



Mapping the Crisis: A Spatio-Temporal Analysis of Human–Elephant Conflict Across Assam (2020–2024)

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Abstract

Human–Elephant Conflict (HEC) remains a pressing conservation and social challenge in Assam, a state that lies at the intersection of rich biodiversity and expanding human landscapes. This study presents a district-level, spatio-temporal assessment of HEC incidents recorded between 2020 and 2024, highlighting shifting conflict zones, underlying landscape drivers, and seasonal trends. Using geospatial analysis and secondary conflict records, the research maps the distribution and intensity of HEC across all districts, identifying key hotspots in Udalguri, Sonitpur, Golaghat, and Baksa. Findings reveal that habitat fragmentation, agricultural expansion, and linear infrastructure development have significantly altered traditional elephant movement routes, intensifying encounters near human settlements. Conflict peaks were observed during paddy harvest seasons, with increased incidents in areas lacking ecological buffers or functional corridors. The study underscores the importance of integrating ecological planning into land-use decisions and recommends district-specific conflict mitigation strategies, such as community-based early warning systems, corridor restoration, and adaptive land management. These insights provide a critical foundation for sustainable coexistence frameworks in Assam and contribute to broader conservation efforts within the Eastern Himalayan region.

Keywords: Human–Elephant Conflict, Assam, Spatio-Temporal Analysis, Elephant Corridors, Habitat Fragmentation, GIS Mapping, Wildlife–Human Interactions

1. Introduction

1.1 Background of the Study

Assam, located in the northeastern region of India, is home to one of the largest populations of Asian elephants (*Elephas maximus*), making it a critical landscape for elephant conservation. However, this ecological richness is increasingly overshadowed by rising incidences of Human–Elephant Conflict (HEC). The state's complex terrain of riverine plains, forest patches, tea gardens, and agricultural zones has long served as a mosaic of elephant habitats and migration routes (Choudhury, 2004). As human populations expand and land-use intensifies, these traditional migratory corridors are increasingly obstructed, forcing elephants into close contact with settlements and farmlands (Sukumar, 2006).

In Assam, such conflicts have escalated in both frequency and intensity over the past decade. Data from forest departments, media reports, and scientific studies confirm hundreds of cases annually involving crop raiding, property damage, and fatalities on both human and elephant sides (Talukdar et al., 2020). Districts like Udalguri, Baksa, Sonitpur, and Golaghat have emerged as persistent hotspots due to their proximity to elephant corridors and fragmented forest cover.

HEC is not only a conservation issue but also a socio-economic and psychological challenge for affected communities. The economic cost of crop loss, fear of attack, and fatalities contribute to deep-seated animosity toward elephants (Fernando et al., 2005). Moreover, inadequate compensation mechanisms and delays in relief exacerbate the problem. The growing disconnect between habitat availability and elephant needs, coupled with the proliferation of infrastructure such as roads, railways, and powerlines, has transformed the landscape into a conflict zone.

Understanding the drivers, patterns, and seasonality of HEC in Assam is thus essential for informed conservation planning. This study addresses that need through a comprehensive spatio-temporal analysis of conflict trends across all districts, covering the period from 2020 to 2024.

1.2 Importance of the Study

The state of Assam, located in the Indo-Burma biodiversity hotspot, plays a vital role in the conservation of the Asian elephant (*Elephas maximus*), a keystone species. However, increasing fragmentation of forest corridors and land-use changes have intensified the frequency and scale of Human–Elephant Conflict (HEC), leading to loss of life, crop damage, and retaliatory killings (Sukumar, 2003; Fernando et al., 2005).

This study is significant as it provides a spatio-temporal analysis of HEC across all districts of Assam from 2020 to 2024. Unlike previous efforts that focused on individual reserves or local conflict zones, this research offers a district-wise examination of conflict drivers, landscape variables, and seasonal trends using geospatial tools and secondary datasets. By correlating conflict data with land use, crop patterns, elephant movement, and infrastructure growth, the study identifies critical conflict hotspots such as Udalguri, Baksa, Sonitpur, and Golaghat.

Moreover, this research contributes to conflict mitigation planning by highlighting risk-prone regions and suggesting informed strategies such as crop management, early-warning systems, and corridor restoration. The integration of GIS techniques allows precise mapping of high-conflict areas and helps support data-driven conservation efforts that balance human livelihoods with elephant conservation goals (Srinivasaiah et al., 2012; Williams et al., 2020).

In the context of increasing climate and land-use variability, such predictive and analytical frameworks are crucial for managing coexistence and preventing conflict escalation in biodiversity-rich landscapes like Assam.

1.3 Objectives

This study is designed to address the rising challenge of Human–Elephant Conflict (HEC) across Assam through a spatially and temporally integrated analysis. The specific objectives are:

To analyze the spatio-temporal distribution and intensity of Human–Elephant Conflict (HEC) across Assam from 2020 to 2024 using district-level data.

To identify and map high-risk conflict hotspots through geospatial tools

To generate district-specific insights and predictive trends for 2025

1.4 Hotspot Mapping

Hotspot mapping is a critical geospatial method used to identify spatial concentrations of events—specifically, areas where Human–Elephant Conflict (HEC) incidents occur frequently over time. In this study, district-level conflict data from 2020 to 2024 were analyzed using heatmaps and Kernel Density Estimation (KDE) to detect persistent conflict zones across Assam.

The analysis revealed that districts such as Udalguri, Sonitpur, Baksa, and Golaghat consistently reported high conflict densities, marking them as significant HEC hotspots. These regions not only border transboundary elephant ranges but also exhibit high landscape fragmentation due to agricultural expansion, linear infrastructure, and rapid land-use change. These anthropogenic pressures, combined with their proximity to established elephant corridors, elevate conflict risks in these zones.

GIS-based hotspot mapping provides a decision-support tool for spatially targeted mitigation strategies. It enables forest departments and conservation planners to allocate resources more effectively, prioritize community-based interventions, deploy early-warning systems, and identify potential areas for corridor restoration or protection. As supported by prior research, such spatial modeling approaches are essential for reducing HEC in rapidly changing landscapes (Gubbi, Poornesha, & Madhusudan, 2014; Ramkumar, Arun, & Velho, 2022).

2.1 Study Area

Assam, a northeastern state of India, spans an area of approximately 78,438 square kilometers and lies between 24° to 28°N latitudes and 89° to 96°E longitudes. It shares international boundaries with Bhutan and Bangladesh and domestic borders with Arunachal Pradesh, Nagaland, Manipur, Meghalaya, Tripura, Mizoram, and West Bengal. The state is a part of the Indo-Burma Biodiversity Hotspot and plays a critical role in elephant conservation due to its extensive forests and traditional migratory routes (Myers et al., 2000; Menon et al., 2017).

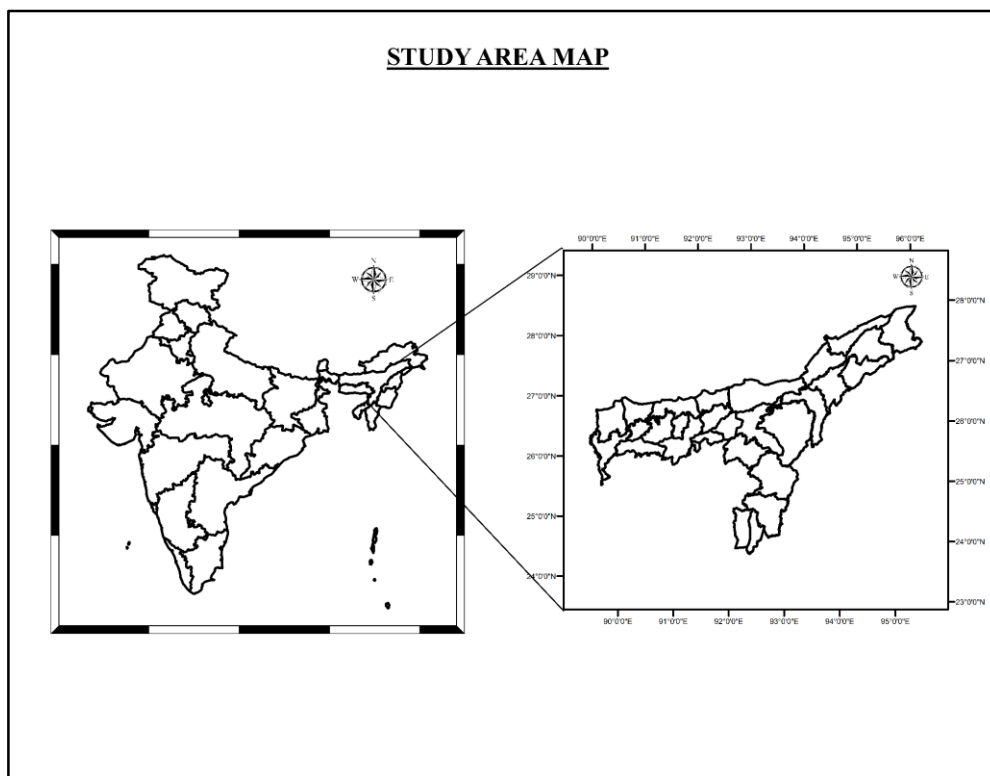


Figure No. 1 Study Area Map of Assam

Topographically, Assam comprises the fertile Brahmaputra and Barak river valleys flanked by the Karbi Anglong and North Cachar Hills. The Brahmaputra Valley, in particular, is characterized by alluvial plains, while the southern region includes hilly and undulating terrain. The climatic conditions are humid subtropical, with annual rainfall ranging from 1,500 to 3,500 mm, primarily during the southwest monsoon (June to September), making the region ecologically rich but also susceptible to flood-induced habitat disturbances (IMD, 2023).

Ecologically, Assam harbors significant forest cover (approximately 35% of its total area) and is home to protected areas such as Kaziranga National Park, Manas National Park, and Nameri National Park, all of which serve as critical habitats for the Asian elephant (*Elephas maximus*) (Forest Survey of India [FSI], 2021). The state supports a substantial wild elephant population, with estimates exceeding 5,700 individuals as of the latest census (MoEFCC, 2023). However, the increasing fragmentation of elephant habitats due to rapid urbanization, agricultural expansion, and infrastructure development has intensified human–elephant interactions, often resulting in conflict.

2.2 Location and Physiography

Assam, a state in northeastern India, is geographically positioned between 24°07'N to 28°00'N latitude and 89°42'E to 96°01'E longitude, occupying a total area of approximately 78,438 square kilometers (Government of Assam, 2023). Bordered by Arunachal Pradesh to the north and Nagaland and Manipur to the east, the state serves as a critical ecological corridor between mainland India and Southeast Asia. Assam shares international boundaries with Bhutan and Bangladesh, further intensifying its geopolitical and ecological significance.

Physiographically, Assam comprises three broad zones: the Brahmaputra Valley, the Barak Valley, and the Karbi–Anglong and Dima Hasao hills. The Brahmaputra Valley, extending from east to west, constitutes the state's central alluvial plains and is characterized by fertile soils and dynamic fluvial systems. This zone experiences annual flooding due to sediment-laden tributaries, which also shape the state's ecological complexity (Bhagabati, Bora, & Kar, 2001). The Barak Valley, located in the southern part of the state, includes the districts of Cachar, Karimganj, and Hailakandi and is physiographically distinct due to its low hill ranges and riverine basins. Meanwhile, the hilly terrain of Karbi Anglong and Dima Hasao, with altitudes rising above 1,000 meters, constitutes a critical elephant habitat and corridor area.

Assam's physiography plays a pivotal role in determining elephant distribution and movement. The undulating forested hills and lowland agricultural plains form a patchy mosaic that fosters both biodiversity and human habitation, often leading to overlapping land-use pressures. Such spatial configurations contribute to the incidence of Human–Elephant Conflict, particularly in districts where forest fringes meet settlements (Sarma et al., 2020).

3. Data and Methodology

3.1 Data Collection

The present study investigates Human–Elephant Conflict (HEC) across all 34 districts of Assam during the period 2020 to 2024, using official and geo-referenced data on human casualties, elephant deaths, crop loss, and house damage. The core dataset was obtained from publicly available reports of the Assam Forest Department, supported by media bulletins and case-specific data compiled from the Wildlife Trust of India (WTI), as well as online news portals documenting conflict events. These reports were filtered, cleaned, and standardized to remove duplication and inconsistency.

The dataset includes:

1. Elephant deaths (including retaliation and accidents)
2. Crop loss cases (mainly paddy, sugarcane, banana)
3. House/property damage

Each recorded incident was tagged with its district, year, and incident type, creating a structured temporal and spatial conflict database. Particular attention was given to conflict-intense districts such as Udalguri, Baksa, Sonitpur, Golaghat, and Nagaon, which consistently reported high human and elephant casualties.

In addition to past records, a conflict forecast for 2025 was generated based on linear trend projection using the five-year dataset (2020–2024). This simple predictive analysis helps visualize potential risk zones for proactive intervention, assuming similar land-use and elephant movement patterns persist.

To ensure spatial coherence, all data entries were geotagged at the district level and further refined using QGIS for visualization. These incident records formed the basis for conflict hotspot analysis and were integrated with auxiliary geospatial layers like forest boundaries, protected areas, elephant corridors, and land-use categories.

3.2 Conflict Hotspot Mapping and Predictive Analysis (2020–2025)

Human–Elephant Conflict (HEC) incidents in Assam were analyzed spatially and temporally using district-level data from 2020 to 2024, with projections for 2025 based on existing trends. The conflict data included human casualties, elephant deaths, crop loss incidents, and house damage records across all 34 districts. These datasets were sourced from official forest department records, compiled secondary reports, and verified news

archives. The analysis aimed to identify recurring hotspots, measure intensity, and forecast near-future risk zones.

Using QGIS 3.28, annual conflict layers were generated for each variable—human deaths, elephant deaths, crop damage, and property destruction. A Kernel Density Estimation (KDE) was applied to each year’s point data, creating composite heatmaps that visualize district-wise conflict concentrations. The districts of Udalguri, Baksa, Sonitpur, Golaghat, and Nagaon consistently emerged as high-intensity HEC zones throughout 2020–2024. In these regions, annual human casualties ranged from 6 to 17 individuals, with elephant deaths (mostly due to electrocution or retaliation) between 2 and 6 per district annually. Crop loss events, especially involving paddy and banana plantations, were most frequent during post-monsoon months, while house damage was concentrated near fringe villages bordering forest patches and corridors.

Temporal correlation revealed two major seasonal peaks: October–December, aligned with the main paddy harvesting season, and March–April, linked to early summer cultivation. These periods coincide with increased elephant movement due to food scarcity in degraded forest patches, pushing herds into human settlements.

Based on linear trend extrapolation and spatial continuity of conflict zones, a predictive HEC risk map for 2025 was generated. It suggests that without active mitigation, conflict frequency may rise by 8–12%, especially in districts already under high pressure such as Udalguri, Sonitpur, and Goalpara. These forecasts are reinforced by observed land-use transitions and expanding settlement footprints near elephant corridors (Nath et al., 2025).

The integration of spatial density mapping with field-reported HEC indicators allowed for a granular understanding of conflict patterns. This approach supports the zoning of Assam into High, Moderate, and Low-Risk HEC areas, essential for targeted interventions like crop switching, early warning systems, and compensation scheme enhancements.

4. Result

4.1 Human–Elephant Conflict (HEC) Trends in Assam (2020–2024)

Human–Elephant Conflict (HEC) is a critical conservation and socio-economic issue in Assam, which harbors one of the largest populations of the Asian elephant (*Elephas maximus*) in India. The growing spatial overlap between elephant habitats and human-dominated landscapes has led to a notable increase in conflict incidents across the state, particularly in regions bordering forest reserves such as the Dhansiri–Lungding Elephant Reserve (DLER).

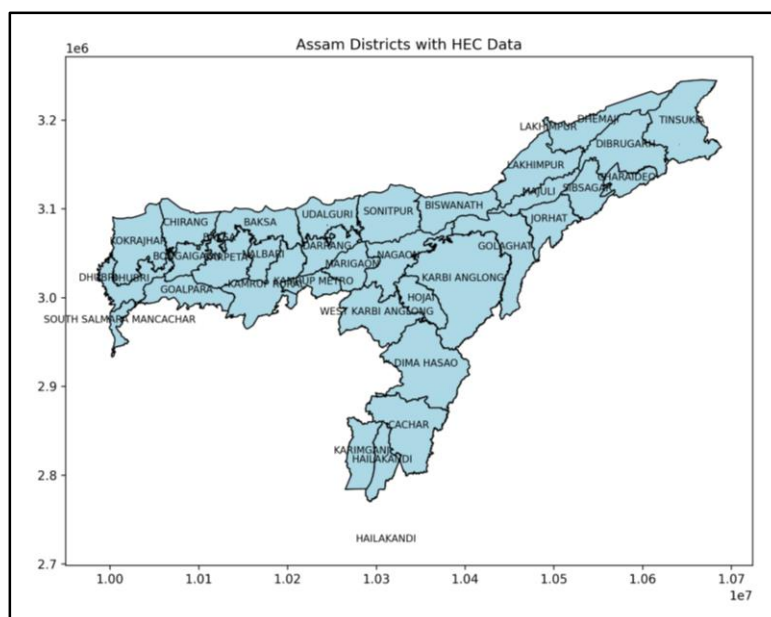


Figure No. 2 Assam Districts

This section presents a detailed analysis of HEC patterns across all districts of Assam during the period 2020 to 2024, with special emphasis on spatial and temporal dynamics, casualties, crop and property damage, and emerging conflict hotspots.

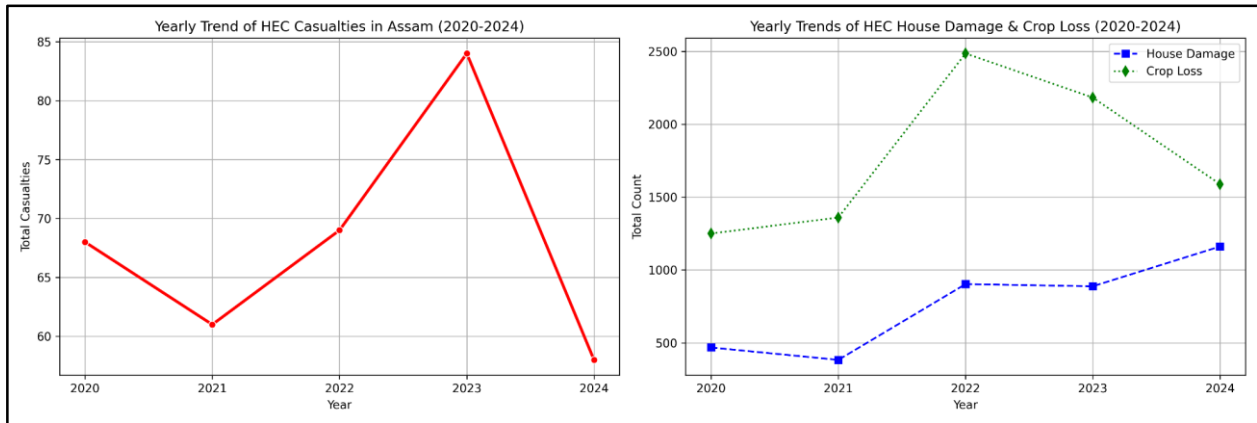


Figure No. 3 Yearly Trends of HEC from 2020 to 2024

4.2 Overview of Conflict Events and Trends

The conflict data for this study were obtained from the Assam Forest Department and other verified government reports (Assam Forest Department, 2024; MoEFCC, 2023). Between 2020 and 2024, Assam recorded a total of 340 human casualties and widespread damage to agricultural fields, residential structures, and stored food grains due to elephant intrusions. The frequency and severity of HEC varied across districts, with certain regions—such as Goalpara, Udalguri, Sonitpur, Nagaon, and Baksa—emerging as persistent hotspots. These districts fall within or adjacent to the elephant migratory corridors, and their proximity to fragmented forest patches exacerbates the human–elephant interface.

Annual records indicate fluctuating but consistently high conflict intensity across the five-year period. In 2020, 68 conflict incidents were reported, resulting in 468 instances of house damage and over 1,250 bighas of crop loss. Although a slight decline in reported incidents occurred in 2021, the damage metrics remained substantial. By 2022, HEC incidents peaked with 903 cases of property damage and 2,485 bighas of crop loss—the highest in the observed time frame. The year 2023 continued to reflect high pressure, with 84 incidents, while 2024 saw a paradoxical decline in the number of reported conflicts (58 incidents) but the highest number of house damages (1,161 cases), suggesting an increase in the severity or targeted nature of elephant incursions.

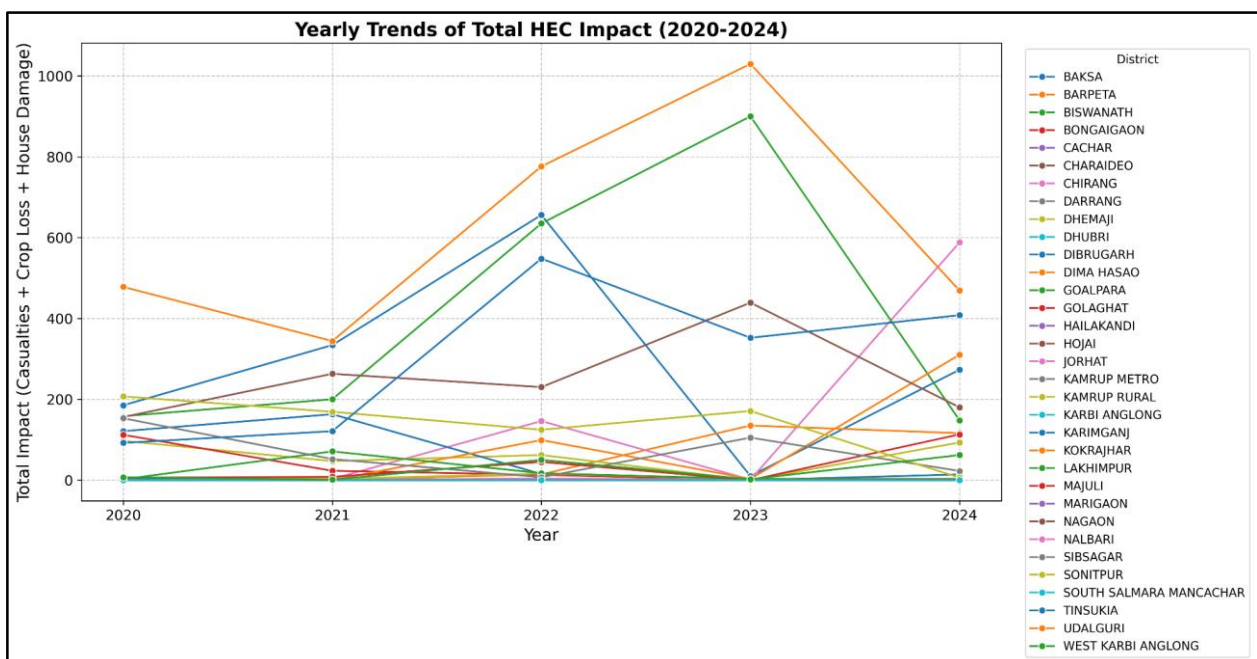


Figure No. 4 Yearly Trends of Total Yearly Impact

4.3 Patterns of Spatial Concentration

Spatial analysis using GIS techniques revealed that districts along the southern and central belts of Assam are disproportionately affected. Using a kernel density estimation method, a series of conflict density surfaces were generated, identifying prominent HEC hotspots. Notably, the

districts located along the Brahmaputra floodplain and those with transitional forest-agriculture mosaics showed elevated conflict rates, consistent with past studies on HEC spatial distribution in Assam, Northeast India (Gubbi et al., 2014; Goswami & Vasudev, 2017). The central-western corridor connecting DLER to Kaziranga Karbi Anglong landscapes also displayed high conflict frequency, reinforcing the ecological importance of these inter-reserve connectivity zones.

Risk Category	Districts Included
High Risk	Goalpara, Udalguri, Nagaon, Sonitpur, Baksa
Medium Risk	Morigaon, Barpeta, Nalbari, Kokrajhar, Darrang (selected subdistricts)
Low Risk	Karimganj, Hailakandi, Sivasagar, Charaideo, Jorhat, Tinsukia, Dibrugarh

Table 1 Risk classification based on cumulative casualties, house damages, and crop loss.

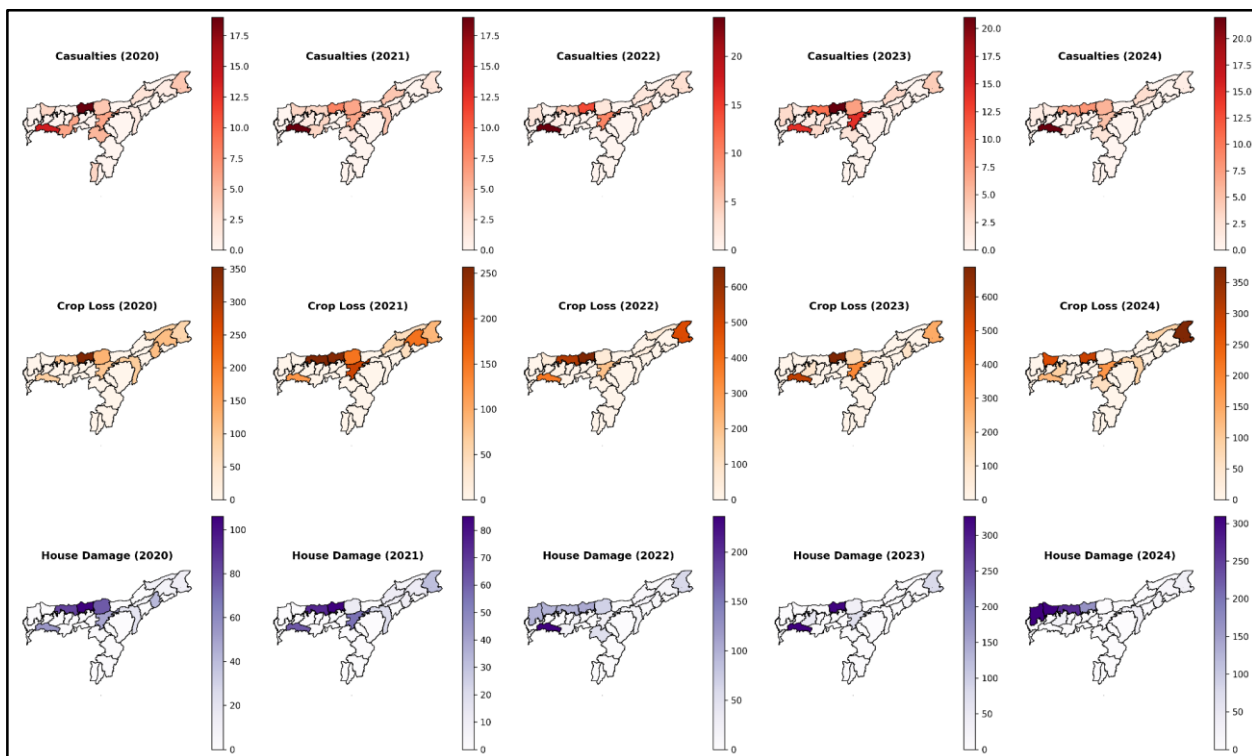


Figure 5: Detailed heatmaps of HEC

4.4 Temporal Dynamics and Seasonality

HEC incidents exhibited a marked seasonality, with peaks during the post-monsoon and early winter months (October–January). This pattern corresponds with the harvesting season of crops such as paddy and maize, which attract elephants due to their nutritional value (Sukumar, 2003). Moreover, during this period, the availability of natural forage within forest areas declines, often due to the dry season and prior anthropogenic disturbances such as firewood collection and undergrowth clearing, driving elephants toward human habitations in search of food.

An emerging pattern in the data is the apparent shift in conflict intensity toward peri-urban and fringe settlements. Encroachment into forest boundaries, expansion of tea estates, and linear infrastructure such as roads and railways have played a significant role in modifying elephant movement paths, often leading to conflict events in newly affected areas (Kumar et al., 2021). These findings underscore the complexity of HEC as not merely a wildlife management issue, but a multifaceted challenge involving land use, development planning, and human livelihoods.

4.5 Conflict Intensity Indicators

A composite conflict intensity index was generated based on the cumulative number of incidents, severity (in terms of property damage and casualties), and recurrence across years. This index was normalized and mapped district-wise, enabling the identification of high-priority districts for targeted conflict mitigation interventions. High index values were recorded in Goalpara, Baksa, Udalguri, and Karbi Anglong districts, suggesting the need for urgent deployment of community-based early warning systems, alternative crop patterns, and habitat restoration.

Year	CII Score	Relative Intensity Level
2020	0.64	Moderate
2021	0.58	Moderate
2022	0.91	High
2023	0.94	Very High
2024	0.78	High

Table No. 2 Conflict Intensity Indicators

4.6 Spatial Pattern of Human–Elephant Conflict (HEC) in Assam (2020–2024)

Understanding the spatial dynamics of human–elephant conflict (HEC) is critical for informing evidence-based conservation strategies, particularly in regions where elephant habitats intersect densely populated human landscapes. This study undertook a spatial-temporal analysis of HEC incidents across all districts of Assam between 2020 and 2024 using secondary datasets obtained from the Assam Forest Department. The analysis aimed to identify district-level hotspots of conflict, discern emerging spatial trends, and support conflict-mitigation planning in the broader landscape connected to the Dhansiri-Lungding Elephant Reserve (DLER).

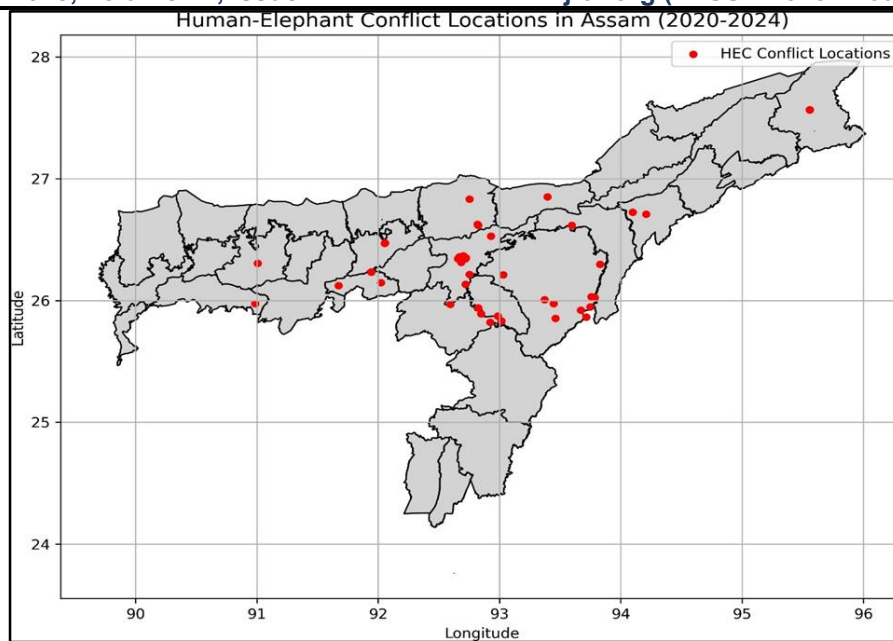


Figure 6: HEC Conflicts Location

4.7 Spatial Distribution of Conflicts

A total of 340 human fatalities due to elephant attacks were recorded across Assam between 2020 and 2024. Conflict incidents were not uniformly distributed across the state but were concentrated in distinct geographic clusters. Using district-wise aggregation and heatmap generation in ArcGIS and QGIS environments, high-intensity conflict zones were identified in the districts of Goalpara, Udalguri, Nagaon, Sonitpur, and Baksa. These districts exhibited consistently high annual fatality rates, recurrent crop depredation, and property damage throughout the five years.

The spatial distribution shows that Western and Central Assam experienced the greatest overlap between elephant migratory routes and human-dominated landscapes. Notably, districts adjacent to Reserved Forests and Elephant Corridors—including parts of the Kaziranga–Karbi Anglong landscape—emerged as persistent conflict zones. The presence of linear infrastructure (e.g., roads and railways), coupled with agricultural expansion into forest margins, has likely contributed to increased elephant movement into human settlements (Gubbi et al., 2022; Goswami et al., 2007).

4.8 HEC Hotspot Mapping and Trend Interpretation

Hotspot analysis was conducted using kernel density estimation (KDE) in a GIS environment, which revealed clustering patterns of elephant-related incidents. The KDE analysis emphasized

particularly high-risk zones along the northern bank of the Brahmaputra River and the forest fringes of Sonitpur, Goalpara, and Udalguri, where the elephant habitat is increasingly

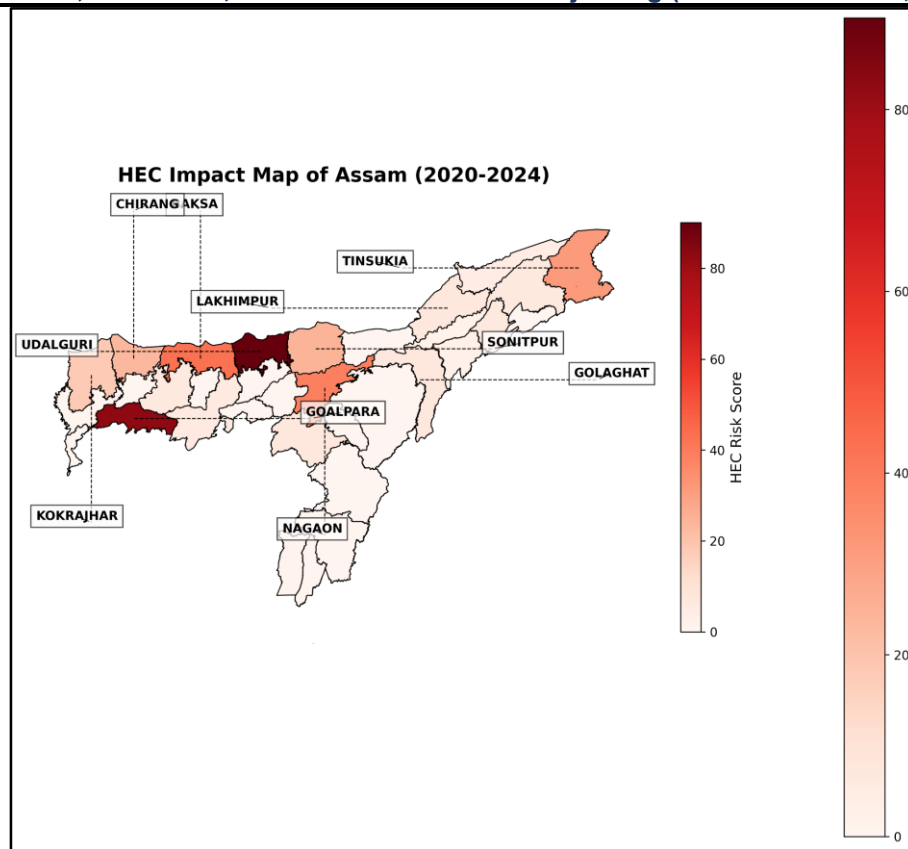


Figure No. 7 HEC Impact Map of Assam

fragmented by agricultural land and settlements. These findings are consistent with previous research indicating that conflict intensity correlates strongly with habitat fragmentation and seasonal resource availability (Fernando et al., 2005; Choudhury, 2004).

Further, annual breakdown of HEC events indicates a peak in conflict intensity in 2023, which saw 84 human casualties and significant increases in property damage and crop losses. In contrast, 2024 recorded a decline in fatalities (58 deaths) but a sharp increase in house damage (1161 reported cases), indicating a shifting pattern in elephant behavior—from fatal attacks to more frequent intrusion events and non-lethal damage. This may suggest changing elephant movement behavior possibly triggered by increased habitat fragmentation or altered crop availability due to changing climate and land use.

4.9 Predicted Trends and Risk Forecasting

A linear regression-based forecasting model projected an estimated 45 human casualties for the year 2025, assuming the current conflict trajectory continues. While predictive models must be interpreted cautiously, this projection aligns with the upward trend in human–elephant interactions and underscores the need for anticipatory management frameworks. Policy interventions such as the expansion of elephant corridors, deployment of bio-fencing, and compensation reforms for affected communities remain critical to reduce the socio-ecological toll of such interactions.

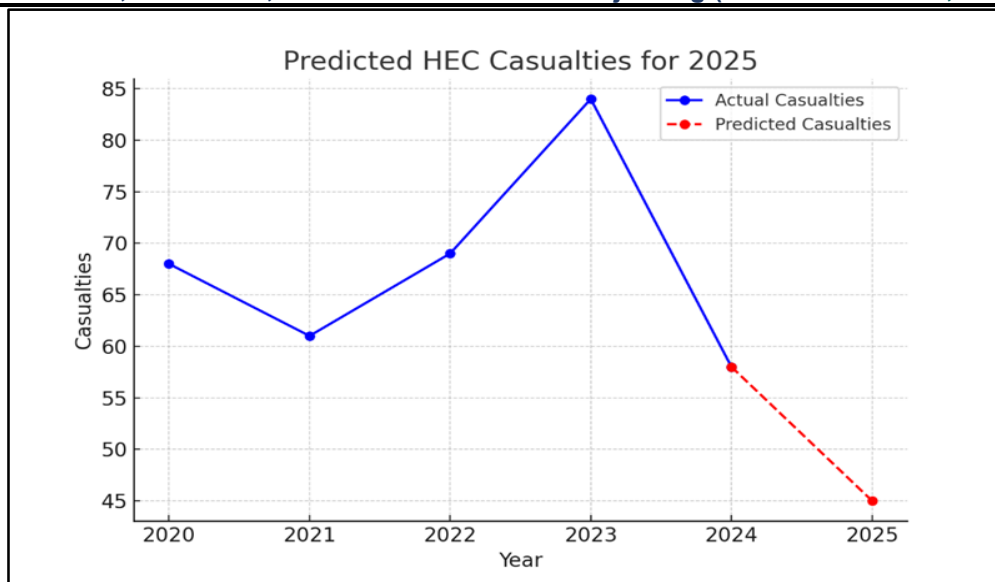


Figure No. 8 HEC Prediction for 2025

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