaries, including divisions, and village limits, were used as primary spatial units to contextualize mortality patterns and evaluate spatial clustering across the major elephant-bearing landscapes of Keralam.

Landscape Fragmentation Analysis

Landscape fragmentation in Keralam was assessed using FRAGSTATS (version 4.2) with LULC data reclassified into two primary categories: forest and non-forest. Key landscape metrics, including Patch Density (PD), Edge Density (ED), and Largest Patch Index (LPI), were computed to quantify forest structure across the five temporal intervals (2005, 2010, 2015, 2020, 2025). These metrics provided insights into the degree of habitat fragmentation, changes in forest patch configuration, and implications for habitat connectivity across Keralam's elephant ranges. A moving window with a 7 km radius was applied to calculate localized fragmentation metrics around each forest pixel, as this corresponds to a daily movement of elephants around ~7 km (Cushman *et al.*, 2010). Fragmentation metrics were further examined to assess their potential influence on elephant mortality patterns across divisions. Spatially explicit maps of PD, ED, and LPI were generated to visualize fragmentation gradients and to identify high-risk zones where reduced habitat connectivity may contribute to increased elephant movement into human-dominated landscapes. This analysis forms an important basis for understanding how changing land-use patterns affect elephant ecology and conflict risk in Keralam.

Table 1.2: *Landscape Metrics: Definitions and Computational Formulas*

Landscape Metric	Description	Formula
Patch Density (PD)	Number of patches per unit area	PD = (N / A) × 10,000 × 100
Edge Density (ED)	Total edge length per unit area	ED = (Σ e_{ik} / A) × 1000
Largest Patch Index (LPI)	Percentage of total landscape area comprised by the largest patch	LPI = (max(a_{ij}) / A) × 100

Where: N = number of patches, A = total landscape area (m^2), Σ e_{ik} = sum of all edge lengths, max(a_{ij}) = area of the largest patch, i, j, k = patch/edge identifiers, Units: PD (patches/100 ha), ED (m/ha), LPI (%)

Predictors of Elephant Mortality and Human Mortalities & Injuries

To identify the environmental and anthropogenic factors influencing elephant mortality in Keralam, a generalized linear model (GLM) with a binomial distribution was implemented using R (version 4.3.1). Spatial attributes of mortality events were integrated with GIS-based environmental layers representing key landscape variables of the state. Mortality incidents/ HEC incidents were coded as 1, while pseudo-absence points (coded as 0) were generated randomly across non-mortality landscape units to allow comparison between presence and background conditions. A suite of explanatory variables representing major ecological and human-modified features in Keralam was selected for analysis. These included distance to forest, cropland, built-up areas, roads, water sources, railways, protected areas, elephant reserves, and plantation zones such as tea or coffee estates (Table 1.3). These predictors were chosen based on their documented influence on elephant movement, habitat selection, and conflict occurrence in the Western and Eastern Ghats landscapes.

To assess multicollinearity among predictors, Variance Inflation Factors (VIF) were computed, and highly correlated variables (VIF > 3) were removed to ensure model stability. Model performance was evaluated using the Akaike Information Criterion (AIC), and a set of competing models was generated. Model ranking and selection followed Burnham and Anderson's (2002) information-theoretic approach, where models within ΔAIC ≤ 2 were considered equally plausible. The final predictive model was obtained by averaging top-ranked models, providing a robust and parsimonious representation of factors driving elephant mortality in Keralam.

Table 1.3: *A Priori Hypotheses on Environmental and Anthropogenic Factors Influencing Elephant Mortalities and Human Casualties in* Keralam.

Feature	**Variable**	**Description and source**	**A priori hypotheses for elephant mortality**	***A priori* hypotheses for Human casualties**
Land cover	Distance from built-up areas (db)	Classified land-cover types, such as built-up areas, cropland, forests, waterbodies, and plantation were used to calculate distances between conflict points and each landcover type using the “Near Table” tool in ArcPro 3.0.0	Closer proximity to built-up areas was expected to increase mortality risk because of greater interaction with settlements and associated infrastructure.	Closer proximity to built-up areas was expected to increase HEC by increasing encounters between people and elephants
	Distance from cropland (dc)		Closer proximity to croplands was expected to increase mortality risk because of crop raiding, retaliatory actions, and exposure to electrical infrastructure.	Closer proximity to croplands was expected to increase HEC because cultivated crops can attract elephants.
	Distance from forest (df)		Mortality risk was expected to be higher closer to forests because elephants frequently use forest edges and adjoining human-dominated areas	Closer proximity to forests was expected to increase HEC because elephants frequently move between forests and adjoining human-used areas.
	Distance from waterbodies (dw)		Proximity to waterbodies was expected to influence mortality risk by concentrating elephant movement around water-associated landscapes.	Closer proximity to water sources was expected to increase HEC because elephants regularly use water-associated landscapes.
	Distance from plantation (dpla)		Closer proximity to plantation was expected to increase mortality risk because of fragmentation forest patches and reduce connectivity	Closer proximity to plantations was expected to increase HEC because plantation landscapes fragment forests, reduce habitat connectivity, leading to more frequent interactions with people.

Anthropogenic	Distance from mines and quarries (dmn)	Mines and quarries were identified using the Indian Geomorphology layer and further digitized using Google Earth Pro. Distance from each observation location was calculated using the "Near Table" tool in ArcGIS Pro 3.0.0.	Closer proximity to mining areas was expected to increase mortality risk because of habitat disturbance, fragmentation, and increased anthropogenic activity.	Closer proximity to mines was expected to increase HEC because mining and associated development can fragment habitat and disrupt elephant movement
	Distance from roads (dr)	Road network and railway network shapefiles were sourced from OpenStreetMap. Distance from each observation location was calculated using the "Near Table" tool in ArcGIS Pro 3.0.0.	Closer proximity to roads was expected to increase mortality risk because of vehicle collisions and habitat disturbance and fragmentation.	Closer proximity to roads was expected to increase HEC because roads increase habitat fragmentation, human accessibility and encounter risk
	Distance from railways (drail)		Closer proximity to railways was expected to increase mortality risk because of train collisions and disruption of elephant movement routes.	Closer proximity to railways was expected to increase HEC because railway corridors can fragment habitat and constrain elephant movement.
Protected areas	Distance from protected areas (dpa)	Distance from each observation location to the nearest protected-area boundary and elephant reserve boundary (Elephant Cell, Wildlife Institute of India) was calculated using the "Near Table" tool in ArcGIS Pro 3.0.0.	Mortality risk was expected to be lower closer to protected areas because of comparatively lower anthropogenic pressure and greater habitat protection.	HEC was expected to be lower near protected areas and increase with distance because protected landscapes generally experience lower human pressure
	Distance from elephant reserves (der)		Mortality risk was expected to be lower closer to elephant reserves because of greater habitat availability and conservation management	Closer proximity to elephant reserves was expected to increase HEC because elephant occurrence and boundary movements may be concentrated near these areas.

Land-scape metrics	Patch Density (pd)	Patch density, edge density, and the largest patch index were calculated using FRAGSTATS v4.2, and the value is extracted using the "Extract Multi Values to Points" tool in ArcGIS Pro 3.0.0.	Higher patch density was expected to increase elephant mortality risk because greater forest subdivision may increase elephant movement through human-used landscapes.	Higher patch density was expected to increase HEC because greater forest subdivision may increase elephant movement through human-used landscapes.
	Edge Density (ed)		Higher edge density was expected to increase elephant mortality risk by expanding the interface between forests and human-dominated areas.	Higher edge density was expected to increase HEC by expanding the interface between forests and human-dominated areas.
	Largest Patch Index (lpi)		A higher LPI was expected to reduce elephant-mortality risk because it represents larger and more continuous forest patches.	Higher LPI was expected to reduce HEC because it represents larger and more continuous forest patches.

Cross-validation techniques were used to evaluate predictive accuracy and reduce overfitting. Spatial predictions from the final model were used to map high-risk zones and identify landscape features strongly associated with mortality hotspots. This analytical approach enhances understanding of the ecological and anthropogenic drivers of elephant deaths and provides critical insights for targeted mitigation strategies and landscape-level planning in Keralam.

Categorizing Villages Based on Intensity of Elephant Mortalities and Human Mortalities

Villages in Keralam were categorized into four mortality-intensity classes based on the total number of elephant mortalities and HEC incidents recorded within or near their administrative boundaries. The categories included: high-incident villages (> 10 elephant mortalities), medium-incident villages (6-9 mortalities), low-incident villages (0-5 mortalities), and non-incident villages.

For human casualties, the villages were classified as high-incident villages (> 20 incidents), medium-incident villages (6-9 incidents), low-incident villages (0-5 incidents), and non-incident villages. This classification was used to investigate potential relationships between mortality intensity and key landscape variables such as forest cover, crop cover, built-up areas, and plantation/mining areas. The severity of HEC was evaluated by examining the frequency of incidents across villages within each forest division across the state.

A Kruskal-Wallis rank sum test, a non-parametric statistical method, was employed to evaluate whether statistically significant differences existed in the median values of landscape variables among the four village categories. This approach is appropriate for datasets that violate normality assumptions and provides a robust comparison across multiple independent groups. To further explore pairwise differences among the incident categories, a Dunn test was conducted as a post-hoc analysis. This test identifies which specific pairs of village categories (e.g., high vs. low, medium vs. no-incident) exhibit significant differences in landscape characteristics while applying appropriate corrections for multiple comparisons. Village boundary data were obtained from ArcGIS Online, using the shapefile *Indian Administrative Layer*. These boundaries were used to extract landscape metrics and link them with mortality-intensity categories for statistical analysis.

RESULTS

Forest Fragmentation Pattern

The temporal distribution of landscape fragmentation metrics in Keralam showed noticeable changes between 2008 and 2025. The largest patch index exhibited a decline in the proportion of grid cells within the very high class, accompanied by increases in the very low, low, and medium classes, indicating a reduction in the dominance of large, contiguous forest patches and an increase in smaller, less continuous patches. Similarly, the edge density distribution shifted from the very low class towards the low, medium, high, and very high classes, reflecting increased edge formation and greater habitat fragmentation. Overall, these changes suggest that Keralam's forest landscape became progressively more fragmented during 2008-2025, with reduced patch continuity and increased edge complexity that may affect habitat connectivity and elephant movement.

The spatial distribution of PD, LPI, and ED indicates distinct patterns of landscape fragmentation across the study area (Figure1.3). High PD and ED values are concentrated in the eastern region, reflecting a fragmented landscape characterized by numerous small and isolated habitat patches. In contrast, LPI values are generally low throughout the landscape, with relatively higher values confined to a few localized areas representing large, contiguous forest patches. Overall, these metrics suggest that forest fragmentation is most severe in the eastern region.

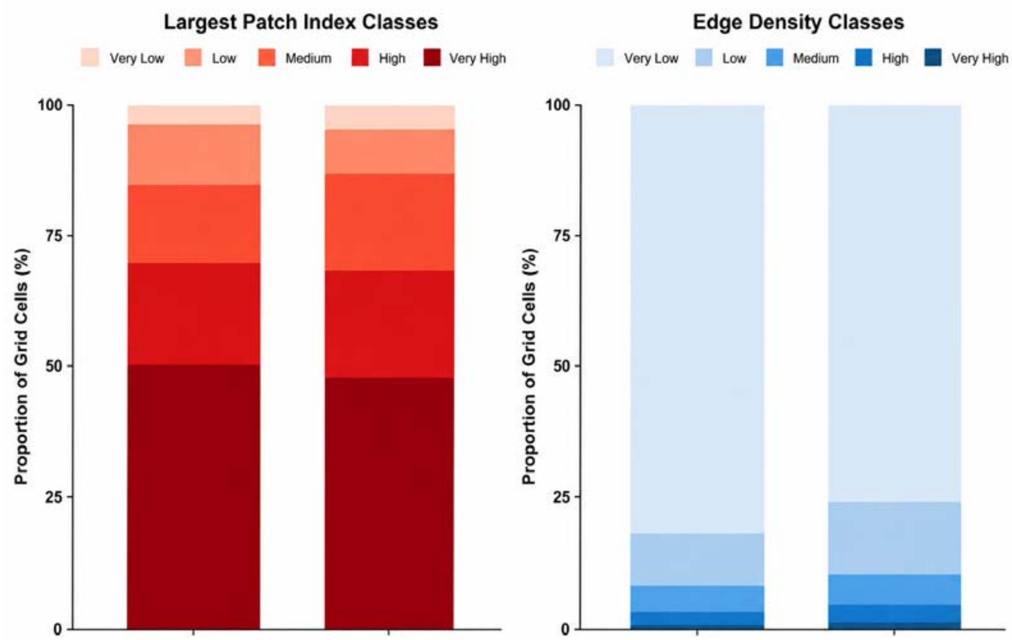


Figure 1.2(a): *Temporal changes in Largest Patch Index (LPI) and Edge Density (ED) classes in Keralam between 2008 and 2025.*

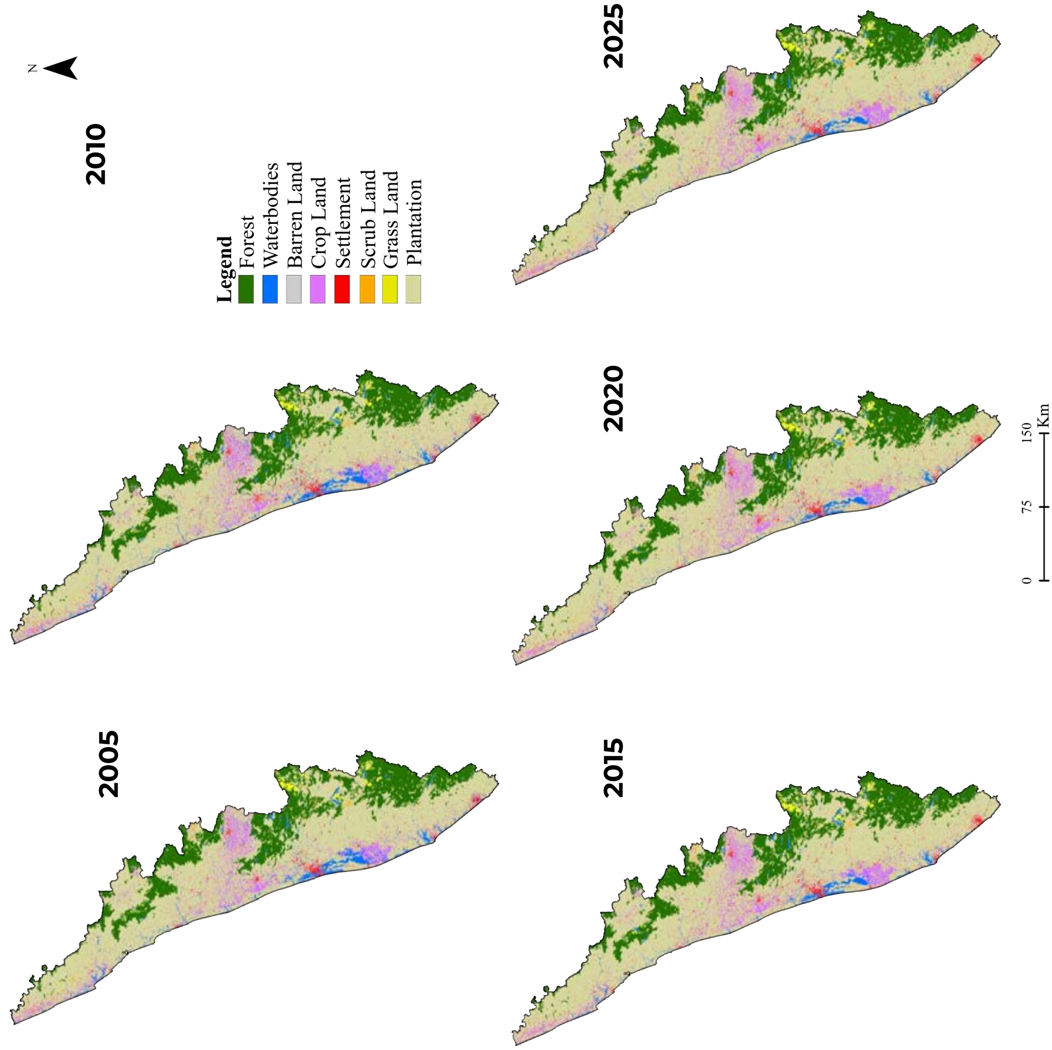


Figure 1.2(b): *Land Use Land Cover (LULC) of* Keralam *from year 2005-2025 (a-e respectively).*

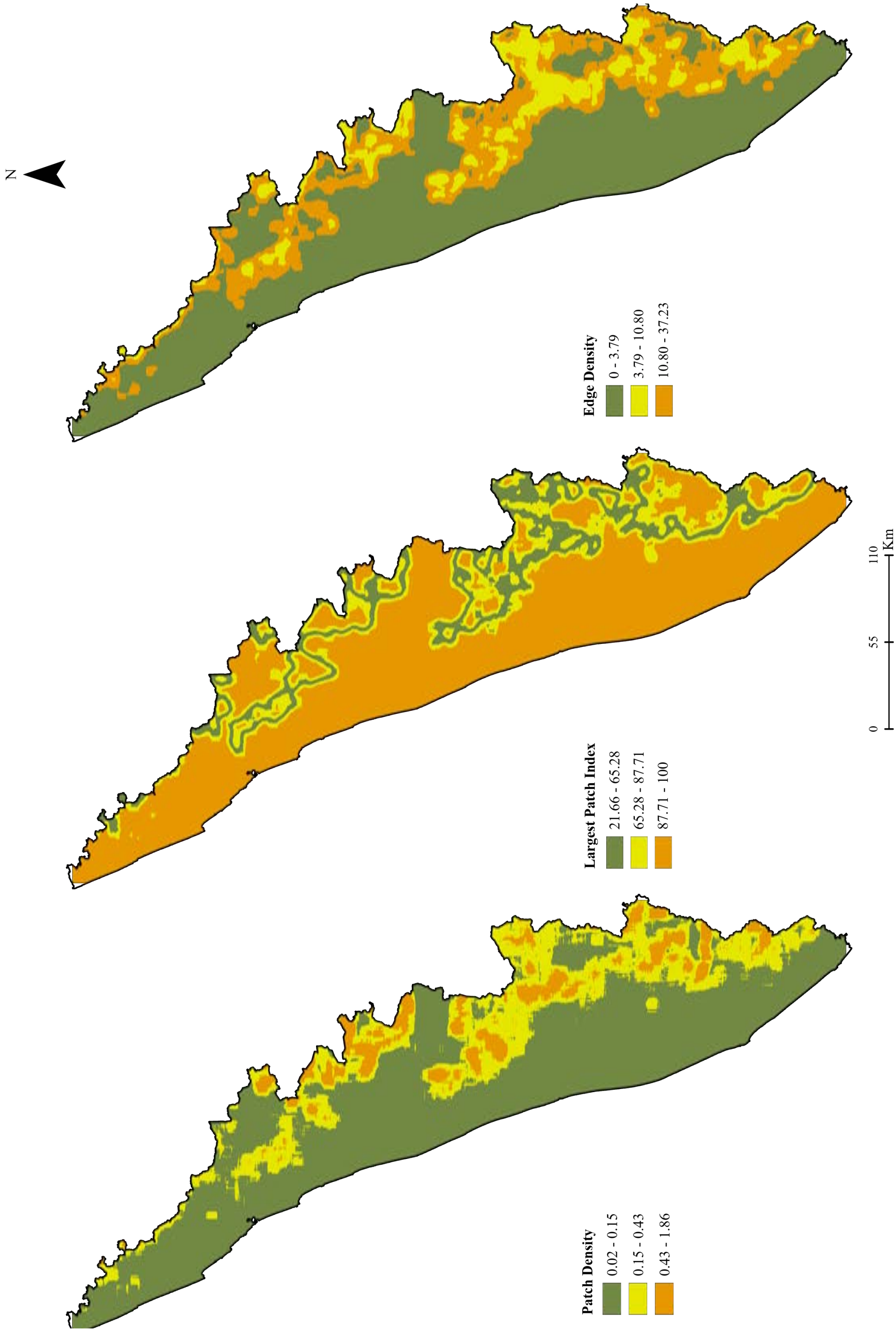


Figure 1.3: *Spatial Distribution of Forest Patch Density, Largest Edge Density, and Patch Index in* Keralam, *respectively.*

Temporal and Seasonal Pattern of Elephant Mortality

Over the past 18 years, total elephant mortality recorded across 36 forest divisions accounts for 695 deaths, including Natural deaths: 469 and Anthropogenic deaths:226. Elephant mortality was unevenly distributed among divisions, with the highest number of deaths recorded in Nilambur North Division (27 cases), followed by Nilambur South (26), Mannarkkad (25), Palakkad (21), Munnar (19), Mankulam (18), and Kothamangalam (16). The highest number of electrocution deaths occurred in Mannarkkad (25 cases), followed by Munnar (19), Mankulam (18), Kothamangalam (16), Malayattoor (15), Konni (13), and both Chalakudy and Wayanad South (12 each). The kernel density analysis supported the observed division-wise mortality pattern (Fig.1.4).

Among the anthropogenic causes, electrocution accounted for the highest number of elephant deaths (154), followed by vehicular accidents (16), train collisions (17), explosive bait (12), retaliatory killing (11), poisoning (5), poaching (7), and snare/trap incidents (4) (Fig.1.5). The frequency of elephant deaths differed significantly among anthropogenic mortality causes ($\chi^2 = 655.63$, df = 7, $P < 0.001$). The distribution of anthropogenic elephant mortality among age-sex classes differed significantly across mortality causes ($\chi^2 = 42.26$, df = 21, $P = 0.0039$). Adult males recorded the highest number of deaths (88), followed by subadult males (59), juveniles (32), adult females (19), subadult females (16), and calves (12).

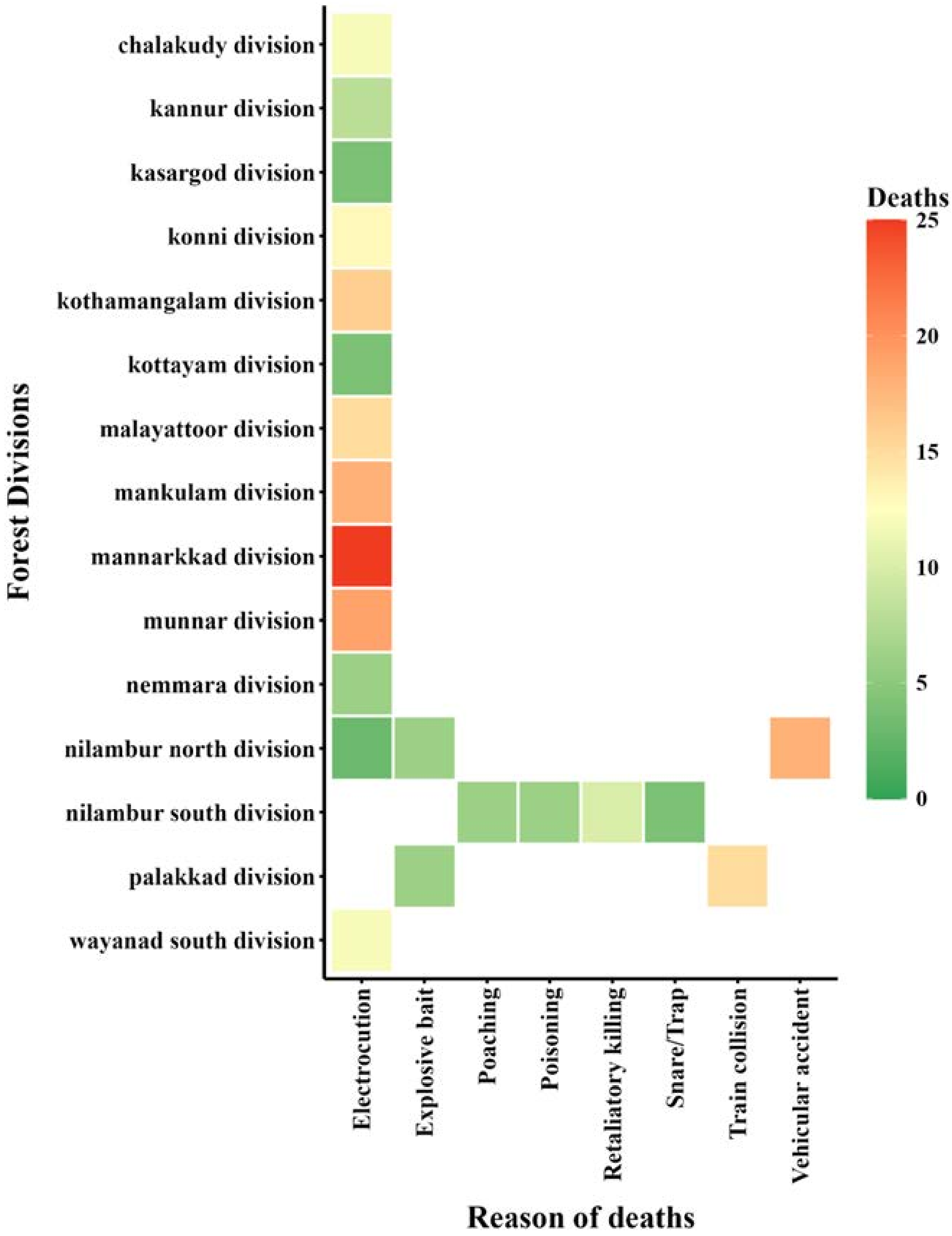


Figure 1.4: *Heatmap illustrating the relationship between causes of elephant mortality and forest divisions in* Keralam, *India, during 2008-2025.*

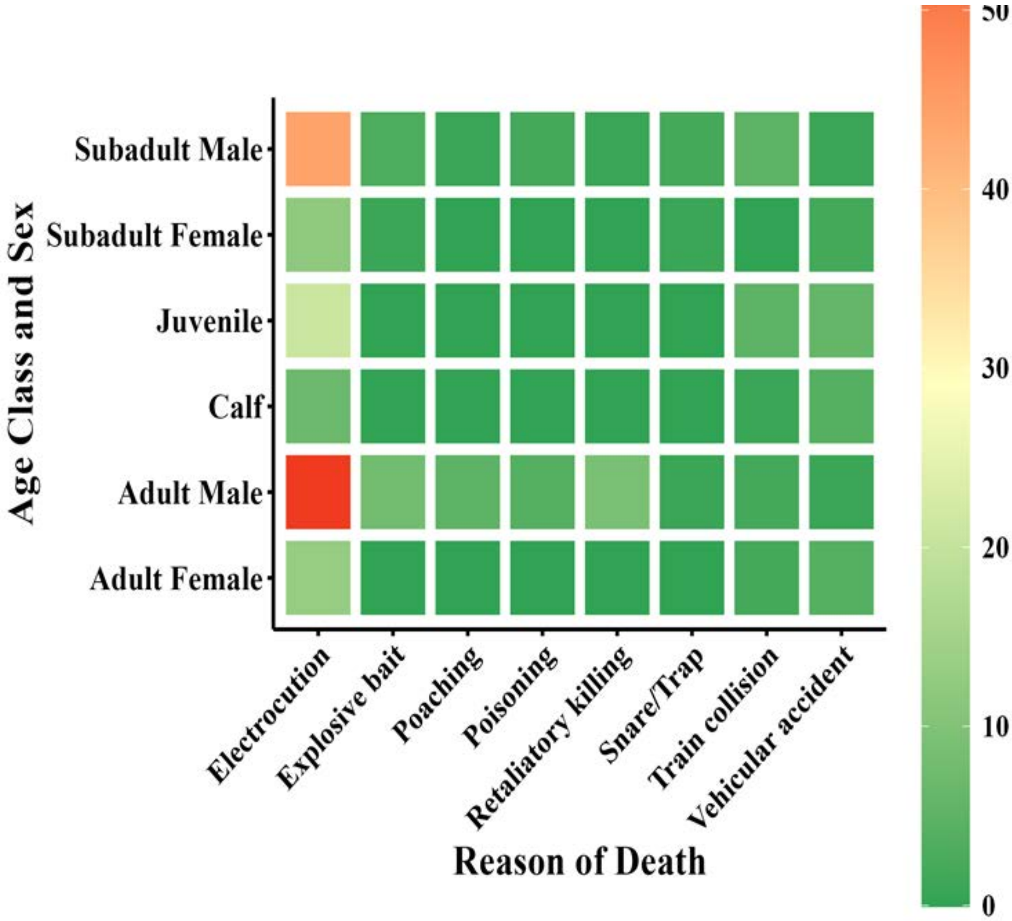


Figure 1.5: *Heatmap illustrating the relationship between causes of elephant mortality and age class demography in* Keralam, *India, during 2008-2025.*

Natural Deaths of Elephants

Over the years, elephant mortality in Keralam state for natural reasons was recorded as 469. Among natural mortality cases, adult males recorded the highest number of deaths (145), followed by subadult males (105), adult females and juveniles (70), calves (43), and subadult females (36).

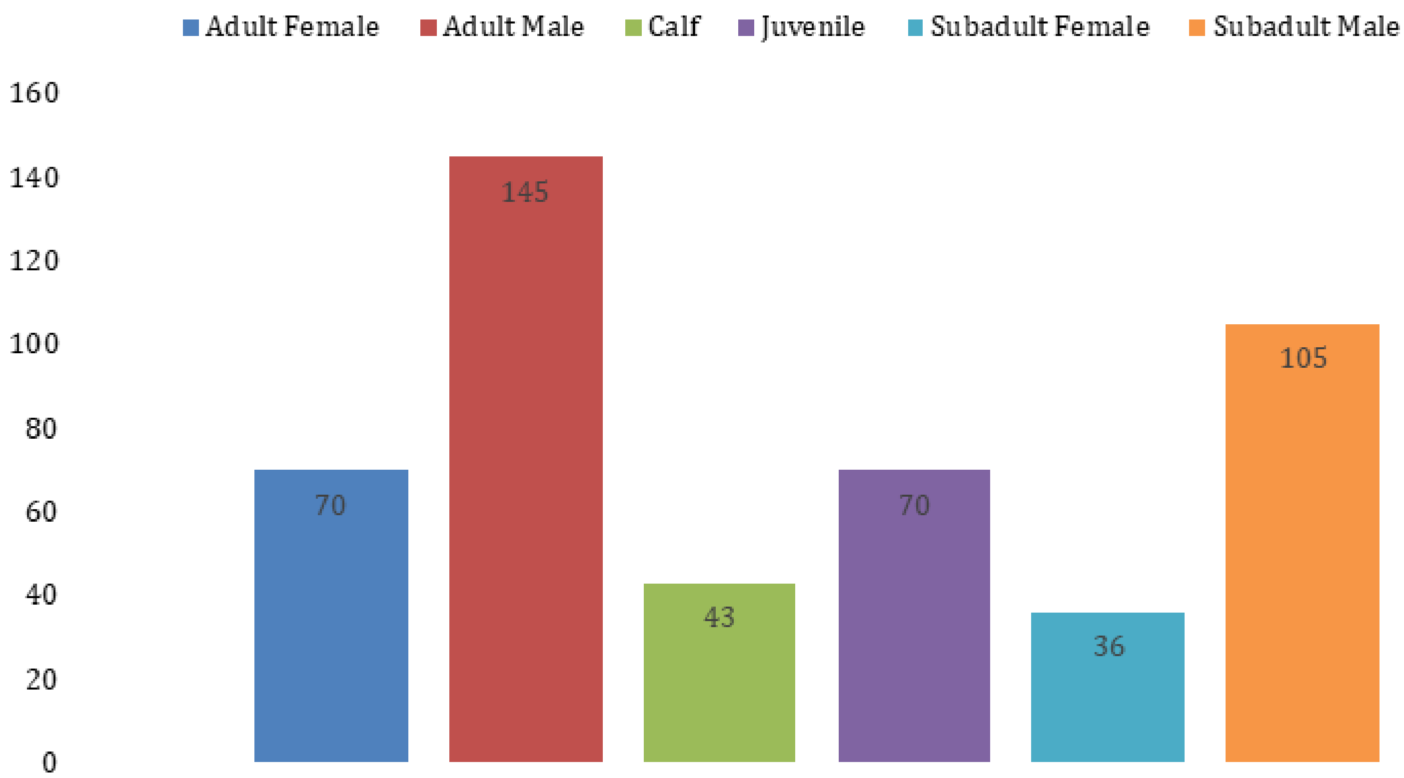


Figure 1.6. *Natural causes of elephant mortality and age class demography in* Keralam, *India, during 2008-2025.*

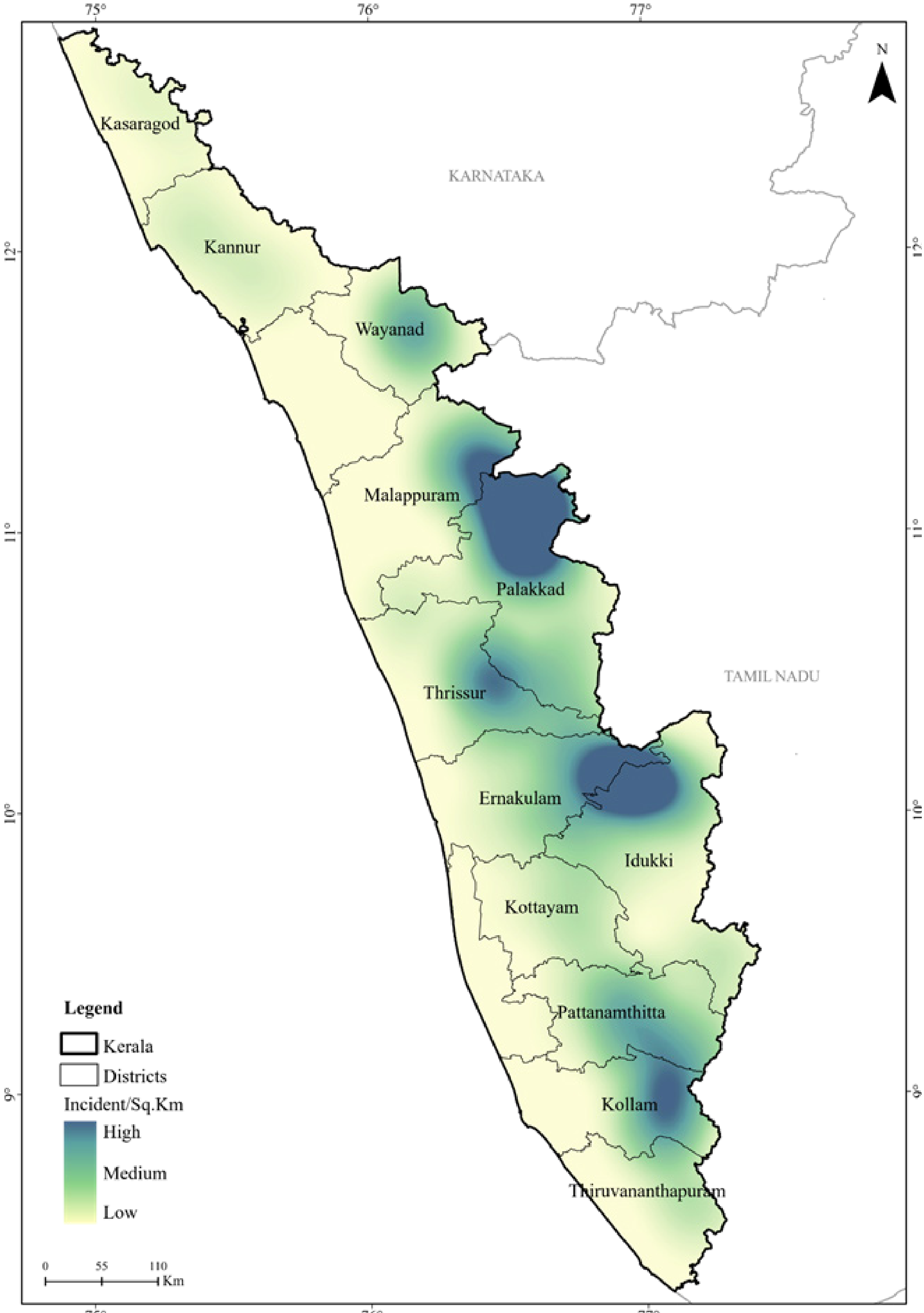


Figure 1.7. *Kernel density map of* Keralam *highlighting high, medium, and low mortality zones for elephant mortality in* Keralam, *India from 2008-2025.*

Ecological and Anthropogenic Variables of Elephant Mortality

The probability of elephant mortality was influenced by a limited number of ecological and landscape factors. Among the variables examined, distance to cropland showed a significant positive relationship with elephant mortality ($\beta = 0.34$, $p = 0.005$), with the predicted probability of mortality increasing as the distance from cropland increased. Distance to plantations also showed a significant positive relationship ($\beta = 0.28$, $p = 0.01$), indicating an increase in mortality probability with increasing distance from plantations. In contrast, distance to elephant reserves exhibited a significant negative relationship ($\beta = -0.27$, $p = 0.04$), suggesting that the probability of elephant mortality declined with increasing distance from elephant reserves. Although the response curve for largest patch index (LPI) showed variation in mortality probability, its effect was not statistically significant ($\beta = -0.18$, $p = 0.14$) (Tables 1.4 and 1.5; Fig. 1.8).

Table 1.4: *Summary of log-likelihood (LogL), number of estimated parameters [df], small-sample corrected Akaike Information Criterion (AICc), relative model support (ΔAICc), and Akaike weights (Wi) for candidate regression models explaining Asian elephant mortality occurrence in* Keralam.

Model	LogL	df	AICc	ΔAICc	Wi
der + lpi + dc + dpla	-283.44	5	577.01	0.00	0.32
df + lpi + dc + dpa + pd + dpla	-281.91	7	578.07	1.06	0.19
der + lpi + dc + dpa + pd + dpla	-282.05	7	578.35	1.34	0.17
der + lpi + dc + db + dpla	-283.31	6	578.82	1.80	0.13
df + dc + db + dpa + pd + lpi + dpla	-281.90	8	580.13	3.12	0.07
der + dc + dpa + pd	-285.21	5	580.56	3.55	0.05
der + dc + db + dpa + pd	-285.00	6	582.19	5.18	0.02
df + lpi + dc + dpa + dpla	-285.28	6	582.74	5.73	0.02
der + dc + dpa	-287.68	4	583.44	6.43	0.01
null	-313.30	1	628.61	51.60	0.00

Table 1.5: *Parameter estimates (β), standard errors, z-values, p-values, and significance of ecological and anthropogenic landscape variables associated with Asian elephant mortality occurrence in* Keralam

Variable	Estimate	Std. Error	z value	p-value	Significance
Intercept	0.01	0.10	0.08	0.94	
distance to elephant reserve (der)	-0.27	0.13	-2.01	0.04	*
largest patch index (LPI)	-0.18	0.12	-1.47	0.14	
distance to crops (dc)	0.34	0.12	2.81	0.00	**
distance to plantations (dpla)	0.28	0.11	2.56	0.01	*

**Indicate statistical significance of result*

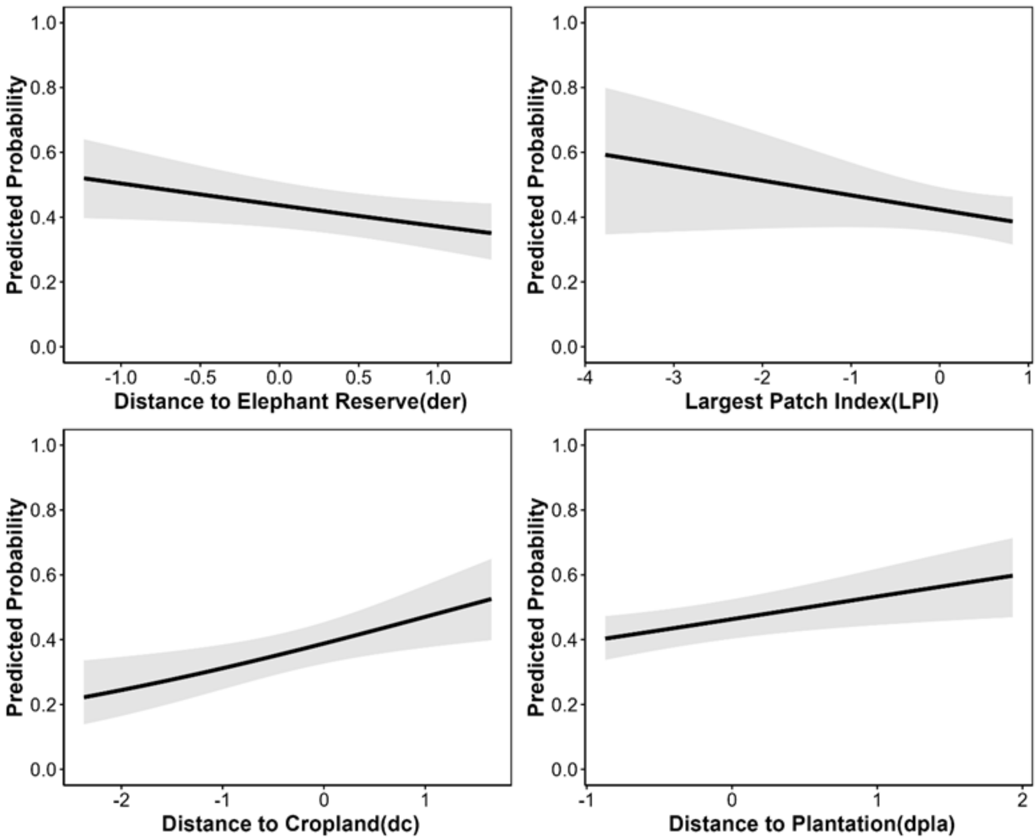


Figure 1.8: *Predicted Probability of Elephant Mortality due to Human-Elephant Conflict* Keralam *Based on Environmental and Landscape Variables*

Temporal and Seasonal Pattern of Human Mortality and Injuries

From 2008 to 2025, a total of 1,781 human-elephant conflict incidents were recorded in Keralam, comprising 581 human deaths and 1,200 injuries (Figure 1.9). Seasonal analysis revealed that the monsoon season accounted for the highest number of conflict incidents, followed by the post-monsoon, pre-monsoon, and winter seasons. Male victims were significantly more numerous than female victims across all seasons (Fig.1.12). Division-wise analysis indicated that Nilambur South recorded the highest number of human deaths (78), followed by Palakkad (57), Mankulam (57), Munnar (50), and Periyar East (42), whereas Kothamangalam registered the highest number of human injuries (164), followed by Marayoor (102), Nilambur North (63), Periyar East (64), and Thiruvananthapuram (58) (Fig.1.10). Kernel density estimation further identified the Nilambur, Palakkad-Mannarkkad, Munnar-Mankulam, and Kothamangalam-Periyar landscapes as major hotspots of HEC, with a high concentration of incidents occurring in and around these forest divisions (Fig.1.11).

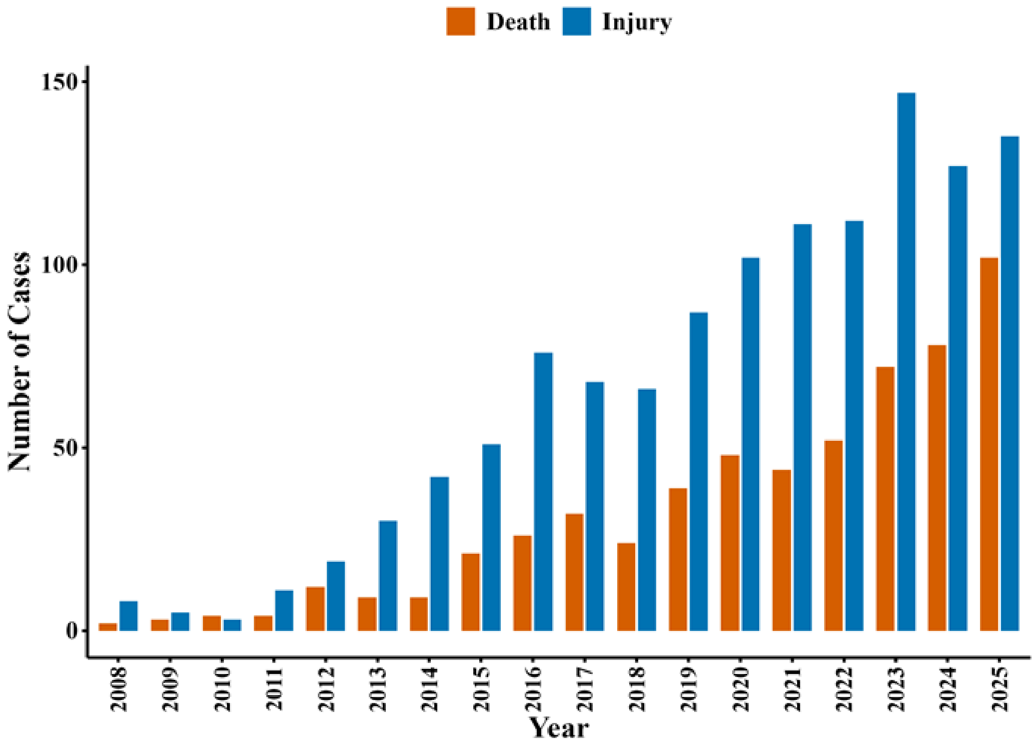


Figure 1.9: *Trends in human fatalities and injuries by elephants in the State of* Keralam, *India (2008-2025).*

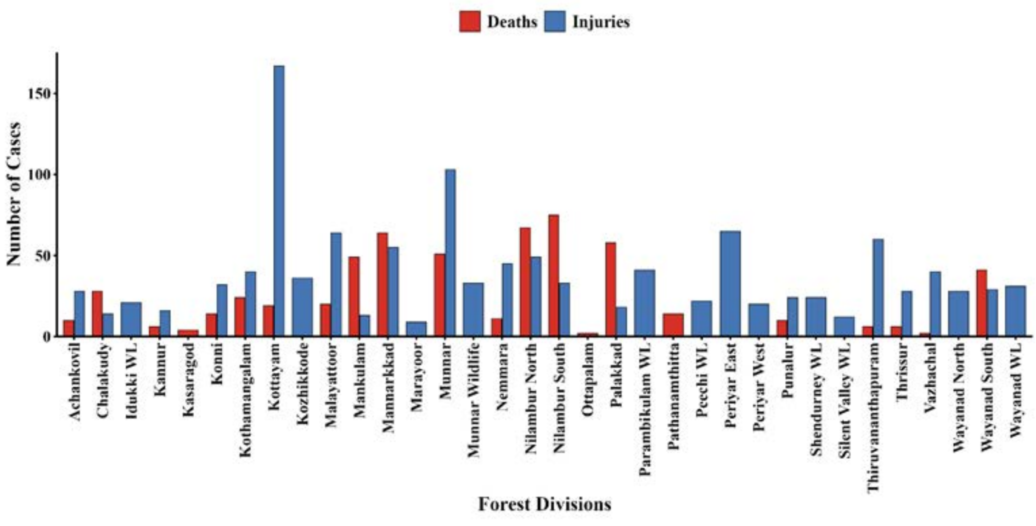


Figure 1.10: *Division-wise patterns of human fatalities and injuries by elephants in the State of* Keralam, *India (2008-2025).*

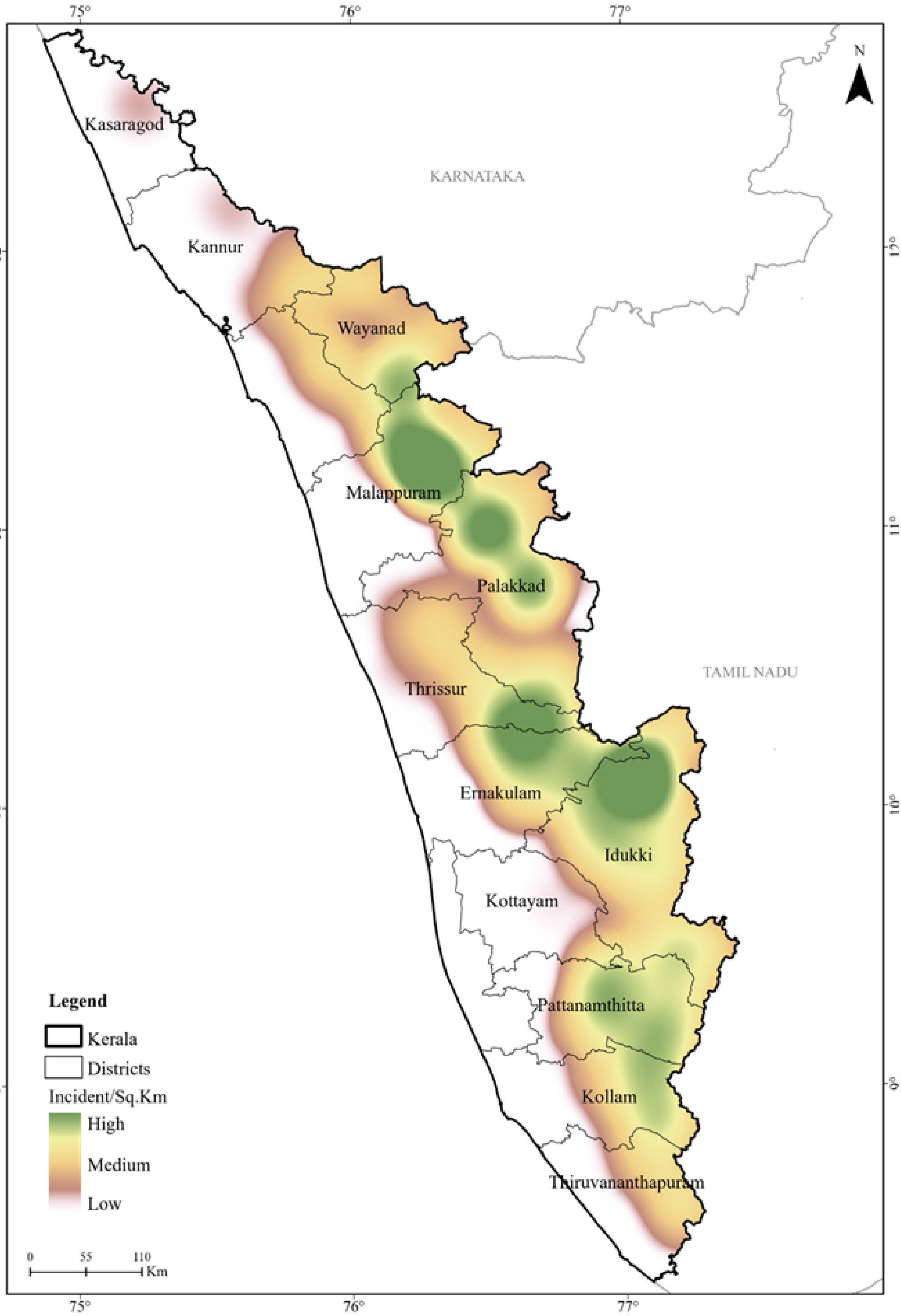


Figure 1.11: *Kernel density map of* Keralam *highlighting high, medium, and low mortality zones for human mortality and injuries in* Keralam, *India from 2008-2025.*

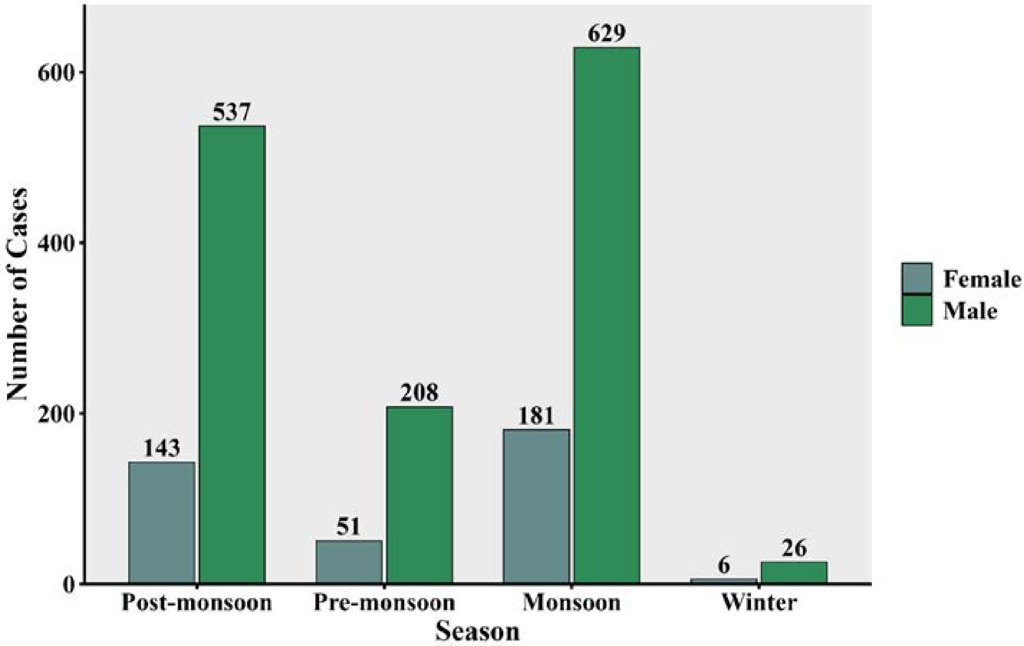


Figure 1.12: *Seasonal patterns of human fatalities and injuries by elephants in the State of* Keralam*, India (2008-2025).*

Ecological and Anthropogenic Variables of Human mortality and Injuries

The probability of human mortality was significantly influenced by both landscape fragmentation and habitat-related variables. Human mortality decreased significantly with increasing distance from forests ($\beta = -0.370$, $p < 0.001$), indicating that fatalities were more likely to occur in close proximity to forested habitats. Similarly, the probability of human mortality declined with increasing distance from protected areas ($\beta = -0.125$, $p < 0.001$), suggesting a higher mortality risk near protected areas. Among the landscape fragmentation metrics, Largest Patch Index showed a significant negative association with human mortality ($\beta = -0.113$, $p = 0.003$), indicating that mortality risk decreased as the proportion of large, contiguous habitat patches increased. In contrast, Patch Density exhibited a significant positive relationship with human mortality ($\beta = 0.126$, $p = 0.001$), suggesting that fragmented landscapes characterized by numerous small habitat patches were associated with a greater probability of human mortality. (Fig. 1.13; Tables 1.6 and 1.7).

Table 1.6: *Summary of log-likelihood (LogL), number of estimated parameters [df (K)], small-sample corrected Akaike Information Criterion (AICc), relative model support (ΔAICc), and Akaike weights (Wi) for candidate regression models explaining human mortality and injury occurrence in* Keralam.

Model	Log-likelihood	AIC	AICc	ΔAICc	Akaike Weight (wi)
lpi + dpa+ pd+ df	-2382.43	4774.863	4774.879	0	0.412
df + pd + lpi + db	-2383.58	4777.164	4777.18	2.301	0.13
df + pd + dpa	-2386.75	4781.49	4781.501	6.621	0.015
df + dw + pd + dpa	-2385.78	4781.559	4781.576	6.697	0.014
df + dw + pd + lpi	-2386.84	4783.673	4783.69	8.81	0.005
df + pd + lpi	-2388.28	4784.56	4784.571	9.692	0.003
df + pd + lpi + dpla	-2387.57	4785.134	4785.151	10.271	0.002
df + pd + dc	-2389.61	4787.228	4787.239	12.36	0.001
Null	-2468.3	4938.594	4938.595	163.7156	<0.001

Table 1.7: *Parameter estimates (β), standard errors, z-values, p-values, and significance of ecological and anthropogenic landscape variables associated with human mortality and injury occurrence in* Keralam

Variable	Estimate	Std. Error	z value	p-value	Significance
(Intercept)	-0.0086	0.0344	-0.251	0.8017	
Largest Patch Index (LPI)	-0.1134	0.0386	-2.935	0.0033	**
Distance to Protected Area (dpa)	-0.1249	0.0371	-3.367	<0.005	***
Patch Density (PD)	0.1258	0.0382	3.296	<0.005	***
Distance to Forest (df)	-0.3699	0.0388	-9.525	<0.005	***
Distance to mines(m)	-0.34	0.05	-6.18	0.00	***

**Indicate statistical significance of result*

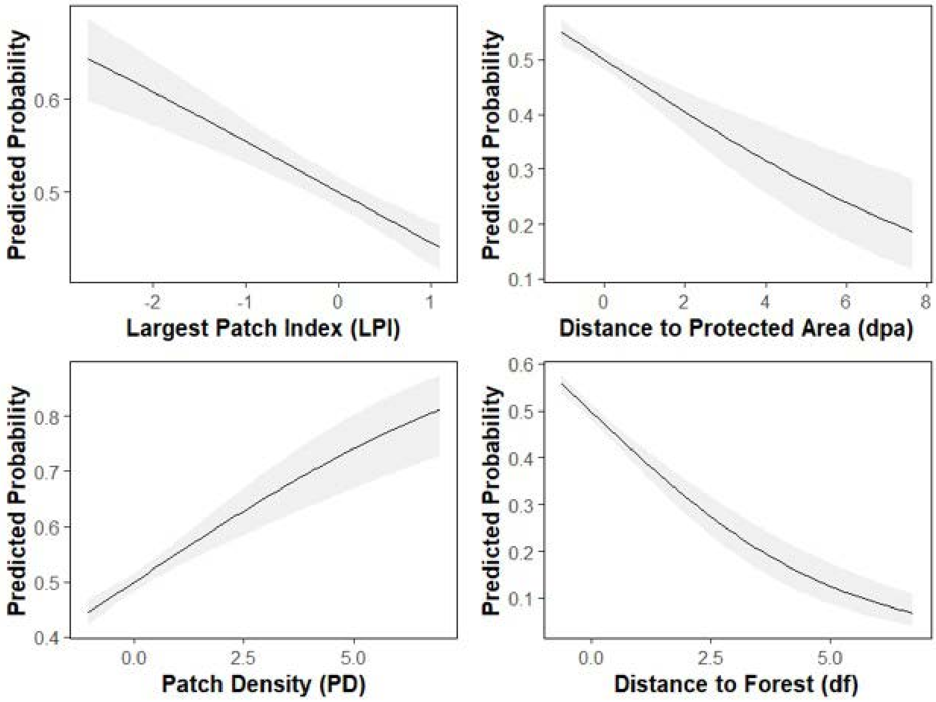


Figure 1.13: *Predicted Probability of Human Fatalities & Injuries due to Human-Elephant Conflict* Keralam *Based on Environmental and Landscape Variables*

Village-Level Analysis of Ecological and Anthropogenic Variables of Elephant Mortalities and HEC

Elephant mortality

From 2008-2025, A total of 102 villages reported elephant mortality incidents during the study period. Of these, 93 villages (91.2%) were classified as low incidence (1-5 incidents), 5 villages (4.9%) as medium incidence (6-9 incidents), and 4 villages (3.9%) as high incidence (>10 incidents). These results indicate that elephant mortality was geographically widespread but occurred predominantly at low frequencies, with only a few villages identified as high-mortality hotspots. Landscape composition differed significantly among elephant mortality intensity categories. The Kruskal-Wallis test indicated significant differences for forest ($\chi^2 = 26.74$, $p < 0.001$), plantation ($\chi^2 = 42.67$, $p < 0.001$), road ($\chi^2 = 34.64$, $p < 0.001$), built-up area ($\chi^2 = 42.33$, $p < 0.001$), and crop cover ($\chi^2 = 12.11$, $p = 0.017$). In contrast, water bodies ($\chi^2 = 2.60$, $p = 0.627$) and railway density ($\chi^2 = 4.07$, $p = 0.254$) did not differ significantly among mortality categories. Dunn's post hoc analysis revealed significant pairwise differences primarily between non-incident villages and medium- or high-mortality villages for forest, plantation, road, and built-up variables, whereas no pairwise differences remained significant for crop after Bonferroni correction. (Fig.1.14)

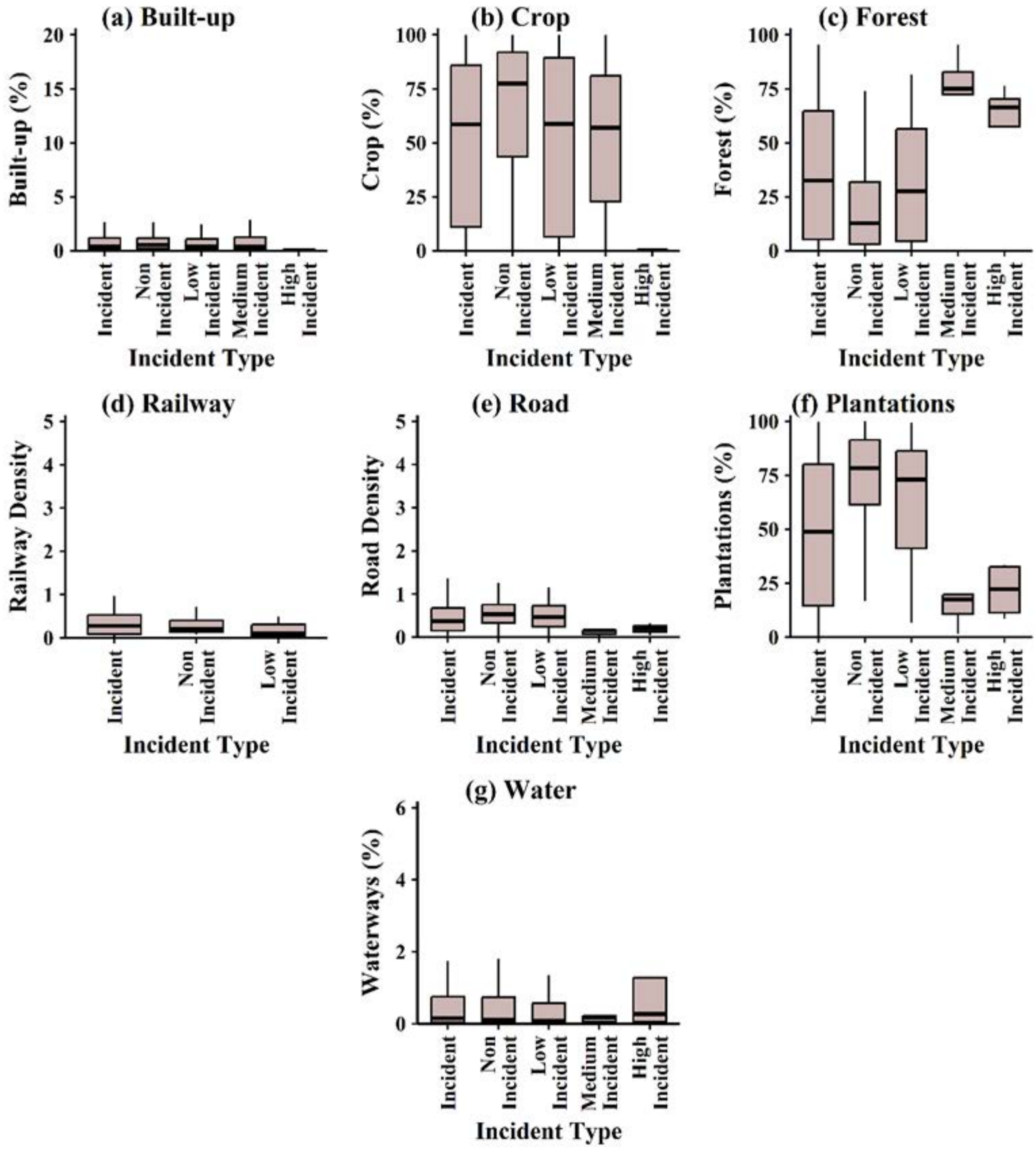


Figure 1.14: *Comparison of ecological and anthropogenic variables across different incident types and non-incidence villages in* Keralam *(Incident-.Elephant mortality)*

Human mortality

A total of 214 villages reported human mortality and injury incidents during the study period. Of these, 175 villages (81.8%) were classified as low incidence (0-10 incidents), 18 villages (8.4%) as medium incidence (10-20 incidents), and 21 villages (9.8%) as high incidence (>20 incidents). This indicates that although HEC affected many villages, the majority experienced relatively few incidents, while only a small proportion of villages were identified as high-conflict hotspots.

Among this Ranni being the most impacted division, recording incidents of 169 cases. Munnar division followed with 144 cases, while Munnar Wildlife and Nilambur North each reported conflicts in 138 and 108 cases respectively. These regions experience high levels of HEC, highlighting the need for targeted mitigation strategies.

A comprehensive examination of ecological and anthropogenic variables showed significant differences in landscape characteristics were also observed among human mortality and injury categories. Forest ($\chi^2 = 92.01$, $p < 0.001$), plantation ($\chi^2 = 116.41$, $p < 0.001$), road ($\chi^2 = 55.93$, $p < 0.001$), built-up area ($\chi^2 = 66.72$, $p < 0.001$), and crop cover ($\chi^2 = 65.04$, $p < 0.001$) varied significantly across conflict categories. Water bodies showed a weak but significant overall incident villages ($\chi^2 = 9.61$, $p = 0.048$), although no significant pairwise differences were detected following Bonferroni correction. Railway density did not differ significantly among conflict categories ($\chi^2 = 6.01$, $p = 0.199$). Dunn's post hoc analysis demonstrated that significant differences were predominantly associated with comparisons involving non-incident villages, particularly for forest, plantation, road, built-up, and crop variables (Fig. 1.15).

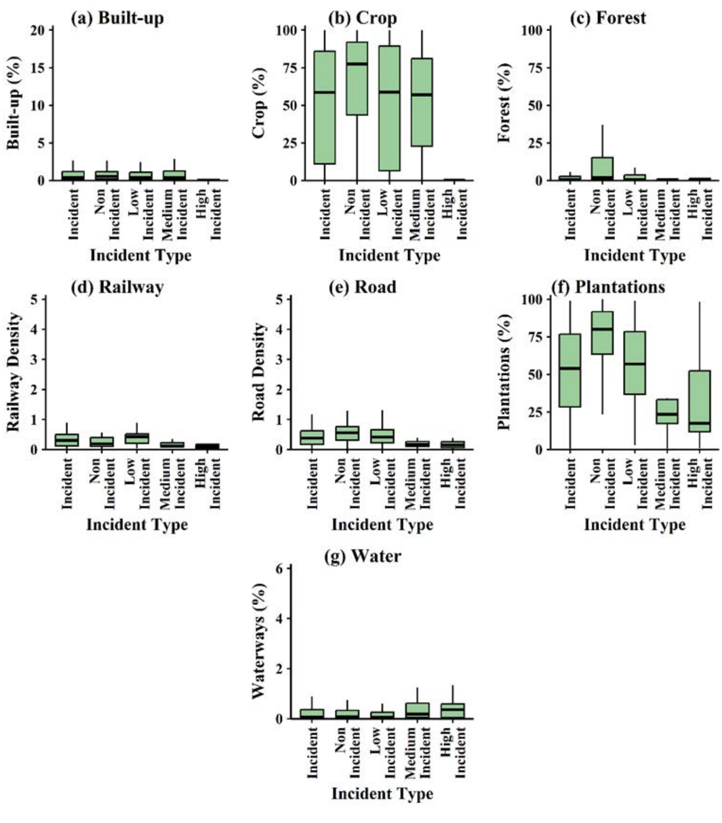


Figure 1.15: *Comparison of ecological and anthropogenic variables across different incident types and non-incidence villages of* Keralam *in relation to Human-Elephant Conflict*


Photo: Reji Chandran.

DISCUSSION

SPATIAL AND TEMPORAL PATTERNS OF ELEPHANT MORTALITY AND HUMAN CASUALTIES

The pronounced clustering of both elephant mortality and human fatalities within a limited number of forest divisions reflects the broader pattern observed across the Western Ghats, where HEC is concentrated at forest agriculture and forest-plantation interfaces and is further intensified by linear infrastructure. Across Keralam, Karnataka, and Tamil Nadu, studies have repeatedly shown that fragmentation of contiguous elephant habitat into plantation mosaics (tea, coffee, arecanut) and settlement edges creates persistent "conflict frontiers" where elephants regularly encounter people (Sukumar, 2003; Gubbi, 2012; Kumar et al., 2010). In the Nilgiri-Wayanad landscape, one of the largest contiguous elephant ranges in Asia, cross-boundary movements between Keralam (Wayanad, Nilambur), Karnataka (Bandipur, Nagarahole), and Tamil Nadu (Mudumalai, Sathyamangalam) concentrate risk along shared corridors and bottlenecks (Baskaran et al., 2013; Easa, 2010). The spatial pattern observed here, therefore, aligns with a regionally consistent mechanism, characterized by high human use at forest edges combined with the permeability of elephant corridors and overlap with anthropogenic infrastructure. These findings further highlight the importance of maintaining functional elephant corridors to sustain landscape connectivity and reduce conflict across fragmented elephant habitats (Pandey et al., 2024a).

Demographic and seasonal patterns also mirror findings from southern India. The predominance of adult male elephant mortality in conflict-related causes reflects well-established behavioural ecology, as males range more widely, are more likely to forage in crops, and consequently incur greater risk near human-dominated habitats (Sukumar, 1990; Fernando et al., 2005; Gubbi et al., 2014). Conversely, females and dependent groups are more frequently involved in accidental or retaliatory contexts when herds traverse settlement-adjacent areas. The strong male bias in fatalities and the concentration of incidents during the monsoon and post-monsoon seasons are consistent with studies from Karnataka and Tamil Nadu, where dense vegetation, reduced visibility, and peak agricultural activity elevate encounter probabilities during crop guarding and other field activities (Gubbi et al., 2014). Evidence from the Nilgiri Biosphere Reserve further indicates that seasonal crop phenology and water availability regulate elephant movement across state boundaries, amplifying conflict risk during particular months and in specific locations (Baskaran et al., 2013; Bal et al., 2011). Collectively, these similarities suggest that the temporal and spatial dynamics observed in Keralam reflect the broader ecological processes governing human-elephant conflict across the Western Ghatsimilar long-term spatial clustering of conflict hotspots and seasonal peaks in human fatalities have also been reported from Assam, Jharkhand, and Chhattisgarh, where long-term spatial analyses likewise identified strong influences of landscape characteristics on conflict occurrence (Pandey et al., 2026a; Athira et al., 2026; Roy et al., 2025a; Roy et al., 2025b).

ANTHROPOGENIC ELEPHANT MORTALITY AND DEMOGRAPHIC VULNERABILITY

Within the Western Ghats, anthropogenic mortality drivers associated with expanding infrastructure recur across states. Electrocution from illegal or poorly insulated power lines and collisions on railway tracks intersecting elephant movement corridors have been identified as major causes of elephant mortality in Keralam and Tamil Nadu, particularly along the Palakkad Gap and the Coimbatore-Palakkad railway sector (Kumar et al., 2010; Baskaran et al., 2013; Johnsingh et al., 2010). These findings are consistent with the concentration of elephant deaths recorded in the present study and emphasize the increasing influence of infrastructure on elephant survival. Comparable patterns of anthropogenic elephant mortality, particularly the predominance of electrocution and infrastructure-related deaths, have also been reported from Jharkhand and Chhattisgarh, highlighting the growing influence of human activities on elephant survival across Indian elephant landscapes (Pandey et al., 2025b; Pandey et al., 2025c). The predominance of adult male mortality further reflects behavioural differences between the sexes. Male elephants generally possess larger home ranges, disperse more extensively, and frequently raid crops, increasing their exposure to anthropogenic threats such as electrocution, railway collisions, and retaliatory killing (Sukumar, 1989; Fernando et al., 2005; Gubbi et al., 2014). Consequently, males experience disproportionately higher mortality than females, whose movements are largely constrained by herd structure and calf protection. These demographic differences highlight the interaction between elephant behaviour and anthropogenic pressures in determining mortality patterns across the landscape.

SHARED LANDSCAPE DRIVERS OF HUMAN-ELEPHANT CONFLICT AND ELEPHANT MORTALITY

The predominance of human-elephant conflict within forest-rich landscapes observed in the present study supports previous findings from Keralam that proximity to forests is one of the strongest determinants of conflict. Forest-fringe villages provide suitable elephant habitat while simultaneously increasing opportunities for encounters as elephants move between protected forests and adjacent agricultural landscapes (Jayson & Christopher, 2016). In Nilambur, villages with greater forest frontage experienced significantly higher levels of elephant conflict, highlighting the importance of forest connectivity in determining conflict intensity. Our findings further demonstrate that human mortality was more likely to occur near both forests and protected areas, emphasizing the importance of the forest-protected area interface as a persistent conflict zone. In addition, the positive relationship between patch density and human mortality, together with the negative association with the Largest Patch Index, indicates that fragmented landscapes composed of numerous small habitat patches are associated with greater conflict risk than landscapes containing larger, contiguous forest patches. These results suggest that landscape configuration, in addition to habitat proximity, plays an important role in shaping the spatial distribution of human-elephant conflict. Studies from Wayanad have similarly shown that conflict is concentrated near forest boundaries, with elephant movements driven by seasonal food availability and the proximity of agricultural fields rather than the overall extent of plantations (Morrison et al., 2025).

Although roads can restrict elephant movement and contribute to habitat fragmentation, severe conflict frequently occurs where forest connectivity remains intact and human settlements are dispersed along forest margins rather than within densely urbanized areas (Rangarajan,2010). Similar observations have been reported from Wayanad, where forest-adjacent landscapes consistently exhibited the highest probability of human elephant conflict. Built-up areas were consistently associated with lower conflict probability, indicating that elephants generally avoid highly urbanized environments and instead utilize rural forest-edge habitats. Recent spatial modelling from Wayanad likewise identified forest-edge settlements and areas adjacent to wildlife sanctuaries as persistent conflict hotspots, whereas densely populated urban centres exhibited comparatively low conflict risk (Morrison et al., 2025). The limited variation observed in waterways, railway density, and cropland suggests that these variables exert comparatively weaker influences than forest cover at the landscape scale. Rather than acting independently, these features likely interact with habitat connectivity, forest fragmentation, and human land-use patterns to shape elephant movement and conflict occurrence. Previous studies across Keralam have similarly emphasized that maintaining forest connectivity and reducing disturbance along forest margins are fundamental for mitigating human-elephant conflict (Jayson & Christopher, 2016; Münster,2012). Our study demonstrates that both ecological and anthropogenic landscape features shape human and elephant mortality in Keralam, although their relative influence differs between the two. Human mortality was strongly associated with proximity to forests and protected areas, whereas landscape fragmentation, characterized by higher patch density and lower largest patch index, significantly increased the probability of human fatalities. In contrast, elephant mortality was primarily influenced by railways and mining landscapes. The higher probability of human mortality near forests and protected areas reinforces the well-established role of the forest-human interface as a major conflict hotspot, where frequent overlap between elephant movements and human activities increases the likelihood of fatal encounters, where elephants frequently move between protected forests and surrounding agricultural and settlement mosaics in search of food and resources. Similar patterns have been reported across the Western Ghats and other elephant landscapes of southern India, where reserve boundaries and forest edges experience disproportionately high levels of human-elephant conflict because of overlapping human and elephant space use (Sukumar, 2003; Gubbi, 2012; Karanth & Kudalkar, 2017). Habitat alteration and fragmentation caused by extractive activities may intensify interactions between elephants and people by disrupting traditional movement routes, a pattern increasingly recognized across Asian elephant landscapes (Goswami et al., 2014). Recent landscape-scale analyses from Assam similarly demonstrated that the spatial distribution of human–elephant conflict is jointly influenced by forest proximity, protected areas, and anthropogenic landscape features, highlighting the importance of landscape configuration in determining conflict risk across Indian elephant landscapes (Pandey et al., 2026a). Comparable relationships between habitat fragmentation, expanding human land use, and mortality risk have also been documented in Assam, Jharkhand, and Chhattisgarh, indicating that anthropogenic landscape modification consistently drives both human-elephant conflict and elephant mortality across diverse Indian elephant landscapes (Athira et al., 2026; Roy et al., 2025a; Roy et al., 2025b; Pandey et al.,2025a; Pandey et al., 2025b).

Elephant mortality in Keralam needs to be viewed within the state's closely connected forest, protected area, plantation, and agricultural landscapes. Elephants regularly move beyond protected forests into human-dominated areas where plantations, farms, and settlements occur adjacent to natural habitats, increasing opportunities for interactions with people (Münster &Münster, 2012). Studies from Keralam have similarly documented frequent elephant use of agricultural areas and associated crop damage, highlighting the close overlap between elephant movement and farming landscapes (Veeramani et al., 2004; Nair & Jayson, 2021). Consistent with this broader landscape context, our analysis identified proximity to forests and protected areas, together with landscape fragmentation, as important predictors of human mortality. These findings suggest that reducing elephant mortality and human-elephant conflict will require management not only within protected forests but also across forest edges and fragmented landscapes that facilitate elephant movement through agricultural and plantation areas. Our study demonstrates that both ecological and anthropogenic landscape features shape human and elephant mortality in Keralam, although their relative influence differs between the two. Human mortality was strongly associated with proximity to elephant reserves and mining areas, whereas elephant mortality was primarily influenced by railways and mining landscapes. The higher probability of human mortality near elephant reserves reinforces the well-established role of the forest human interface as a conflict hotspot where elephants frequently move between protected forests and surrounding agricultural and settlement mosaics in search of food and resources. Similar patterns have been reported across the Western Ghats and other elephant landscapes of southern India, where reserve boundaries and forest edges experience disproportionately high levels of human-elephant conflict because of overlapping human and elephant space use (Sukumar, 2003; Gubbi, 2012; Karanth & Kudalkar, 2017).

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CONCLUSION

The findings reveal that conflict is spatially concentrated in forest-fringe landscapes, with prominent hotspots in the Nilambur, Mannarkkad, Munnar, and Palakkad forest divisions, reflecting the increasing overlap between elephant movement corridors and expanding human land use. Human mortality was primarily associated with proximity to elephant reserves and mining areas, whereas elephant mortality was significantly influenced by railways and mining landscapes, highlighting the growing impact of anthropogenic infrastructure on both human safety and elephant survival. The predominance of adult male elephant mortality further underscores the demographic vulnerability of wide-ranging individuals that frequently utilize human-modified landscapes. Collectively, these findings demonstrate that maintaining habitat connectivity while minimizing the impacts of infrastructure development and extractive activities is essential for reducing conflict and conserving elephant populations. Strengthening landscape-level planning, securing elephant corridors, implementing elephant-friendly infrastructure, and enhancing community-based conflict mitigation and early-warning systems will be critical for promoting long-term human–elephant coexistence in *Keralam* and across the Western Ghats.

Suggested Measures to Minimize Human-Elephant Conflict in the State of Keralam

Between 2008 and 2025, Keralam recorded 695 elephant deaths and 1,781 human-elephant conflict (HEC) incidents, resulting in 581 human fatalities and 1,200 injuries. Electrocution emerged as the leading anthropogenic cause of elephant mortality, followed by train collisions and vehicular accidents. Conflict incidents were concentrated in specific villages and forest divisions. Villages like Kannan Devan Hills, Kuttampuzha, Chittar, Mankulam, Padavayal, and Peechi are identified as persistent hotspots for both elephant mortality and human casualties. These findings highlight the need for landscape-specific, evidence-based mitigation strategies for local conflict drivers rather than a common management approach across the state.

The Keralam Forest Department has adopted an integrated strategy to mitigate HEC through a combination of physical barriers, technological interventions, and landscape-level management. Physical measures include the installation and maintenance of solar-powered fences, hanging solar fences, elephant-proof trenches (EPTs), elephant-proof walls, biological fences, and rail fencing to reduce elephant movement into agricultural fields and human settlements. Under the Mission Solar Fencing programme (2024-2025), approximately 848 km of solar fencing was restored across the state. In Wayanad Wildlife Sanctuary, nearly 190 km of solar fences and trenches have been established, while the Landscape Mitigation Plan for Idukki Wildlife Sanctuary recommends strengthening existing barriers and installing additional hanging solar fences and EPTs in high-conflict areas.

The state has also strengthened conflict monitoring and emergency response through technology-based systems and dedicated response teams. SMS-based early warning systems, real-time elephant monitoring, camera traps, drones, GPS-based tracking, motion sensors, and the Wild Watch mobile application are used to detect elephant movements and provide timely alerts to nearby communities. In addition, the Forest Department has established 28 Rapid Response Teams (RRTs) and more than 60 Primary Response Teams (PRTs) to respond quickly to elephant incursions and support local communities during conflict situations. Public awareness committees and community participation programmes further enhance coordination between forest officials and residents in conflict-prone areas (Keralam Forest Department, 2024, 2025).

Habitat improvement and long-term landscape management are also key components of Keralam's conflict mitigation strategy. Under the Mission Food, Fodder & Water programme, the Forest Department restored 1,434 ponds and check dams, 574 paddy fields, and 308 additional water sources within forest areas to improve food and water availability for wildlife and reduce elephant movement into human-dominated landscapes. The Navakiranam voluntary resettlement programme has relocated 818 eligible families from forest interiors to reduce human-elephant interactions. Together, these initiatives demonstrate that Keralam's approach extends beyond physical barriers by integrating habitat restoration, technological monitoring, rapid response, and community participation to promote long-term coexistence between people and elephants (Keralam Forest Department, 2024, 2025).

In March 2024, Keralam became the first state in India to declare human wildlife conflict (HWC), including HEC, as a state-specific disaster under its disaster management framework (The Hindu, 2024). This policy expanded conflict management beyond the traditional way of the Forest Department by integrating the Keralam State Disaster Management Authority (KSDMA), district disaster management authorities, and other departments, including Revenue, Police, Health, and Local Self-Government Institutions. The framework promotes coordinated preparedness, emergency response, compensation, rehabilitation, and long-term mitigation through a multi-agency approach, enabling more systematic and timely management of HWC across the state (Keralam State Disaster Management Authority, 2024).

Keralam has implemented several measures, including physical barriers, early warning systems, rapid response teams, and habitat management, to reduce human-elephant conflict. However, the continued presence of conflict hotspots suggests that these interventions need further improvement through landscape-specific and evidence-based approaches. Future strategies should prioritize maintaining elephant movement corridors and ecological connectivity while considering local ecological and socio-economic conditions. Rather than applying uniform solutions across the forest division level, mitigation efforts should focus on site-specific measures that effectively balance human safety with long-term elephant conservation.

RECOMMENDATIONS FOR MANAGING ELEPHANT MORTALITY IN KERALAM

High-mortality villages such as Mankulam, Padavayal, Kuttampuzha, Kannan Devan Hills, Pariyaram, and Peechi should be prioritized for mitigation, as elephant mortality in these areas are associated with landscapes covering forests, tea, coffee, and cardamom plantations; roads; and expanding built-up areas. These findings indicate that habitat fragmentation and increasing human activities are major drivers of elephant mortality. Therefore, mitigation efforts should focus on reducing infrastructure-related risks, maintaining habitat connectivity, and improving coexistence between people and elephants in these high-risk landscapes.

Enhancing Existing Barrier Infrastructure

Keralam has already implemented barrier-based mitigation measures, including solar-powered fences, hanging solar fences, elephant-proof trenches (EPTs), and elephant-proof walls. Based on the present findings, these existing barriers should be strengthened in high-mortality villages such as Mankulam, Padavayal, Kuttampuzha, Kannan Devan Hills, Pariyaram, and Peechi. Barriers should be strategically placed around villages and agricultural fields to guide elephants away from human settlements while maintaining natural movement corridors and habitat connectivity. Regular inspection, maintenance, and monitoring of fences and trenches are essential to improve their effectiveness and minimise impacts on elephants. Recent evidence from southern India also highlights that poorly designed or maintained trenches and fences can cause elephant injuries and mortality, showing the need for safer barrier design and management (The Hindu Bureau, 2025).

Mitigation of Electrocution-Related Mortality

Electrocution mitigation should be prioritised in high-risk divisions such as Mannarkkad, Munnar, Mankulam, Kothamangalam, Malayattoor, Konni, Chalakudy, and Wayanad South, where repeated incidents indicate persistent risks from electrical infrastructure. Existing measures, including insulation of vulnerable power lines, modification of hazardous electrical infrastructure, routine inspection and maintenance, and close coordination between the Forest and Electricity Departments, should be further strengthened (Keralam Forest Department, 2024, 2025). Long-term monitoring of elephant movement routes and electrocution hotspots should be integrated with geospatial databases and periodic safety audits to identify high-risk locations and evaluate the effectiveness of mitigation measures. A comprehensive geospatial mapping of all legal power lines and electric fences should be developed and regularly updated to identify illegal or poorly maintained fences that pose a risk to elephants. Stricter enforcement against illegal electrification, and appropriate penalties for violations should be combined with community awareness programmes to promote safe fencing practices and reduce electrocution-related elephant mortality. In addition, power-line mitigation should consider local environmental conditions and land-use patterns, as recent evidence suggests that environmental and socio-economic factors strongly influence elephant movement and the effectiveness of conflict mitigation measures (Prasad *et al.,* 2025). Similarly, joint inspections and coordinated monitoring by the Keralam Forest Department and Keralam State Electricity Board (KSEB) should be established for identifying hazardous electrical infrastructure and ensuring timely corrective action. A dedicated rapid-response mechanism should be established to address damaged power lines, illegal electric fencing, and other electrical hazards immediately after detection. Such an adaptive, evidence-based approach would improve the effectiveness of existing mitigation measures while reducing electrocution-related mortality in Keralam.

Strategies to Reduce Elephant-Train Collisions

The Wildlife Institute of India (WII), Project Elephant Division (MoEFCC), and Ministry of Railways have recommended measures such as permanent speed restrictions, vegetation clearance, joint patrolling, wildlife crossing structures, embankment modifications, and intelligent elephant detection systems to reduce elephant-train collisions in vulnerable railway stretches (PE-MoEFCC-WII, 2025). In Keralam, the recently implemented AI-enabled elephant detection and early warning system along the Walayar-Madukkarai section has successfully reduced collision risk by providing real-time alerts to loco pilots and forest officials (Shaji, 2025). Similarly, an AI-powered smart fencing system using Distributed Acoustic Sensing (DAS) in the Periyar Range of the North Wayanad Forest Division (ONManorama, 2025). Although AI-enabled DAS systems have shown promising results in reducing train accidents, their effectiveness depends on minimizing false alarms caused by environmental noise, non-target animal movements, human activities, train vibrations, fiber-optic disturbances, and AI classification errors. Integrating multi-sensor data, robust AI models, and regular system maintenance can substantially improve detection accuracy and the reliability of early warning systems (Indian Railways Centre for Advanced Maintenance Technology, 2025). Building on this initiative, the system should be evaluated through long-term monitoring and, if found effective, expanded to high-conflict divisions such as Mannarkkad, Munnar, Mankulam, Nilambur North, and Nilambur South. To further improve elephant safety, AI surveillance should be expanded to all identified hotspots; guide fencing should be used to direct elephants toward scientifically designed underpasses and overpasses instead of continuous fencing; and habitat restoration should be undertaken to reduce unnecessary track crossings.

Strengthening Habitat Restoration Measures

Existing initiatives by the Keralam Forest Department, including habitat restoration, planting with native fodder species, water augmentation, invasive species removal, and corridor restoration, should be prioritised within core elephant habitats and large forest blocks (Keralam Forest Department, 2024, 2025). Waterholes and other habitat enhancement measures should be developed primarily within large forest patches rather than in small, isolated forest patches near villages or plantations, where they may attract elephants and increase conflict. These initiatives should be carefully planned to maintain traditional elephant movement routes and ecological corridors, ensuring that habitat improvement complements rather than obstructs natural elephant movement. Long-term monitoring of habitat quality, elephant use of restored habitats, and corridor functionality should be integrated into adaptive management to evaluate and improve the effectiveness of these measures (Keralam Forest Department, 2024, 2025).

Translocation of Conflict Elephants

Solitary adult males are responsible for the highest proportion of HEC incidents, particularly crop raiding and property damage. Long-term monitoring of these conflict-prone individuals should therefore be strengthened. Keralam has already initiated the radio-collaring of selected elephants to monitor their movements and support conflict management. These efforts should be expanded by integrating radio-collar data with real-time early warning systems, community alert networks, and rapid response teams to provide timely warnings before elephants enter villages or agricultural areas. Long-term monitoring of elephant movement patterns and conflict hotspots should also guide the strategic placement of mitigation measures while maintaining traditional movement routes and ecological corridors. Studies from Sri Lanka have shown that translocation rarely provides a long-term solution, as many conflict elephants attempt to return to their original home ranges or continue to cause conflict in new areas after release (Fernando *et al.,* 2012). A similar pattern was observed in Keralam during the translocation of the conflict elephant Arikomban from Chinnakkanal in 2023, where the elephant moved into human-dominated areas after release, requiring further management interventions. This case highlights that long-term monitoring and proactive conflict prevention are more sustainable than relying on repeated translocation of conflict elephants, which often provides only temporary relief (Shankar, 2023; Government of Keralam, 2024).

RECOMMENDATIONS FOR MANAGING HUMAN DEATHS AND INJURIES IN KERALAM

Human-Elephant Conflict (HEC) in Keralam is primarily driven by increasing interaction between elephant movement routes and human-dominated landscapes, resulting from habitat fragmentation, land-use changes, and linear infrastructure development. Spatial analysis identified major conflict hotspots in the Nilambur, Palakkad-Mannarkkad, Munnar-Mankulam, Kothamangalam, and Konni landscapes, with villages such as Kannan Devan Hills, Pariyaram, Chittar, Kuttampuzha, Mlappara, Nilambur, and Palakkad experiencing high conflict intensity. These areas coincide with traditional elephant movement routes and fragmented forest-agriculture interfaces, underscoring the need for landscape-level management approaches that maintain ecological connectivity, avoid disruption of established elephant movement pathways, and reduce interactions between elephants and human settlements through scientifically planned mitigation measures.

Early Warning System

The Keralam Forest Department has implemented a real-time elephant early warning system through the Wild Watch mobile application, AI-enabled surveillance cameras, camera traps, drones, and Division Emergency Operations Centers (DEOCs) to monitor elephant movement and alert communities in conflict-prone areas. The existing system can be further strengthened by adopting GPS-based geofencing so that alerts are issued only to people within a 7 km radius of the detected elephant, thereby minimizing unnecessary panic and alert fatigue. The system should also integrate bulk SMS, automated voice calls in Malayalam, LED display boards, village public address systems, and local cable television scrolls to ensure timely dissemination of warnings, particularly in areas with poor internet connectivity.

Rapid Response Teams (RRTs)

The Keralam Forest Department has deployed Rapid Response Teams in conflict-prone areas to respond to elephant invasions, assist local communities, and coordinate with the Division Emergency Operations Centres. Recently, the department has strengthened this approach by involving RRTs, field staff, and forest watchers in profiling habitual conflict-causing elephants through photographs, videos, and field observations to understand their movement patterns, behaviour, and temporal activity. This operational database helps identify individual elephants that repeatedly enter human settlements, enabling targeted interventions such as radio-collaring, continuous monitoring, and site-specific conflict management rather than broad-scale interventions. The effectiveness of RRTs can be further improved by integrating elephant profiling with GPS-based tracking, AI-enabled early warning systems, and centralized data management to facilitate proactive conflict mitigation in high-risk landscapes (Sajit, 2026).

Compensation Mechanism

The Keralam Forest Department provides ex gratia compensation for human deaths, injuries, crop damage, livestock loss, and property damage caused by HEC. Currently, compensation of ₹10 lakh is provided for human fatalities, medical expenses up to ₹1 lakh for injuries, and financial assistance for crop, livestock, and property losses based on field damage assessment. Claims can be submitted through the e-District portal, Akshaya Centres, or the Divisional Forest Officer, improving access to relief for affected communities (Government of Keralam, 2024). To further strengthen the existing compensation mechanism, claims should be processed within a fixed time frame using mobile-based geotagged verification, online claim tracking, and Direct Benefit Transfer (DBT) to ensure faster, transparent, and efficient disbursement of assistance. Periodic review of compensation rates should also be undertaken to reflect current market values of crops, livestock, and property losses, while integrating compensation records with geospatial conflict databases can help identify recurring hotspots and prioritize preventive interventions. Transparent and timely compensation, combined with community participation and awareness programmes, can improve public trust and encourage greater cooperation in long-term HEC mitigation (Government of Keralam, 2024; Shajna *et al.,* 2025).

Crop Damage and Village Protection

The Keralam Forest Department has implemented solar fencing, elephant-proof trenches, rail fencing, underbrush clearance, and Rapid Response Teams (RRTs) to reduce crop damage and protect villages. Under Mission Solar Fencing 2024, approximately 848 km of solar fencing was restored and made operational (Government of Keralam, 2024). Keralam has recently added additional measures in Wayanad, including expanded 60 km solar fencing, 4 additional RRT, scientific wildlife assessments, and improved forest road management (ONmanorama, 2026). However, the effectiveness of these measures is often reduced by inadequate maintenance and barrier breaches. Existing barriers should therefore be regularly inspected, geospatially mapped, and maintained to identify damaged sections and illegal fence connections. Barrier placement should prioritize protecting villages and agricultural areas rather than blocking traditional elephant movement routes, while smart intrusion sensors, community-based fence monitoring, and less palatable buffer crops along forest boundaries can further improve protection without disrupting ecological connectivity. In plantation landscapes, particularly tea, coffee, and cardamom estates, internal roads should be regularly cleared, safe assembly points established, and workers periodically trained in elephant behaviour and emergency response (Shajna *et al.,* 2025; Government of Keralam, 2024).

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Photo: Reji Chandran.

APPENDIX I

Details of the Villages in Keralam *which witnessed Elephant Mortality. (2008-2025)*

Sl.No	Count	Village	Subdistrict	District	State
1	15	Mankulam	Devikulam	Idukki	Keralam
2	14	Padavayal	Tribal Taluk Office Attappadi	Palakkad	Keralam
3	12	Kannan Devan Hills	Devikulam	Idukki	Keralam
4	12	Kuttampuzha	Kothamangalam	Ernakulam	Keralam
5	8	Aruvappulam	Konni	Pathanamthitta	Keralam
6	8	Karulai	Nilambur	Malappuram	Keralam
7	8	Pariyaram	Chalakkudy	Thrissur	Keralam
8	7	Palakkayam	Mannarkad	Palakkad	Keralam
9	6	Agali	Tribal Taluk Office Attappadi	Palakkad	Keralam
10	5	Amarambalam	Nilambur	Malappuram	Keralam
11	4	Chittar	Konni	Pathanamthitta	Keralam
12	4	Nelliyampathy	Chittur	Palakkad	Keralam
13	4	Puthuppariyaram II	Palakkad	Palakkad	Keralam
14	4	Thannithode	Konni	Pathanamthitta	Keralam
15	3	Nadavayal	Sulthanbathery	Wayanad	Keralam
16	3	Nagalassery	Pattambi	Palakkad	Keralam
17	3	Pottassery I	Mannarkad	Palakkad	Keralam
18	3	Pudur	Tribal Taluk Office Attappadi	Palakkad	Keralam
19	2	Arienkavu	Punalur	Kollam	Keralam
20	2	Ayyampuzha	Aluva	Ernakulam	Keralam
21	2	Chinnakanal	Udumbanchola	Idukki	Keralam
22	2	Chokkad	Nilambur	Malappuram	Keralam
23	2	Edakkara	Nilambur	Malappuram	Keralam
24	2	Elappully II	Palakkad	Palakkad	Keralam
25	2	Karimba I	Mannarkad	Palakkad	Keralam
26	2	Kottathara	Tribal Taluk Office Attappadi	Palakkad	Keralam
27	2	Malampuzha I	Palakkad	Palakkad	Keralam
28	2	Mannamkandam	Devikulam	Idukki	Keralam

29	2	Mannarkad I CT	Mannarkad	Palakkad	Keralam
30	2	Mannur	Palakkad	Palakkad	Keralam
31	2	Muthalamada I	Chittur	Palakkad	Keralam
32	2	Pulpalli	Sulthanbathery	Wayanad	Keralam
33	1	Adoor	Kasaragod	Kasaragod	Keralam
34	1	Aikaranad North	Kunnathunad	Ernakulam	Keralam
35	1	Aikaranad South	Kunnathunad	Ernakulam	Keralam
36	1	Akathethara	Palakkad	Palakkad	Keralam
37	1	Arakuzha	Muvattupuzha	Ernakulam	Keralam
38	1	Baisonvally	Udumbanchola	Idukki	Keralam
39	1	Elappally	Thodupuzha	Idukki	Keralam
40	1	Enmakaje	Manjeswaram	Kasaragod	Keralam
41	1	Eramam	Payyannur	Kannur	Keralam
42	1	Erimayur II	Alathur	Palakkad	Keralam
43	1	Idukki	Idukki	Idukki	Keralam
44	1	Kadampazhipuram II	Ottappalam	Palakkad	Keralam
45	1	Kairady	Chittur	Palakkad	Keralam
46	1	Kalikavu	Nilambur	Malappuram	Keralam
47	1	Kallamala	Tribal Taluk Office Attappadi	Palakkad	Keralam
48	1	Kalloorkkad	Muvattupuzha	Ernakulam	Keralam
49	1	Kanakkari	Meenachil	Kottayam	Keralam
50	1	Kanthippara	Udumbanchola	Idukki	Keralam
51	1	Karakurissi	Mannarkad	Palakkad	Keralam
52	1	Karikkode Part	Thodupuzha	Idukki	Keralam
53	1	Karimkunnam Part	Thodupuzha	Idukki	Keralam
54	1	Karivedakam	Kasaragod	Kasaragod	Keralam
55	1	Kattappana	Idukki	Idukki	Keralam
56	1	Kayaralam	Taliparamba	Kannur	Keralam
57	1	Kedavoor	Kothamangalam	Ernakulam	Keralam
58	1	Keerampara	Kothamangalam	Ernakulam	Keralam
59	1	Keralam Estate	Nilambur	Malappuram	Keralam
60	1	Kizhakkencheri II	Alathur	Palakkad	Keralam
61	1	Kodassery	Chalakkudy	Thrissur	Keralam
62	1	Kodikulam	Thodupuzha	Idukki	Keralam
63	1	Kodumba	Palakkad	Palakkad	Keralam
64	1	Kondoor	Meenachil	Kottayam	Keralam
65	1	Konnathady	Idukki	Idukki	Keralam

66	1	Konni	Konni	Pathanamthitta	Keralam
67	1	Kottappady	Kothamangalam	Ernakulam	Keralam
68	1	Kuttiyeri	Taliparamba	Kannur	Keralam
69	1	Lakkidi Perur II	Ottappalam	Palakkad	Keralam
70	1	Mannarkad II	Mannarkad	Palakkad	Keralam
71	1	Mundur II	Palakkad	Palakkad	Keralam
72	1	Muttil North	Vythiri	Wayanad	Keralam
73	1	Muttil South	Vythiri	Wayanad	Keralam
74	1	Padichira	Sulthanbathery	Wayanad	Keralam
75	1	Paduvilayi CT	Thalassery	Kannur	Keralam
76	1	Palakkuzha	Muvattupuzha	Ernakulam	Keralam
77	1	Panamaram	Mananthavady	Wayanad	Keralam
78	1	Pariyaram CT	Taliparamba	Kannur	Keralam
79	1	Perumbavoor CT	Kunnathunad	Ernakulam	Keralam
80	1	Perunad	Ranni	Pathanamthitta	Keralam
81	1	Piravanthur	Pathanapuram	Kollam	Keralam
82	1	Poopara	Udumbanchola	Idukki	Keralam
83	1	Poothadi	Sulthanbathery	Wayanad	Keralam
84	1	Poovarany	Meenachil	Kottayam	Keralam
85	1	Pothanikkad	Kothamangalam	Ernakulam	Keralam
86	1	Punnala	Pathanapuram	Kollam	Keralam
87	1	Sholayur	Tribal Taluk Office Attappadi	Palakkad	Keralam
88	1	Sivapuram	Thalassery	Kannur	Keralam
89	1	Sreekandapuram	Taliparamba	Kannur	Keralam
90	1	Sreekrishnapuram I	Ottappalam	Palakkad	Keralam
91	1	Thachampara	Mannarkad	Palakkad	Keralam
92	1	Tholambra	Thalassery	Kannur	Keralam
93	1	Thuvvur	Nilambur	Malappuram	Keralam
94	1	Udumbannoor	Thodupuzha	Idukki	Keralam
95	1	Vandazhi I	Alathur	Palakkad	Keralam
96	1	Vannapuram	Thodupuzha	Idukki	Keralam
97	1	Varappetty	Kothamangalam	Ernakulam	Keralam
98	1	Vellathuval	Devikulam	Idukki	Keralam
99	1	Vellayur	Nilambur	Malappuram	Keralam
100	1	Vellikulangara	Chalakkudy	Thrissur	Keralam
101	1	Velliyamattom	Thodupuzha	Idukki	Keralam
102	1	West Eleri	Vellarikkundu	Kasaragod	Keralam

APPENDIX II

Details of Villages in Keralam *which witnessed Human Mortality and Injuries by Elephant. (2008-2025)*

Sl.No	Count	Village	Subdistrict	District	State
1	119	Kannan Devan Hills	Devikulam	Idukki	Keralam
2	94	Pariyaram	Chalakkudy	Thrissur	Keralam
3	73	Chittar	Konni	Pathanamthitta	Keralam
4	69	Kuttampuzha	Kothamangalam	Ernakulam	Keralam
5	61	Mlappara	Peerumade	Idukki	Keralam
6	54	Nilambur CT	Nilambur	Malappuram	Keralam
7	54	Aruvappulam	Konni	Pathanamthitta	Keralam
8	52	Palakkad	Palakkad	Palakkad	Keralam
9	47	Vellayur	Nilambur	Malappuram	Keralam
10	42	Ayyampuzha	Aluva	Ernakulam	Keralam
11	39	Kulathupuzha	Punalur	Kollam	Keralam
12	37	Nelliyampathy	Chittur	Palakkad	Keralam
13	35	Pottassery II	Mannarkad	Palakkad	Keralam
14	25	Karulai	Nilambur	Malappuram	Keralam
15	25	Muppainad	Vythiri	Wayanad	Keralam
16	25	Perunad	Ranni	Pathanamthitta	Keralam
17	25	Idukki	Idukki	Idukki	Keralam
18	24	Mannamkandam	Devikulam	Idukki	Keralam
19	24	Chokkad	Nilambur	Malappuram	Keralam
20	21	Thirunelly	Mananthavady	Wayanad	Keralam
21	21	Padavayal	Tribal Taluk Office Attappadi	Palakkad	Keralam
22	19	Kothamangalam	Kothamangalam	Ernakulam	Keralam
23	19	Thomattuchal	Sulthanbathery	Wayanad	Keralam
24	19	Vazhichal	Kattakkada	Thiruvanantha-puram	Keralam
25	18	Ayyappancoil	Idukki	Idukki	Keralam
26	17	Arienkavu	Punalur	Kollam	Keralam
27	15	Thenmala	Punalur	Kollam	Keralam
28	14	Palakkayam	Mannarkad	Palakkad	Keralam
29	13	Kurumbilangode	Nilambur	Malappuram	Keralam
30	13	Thannithode	Konni	Pathanamthitta	Keralam

31	13	Mannarkad I CT	Mannarkad	Palakkad	Keralam
32	13	Kumily	Peerumade	Idukki	Keralam
33	12	Akampadam	Nilambur	Malappuram	Keralam
34	12	Muthalamada I	Chittur	Palakkad	Keralam
35	12	Kanjikuzhi	Idukki	Idukki	Keralam
36	11	Peechi	Thrissur	Thrissur	Keralam
37	11	Aralam	Iritty	Kannur	Keralam
38	11	Marayoor	Devikulam	Idukki	Keralam
39	11	Thennoor	Nedumangad	Thiruvananthapuram	Keralam
40	10	Kidanganad	Sulthanbathery	Wayanad	Keralam
41	10	Noolpuzha	Sulthanbathery	Wayanad	Keralam
42	10	Vannapuram	Thodupuzha	Idukki	Keralam
43	10	Mankulam	Devikulam	Idukki	Keralam
44	9	Chakkittapara	Koyilandi	Kozhikode	Keralam
45	9	Vithura	Nedumangad	Thiruvananthapuram	Keralam
46	9	Konnathady	Idukki	Idukki	Keralam
47	8	Edakkara	Nilambur	Malappuram	Keralam
48	8	Pullipadam	Nilambur	Malappuram	Keralam
49	8	Mannarkad II	Mannarkad	Palakkad	Keralam
50	8	Punalur	Punalur	Kollam	Keralam
51	8	Pudur	Tribal Taluk Office Attappadi	Palakkad	Keralam
52	8	Udumbannoor	Thodupuzha	Idukki	Keralam
53	8	Mambad	Nilambur	Malappuram	Keralam
54	7	Puthuppariyaram II	Palakkad	Palakkad	Keralam
55	7	Peringamala	Nedumangad	Thiruvananthapuram	Keralam
56	7	Edamon	Punalur	Kollam	Keralam
57	7	Keezhanthoor	Devikulam	Idukki	Keralam
58	7	Thankamony	Idukki	Idukki	Keralam
59	7	Erumeli South	Kanjirappally	Kottayam	Keralam
60	6	Poopara	Udumbanchola	Idukki	Keralam
61	6	Thondernad	Mananthavady	Wayanad	Keralam
62	6	Iravan	Konni	Pathanamthitta	Keralam
63	6	Chempanoda	Koyilandi	Kozhikode	Keralam
64	6	Cheruvanchery	Thalassery	Kannur	Keralam
65	6	Thariyode	Vythiri	Wayanad	Keralam

66	6	Kunjithanny	Devikulam	Idukki	Keralam
67	6	Parathodu	Udumbanchola	Idukki	Keralam
68	6	Kombanad	Kunnathunad	Ernakulam	Keralam
69	5	Pudussery East	Palakkad	Palakkad	Keralam
70	5	Thiruvambadi	Thamarassery	Kozhikode	Keralam
71	5	Vazhikkadavu	Nilambur	Malappuram	Keralam
72	5	Mannoorkara	Kattakkada	Thiruvanantha-puram	Keralam
73	5	Konnithazham	Konni	Pathanamthitta	Keralam
74	5	Pottassery I	Mannarkad	Palakkad	Keralam
75	5	Chinnakanal	Udumbanchola	Idukki	Keralam
76	5	Kalikavu	Nilambur	Malappuram	Keralam
77	5	Kottathara	Tribal Taluk Office Attappadi	Palakkad	Keralam
78	5	Karunapuram	Udumbanchola	Idukki	Keralam
79	5	Kottakamboor	Devikulam	Idukki	Keralam
80	5	Kalkoonthal	Udumbanchola	Idukki	Keralam
81	4	Santhanpara	Udumbanchola	Idukki	Keralam
82	4	Kottiyoor	Iritty	Kannur	Keralam
83	4	Udumbanchola	Udumbanchola	Idukki	Keralam
84	4	Channappetta	Punalur	Kollam	Keralam
85	4	Chungathara	Nilambur	Malappuram	Keralam
86	4	Koodaranji	Thamarassery	Kozhikode	Keralam
87	4	Kavilumpara	Vatakara	Kozhikode	Keralam
88	4	Periya	Mananthavady	Wayanad	Keralam
89	4	Malampuzha I	Palakkad	Palakkad	Keralam
90	4	Irulam	Sulthanbathery	Wayanad	Keralam
91	4	Pananchery	Thrissur	Thrissur	Keralam
92	4	Thinkalkarikkakom	Punalur	Kollam	Keralam
93	4	Adoor	Kasaragod	Kasaragod	Keralam
94	4	Manalithara	Talappilly	Thrissur	Keralam
95	4	Kattappana	Idukki	Idukki	Keralam
96	4	Thrissur	Thrissur	Thrissur	Keralam
97	4	Piravanthur	Pathanapuram	Kollam	Keralam
98	4	Punnala	Pathanapuram	Kollam	Keralam
99	4	Amarambalam	Nilambur	Malappuram	Keralam
100	4	Vettilappara	Ernad	Malappuram	Keralam
101	4	Anaviratty	Devikulam	Idukki	Keralam

102	4	Upputhode	Idukki	Idukki	Keralam
103	4	Neriamangalam	Kothamangalam	Ernakulam	Keralam
104	3	Pozhuthana	Vythiri	Wayanad	Keralam
105	3	Vellad	Taliparamba	Kannur	Keralam
106	3	Kollamula	Ranni	Pathanamthitta	Keralam
107	3	Ambalapara II	Ottappalam	Palakkad	Keralam
108	3	Vellarimala	Vythiri	Wayanad	Keralam
109	3	Kottappadi Part	Vythiri	Wayanad	Keralam
110	3	Attoor	Talappilly	Thrissur	Keralam
111	3	Chakkupallam	Udumbanchola	Idukki	Keralam
112	3	Vandanmedu	Udumbanchola	Idukki	Keralam
113	3	Koodal	Konni	Pathanamthitta	Keralam
114	3	Malayalapuzha Part	Konni	Pathanamthitta	Keralam
115	3	Varappetty	Kothamangalam	Ernakulam	Keralam
116	3	Karakurissi	Mannarkad	Palakkad	Keralam
117	3	Kizhakkencheri II	Alathur	Palakkad	Keralam
118	3	Wandoor	Nilambur	Malappuram	Keralam
119	3	Keralam Estate	Nilambur	Malappuram	Keralam
120	3	Vandazhi I	Alathur	Palakkad	Keralam
121	3	Vattavada	Devikulam	Idukki	Keralam
122	3	Kanthalloor	Devikulam	Idukki	Keralam
123	3	Vathikudy	Idukki	Idukki	Keralam
124	3	Kanthippara	Udumbanchola	Idukki	Keralam
125	3	Puthuppadi	Thamarassery	Kozhikode	Keralam
126	3	Velliyamattom	Thodupuzha	Idukki	Keralam
127	3	Vellathuval	Devikulam	Idukki	Keralam
128	3	Malayattoor	Aluva	Ernakulam	Keralam
129	2	Agali	Tribal Taluk Office Attappadi	Palakkad	Keralam
130	2	Rajakumari	Udumbanchola	Idukki	Keralam
131	2	Vadasserikkara	Ranni	Pathanamthitta	Keralam
132	2	Alanallur III	Mannarkad	Palakkad	Keralam
133	2	Erumeli North	Kanjirappally	Kottayam	Keralam
134	2	Nellipoyil	Thamarassery	Kozhikode	Keralam
135	2	Ayyankunnu	Iritty	Kannur	Keralam
136	2	Thrissilery	Mananthavady	Wayanad	Keralam
137	2	Akathethara	Palakkad	Palakkad	Keralam

138	2	Killannur CT	Thrissur	Thrissur	Keralam
139	2	Nadavayal	Sulthanbathery	Wayanad	Keralam
140	2	Baisonvally	Udumbanchola	Idukki	Keralam
141	2	Pallivasal	Devikulam	Idukki	Keralam
142	2	Wadakkanchery CT	Talappilly	Thrissur	Keralam
143	2	Kizhakkencheri I	Alathur	Palakkad	Keralam
144	2	Palode	Nedumangad	Thiruvanantha-puram	Keralam
145	2	Pampadumpara	Udumbanchola	Idukki	Keralam
146	2	Alayamon	Punalur	Kollam	Keralam
147	2	Panamaram	Mananthavady	Wayanad	Keralam
148	2	Amboori	Kattakkada	Thiruvanantha-puram	Keralam
149	2	Keerampara	Kothamangalam	Ernakulam	Keralam
150	2	Eramalloor CT	Kothamangalam	Ernakulam	Keralam
151	1	Pazhavangadi	Ranni	Pathanamthitta	Keralam
152	1	Kottoppadam I	Mannarkad	Palakkad	Keralam
153	1	Vagamon	Peerumade	Idukki	Keralam
154	1	Sholayur	Tribal Taluk Office Attappadi	Palakkad	Keralam
155	1	Thrippangottur	Thalassery	Kannur	Keralam
156	1	Karavaloor Part	Punalur	Kollam	Keralam
157	1	Vallicode Kottayam	Konni	Pathanamthitta	Keralam
158	1	Poovarany	Meenachil	Kottayam	Keralam
159	1	Kondoor	Meenachil	Kottayam	Keralam
160	1	Padinharethara	Vythiri	Wayanad	Keralam
161	1	Thavinhal	Mananthavady	Wayanad	Keralam
162	1	Thinoor	Vatakara	Kozhikode	Keralam
163	1	Pilakkad	Talappilly	Thrissur	Keralam
164	1	Kumaranellur CT	Talappilly	Thrissur	Keralam
165	1	Pirayiri CT	Palakkad	Palakkad	Keralam
166	1	Malampuzha II	Palakkad	Palakkad	Keralam
167	1	Madakkathara	Thrissur	Thrissur	Keralam
168	1	Tholambra	Thalassery	Kannur	Keralam
169	1	Thachampara	Mannarkad	Palakkad	Keralam
170	1	Kurupuzha	Nedumangad	Thiruvanantha-puram	Keralam
171	1	Kondazhy	Talappilly	Thrissur	Keralam
172	1	Pazhayannur	Talappilly	Thrissur	Keralam

173	1	Pulpalli	Sulthanbathery	Wayanad	Keralam
174	1	Ayiranalloor	Punalur	Kollam	Keralam
175	1	Kodencheri	Thamarassery	Kozhikode	Keralam
176	1	Vilakkudy	Pathanapuram	Kollam	Keralam
177	1	Kunnathidavaka	Vythiri	Wayanad	Keralam
178	1	Kadangode	Kunnamkulam	Thrissur	Keralam
179	1	Killimangalam	Talappilly	Thrissur	Keralam
180	1	Varavoor	Talappilly	Thrissur	Keralam
181	1	Pangarappilly	Talappilly	Thrissur	Keralam
182	1	Ottappalam	Ottappalam	Palakkad	Keralam
183	1	Puthuppariyaram 1	Palakkad	Palakkad	Keralam
184	1	Kalanjoor	Konni	Pathanamthitta	Keralam
185	1	Periyar	Peerumade	Idukki	Keralam
186	1	Anakkara	Udumbanchola	Idukki	Keralam
187	1	Neyyasseri	Thodupuzha	Idukki	Keralam
188	1	Kumaramangalam Part	Thodupuzha	Idukki	Keralam
189	1	Pathanapuram	Pathanapuram	Kollam	Keralam
190	1	Chethakkal	Ranni	Pathanamthitta	Keralam
191	1	Kedavoor	Kothamangalam	Ernakulam	Keralam
192	1	Mannamangalam	Thrissur	Thrissur	Keralam
193	1	Kairady	Chittur	Palakkad	Keralam
194	1	Mananthavady	Mananthavady	Wayanad	Keralam
195	1	Pangode	Nedumangad	Thiruvanantha-puram	Keralam
196	1	Thichur	Talappilly	Thrissur	Keralam
197	1	Venganellur	Talappilly	Thrissur	Keralam
198	1	Kallamala	Tribal Taluk Office Attappadi	Palakkad	Keralam
199	1	Nedumpura CT	Talappilly	Thrissur	Keralam
200	1	Nuchiyad	Iritty	Kannur	Keralam
201	1	Chathurangapara	Udumbanchola	Idukki	Keralam
202	1	Mattathur	Chalakkudy	Thrissur	Keralam
203	1	Manjumala	Peerumade	Idukki	Keralam
204	1	Peerumade	Peerumade	Idukki	Keralam
205	1	Purakkadi	Sulthanbathery	Wayanad	Keralam
206	1	Thrikkaipatta Part	Vythiri	Wayanad	Keralam
207	1	Valat	Mananthavady	Wayanad	Keralam

208	1	Kedavur	Thamarassery	Kozhikode	Keralam
209	1	Vekkalam	Thalassery	Kannur	Keralam
210	1	Marutharode CT	Palakkad	Palakkad	Keralam
211	1	Kuppadi	Sulthanbathery	Wayanad	Keralam
212	1	Enkakkad CT	Talappilly	Thrissur	Keralam
213	1	Anavilasam	Udumbanchola	Idukki	Keralam
214	1	Manjalloor	Muvattupuzha	Ernakulam	Keralam

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