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Margins of Coexistence: Understanding Human–Elephant Conflict and Community Resilience in Assam's Kakoi Reserve Forest

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Abstract

This study examines the dynamics of human–elephant conflict (HEC) in the fringe villages surrounding Kakoi Reserve Forest (RF) in Assam, India, a region marked by rich biodiversity and intense human–wildlife interaction. From 2017 to 2019, data were collected from seven villages within a 3 km radius of the forest boundary using Rapid Rural Appraisal, semi-structured interviews, and forest department records. A total of 67 crop-raiding incidents, 12 instances of property damage, and 8 human fatalities were recorded during the period. Crop depredation was highest in villages nearest to elephant corridors, with rice, banana, and coconut being the most targeted crops. Peak raiding occurred during the Ahu and Sali paddy seasons. Solitary male elephants (makhnas) were the primary raiders, responsible for over 70% of damage, often acting destructively and unpredictably. The total economic loss—including livestock and sericulture infrastructure—was estimated at ₹1.41 lakh, with broader crop losses pushing this figure substantially higher. Residents used traditional deterrents such as firecrackers, torches, and watch-platforms, though these yielded inconsistent results. While villagers maintained some cultural tolerance toward elephants, most expressed frustration with bureaucratic compensation processes and advocated for electric fencing, improved patrolling, and cultivation of non-palatable crops like lemon and tea. The findings highlight the urgent need for integrated conflict mitigation strategies that combine rapid compensation, landscape-level planning, corridor protection, and community-based interventions. The Kakoi RF conflict zone serves as a critical microcosm of HEC challenges in South Asia, where coexistence depends on harmonizing ecological realities with socioeconomic resilience.

Keywords: Human–Elephant Conflict, Crop Raiding Patterns, Community-Based Mitigation

1. Introduction

The Asian elephant (Elephas maximus), listed under Schedule I of the Indian Wildlife Protection Act, is one of the most ecologically significant yet vulnerable megafauna in Asia. India is home to the largest remaining population of wild Asian elephants, with an estimated 25,000 individuals (MoEFCC, 2019). These elephants have long been intertwined with the cultural, religious, and ecological fabric of the Indian subcontinent.

The wild population in India is primarily distributed across four major zones—Northern, North-eastern, Central, and Southern India (Sukumar, 1990). Within Northeast India, the state of Assam alone harbors over 19% of the country's elephant population, approximately 5,719 individuals, second only to Kerala (MoEFCC, 2019). Additionally, five of India's 32 designated elephant reserves are located in Assam,

emphasizing the region's strategic importance to elephant conservation. Significant elephant populations are also found in the Himalayan foothills that stretch from north-western Bengal through Arunachal Pradesh via Assam to southern Bhutan, housing an estimated 4,800–5,800 individuals (Menon, 2013).

Despite these concentrations, elephant populations are under severe pressure from anthropogenic threats. Fragmentation of elephant corridors—narrow, forested routes critical for seasonal migration—is a growing conservation challenge. The loss of these corridors due to deforestation, infrastructure development, and agricultural encroachment not only threatens elephant mobility and survival but also increases the frequency and severity of human-elephant conflict (HEC) (Gubbi et al., 2014; Talukdar & Barman, 2003).

HEC is a particularly acute issue in Assam, where expanding human populations and demand for cultivable land have led to widespread degradation of forest habitats. Every year, nearly 500,000 households in India are affected by HEC (Rangarajan et al., 2010), resulting in loss of crops, property, and even human lives. This dynamic jeopardizes both local livelihoods and conservation outcomes, especially in areas where elephants are perceived as threats rather than heritage (Hopker et al., 2020; Naha et al., 2020).

Furthermore, the traditional migratory behavior of elephants is being altered by corridor fragmentation, with herds exhibiting unpredictable movements and extended stays in human-dominated landscapes. Such behavioral shifts intensify conflicts and erode public support for conservation efforts. As Choudhury (2001) observed, habitat loss remains the foremost threat to elephant populations across Northeast India, where deforestation continues at an alarming pace.

2. Study Area

The present study was conducted in the fringe villages located along the southern periphery of Kakoi Reserve Forest (RF) in the Lakhimpur district of Assam, India. Kakoi RF lies within the coordinates 27.42° N and 94.11° E and 27.34° N and 94.12° E, forming part of the northernmost landscape of the district, adjoining the Himalayan foothills.

Covering an area of approximately 4,415.03 hectares, Kakoi RF is a biologically rich tract of semi-evergreen and tropical rainforest, interspersed with riverine grasslands, secondary forests, and hilly terrains. The region falls under the Assam Himalayan biodiversity sub-zone, a transitional zone between the Eastern Himalayas and Brahmaputra floodplains, known for high ecological productivity and species diversity.

The selected fringe villages for this study—Bokanullah, Dirgha Naharbari, Kakoi Rajgarh, Rajgarh Bangalibasti, Joyhing, and Kakoi Dhekiajuli—are situated immediately adjacent to the reserve. These villages experience frequent human–elephant interactions due to their proximity to traditional elephant corridors that traverse Kakoi RF and connect larger forest tracts in Arunachal Pradesh.

The land-use matrix in the region is dominated by subsistence agriculture, shifting cultivation, and small-scale plantations, creating a sharp ecological interface between human and wild habitats. During peak crop seasons, elephants often descend into agricultural fields, leading to incidents of crop raiding, property damage, and occasional human injury or death, making this zone a critical HEC hotspot in upper Assam.

Given its geographical, ecological, and sociopolitical relevance, Kakoi RF and its surrounding villages present a representative microcosm of the larger conservation challenge facing northeastern India.

3. Methodology

This study adopted a qualitative, case-based approach to explore the dynamics of human–elephant conflict (HEC) in the fringe areas of Kakoi Reserve Forest (RF) in Lakhimpur district, Assam. Each reported conflict instance was treated as an independent test case, allowing for in-depth contextual analysis.

Villages that had experienced recent elephant raids were selected purposively, with a focus on those within a 3 km radius of the forest boundary, including partially forested zones. A total of seven fringe villages—namely Bokanullah, Dirgha Naharbari, Kakoi Rajgarh, Rajgarh Bangalibasti, Joyhing, and Kakoi Dhekiajuli—were identified as primary sites of investigation based on field reconnaissance and historical incident reports.

The research was conducted between 2017 and 2019, capturing data across multiple agricultural cycles in the pre-COVID-19 period. The Rapid Rural Appraisal (RRA) technique (Chambers, 1994) was employed to collect firsthand information through semi-structured questionnaires and informal interviews with local farmers and residents who had directly experienced crop damage or herd encounters.

The questionnaire sought to capture diverse variables, including types and timing of cultivated crops, nature and frequency of elephant raids, herd behavior, damage assessments, mitigation strategies employed, and local perceptions toward elephants and government interventions. Data on historical conflict episodes since 1999 were also reviewed with the support of documentation from the Divisional Forest Office, North Lakhimpur (Talukdar et al., 2003), providing a long-term perspective on conflict trends.

Data were collated and organized manually using Microsoft Excel, allowing for thematic grouping and trend analysis. All respondents were approached with verbal informed consent, and confidentiality was maintained throughout the process in accordance with ethical research practices.

4. Results and Discussion

Compared to other regions in Assam experiencing human–elephant conflict (HEC), the research area exhibits a relatively high intensity of conflict. This is attributed to the increasing pressures on the local elephant population, primarily driven by disturbances such as illegal logging, unsustainable grazing, encroachment, and overharvesting of non-timber forest products (NTFPs) (Das et al., 2021). From 2017 to 2019, more than 67 crop-raiding incidents, 12 cases of residential and property damage, and 7 human fatalities were recorded (see Tables 2, 3 & 4).

If this trend continues, both humans and elephants may face escalating threats in the near future. While the Lakhimpur Forest Division has maintained some records of crop-raiding and property damage cases, the data associated with Ex Gratia compensation claims may carry potential biases. However, the records of elephant-related human fatalities are more reliable and serve as critical indicators of the growing severity of HEC in this region (Sarma et al., 2020).

Patterns of Elephant Depredation

4.1. Crop Annihilation

4.1.1 Distribution of Crop-Raiding Incidents

Crop-raiding was not uniformly distributed across all fringe villages. The spatial distribution revealed that villages located closer to the forest fringe experienced significantly more incidents. The frequency

of such raids was inversely correlated with the distance from the forest boundary. Peripheral settlements reported higher crop losses, while conflict intensity gradually decreased with distance from the forest. Similar spatial patterns have been observed in studies by Marak et al. (2012) in Africa and Sukumar (2013) in Assam, affirming that proximity to forest areas is a key determinant in the likelihood of elephant intrusion.

In this study, a large herd consisting of 56 elephants was reported to travel in three sub-groups across a corridor stretching from Ranga Reserve Forest to Dulung Reserve Forest, covering a seasonal distance of nearly 62 km. The herd typically remains within a 3 km radius of the Kakoi Reserve Forest during crop raids. Between 2017 and 2019, ten fringe villages were identified as having experienced repeated incidents of agricultural depredation.

4.1.2 Raiding Seasons and Crop Preferences

During the study period, a total of 67 crop-raiding cases were reported, including damage to both field crops and home garden plots. Paddy (Oryza sativa) emerged as the most targeted crop by elephants, with raids beginning at the vegetative stage and intensifying toward maturity and harvest. The peak raiding periods coincided with the two major paddy harvests: June–August (Ahu paddy) and October–December (Sali paddy).

From February to April, crop-raiding activity was minimal due to the post-harvest landscape, with most fields lying fallow or in early cultivation stages. During the pre-monsoon season, Ahu paddy is sown and remains in its vegetative stage, making it vulnerable but comparatively less attractive to elephants.

Among horticultural crops, elephants inflicted significant damage to banana (Musa spp.), coconut (Cocos nucifera), and areca nut (Areca catechu) plantations, which hold high commercial value. Farmers often reported that these plants were uprooted or broken rather than consumed, indicating destructive foraging behavior (Ramakrishnan & Häger, 2020). These forms of non-consumptive destruction resulted in high economic losses for local households.

4.1.3 Crop Damage Patterns by Village

Analysis of crop damage data collected between 2017 and 2019 (Table 1) reveals a clear spatial gradient in human–elephant conflict (HEC) severity, with villages closer to the forest boundary experiencing disproportionately higher damage. Dirgha Naharbari recorded the highest loss, with 25 bighas of crops damaged, while villages further from the reserve—such as Rajgarh Bangalibasti and Kakoi Rajgarh—reported lower damage, at 12 and 13 bighas, respectively. This inverse correlation between distance from the forest and crop damage aligns with broader wildlife conflict studies, which identify proximity as a significant predictor of crop-raiding risk (Sukumar, 1990; Marak et al., 2012).

The bar chart provided visually corroborates these patterns, depicting a descending trend in crop damage as one moves away from Kakoi Reserve Forest. Villages such as Bokanullah Nepali Gaon and Dirgha Nepalibasti, located nearer to traditional elephant corridors, experienced elevated levels of crop destruction—22 and 18 bighas respectively—indicating frequent elephant movement through these peripheral zones. Similar relationships have been documented throughout Northeast India, where adjacency to corridors significantly increases HEC risk (Neupane et al., 2022).

Furthermore, the predominance of rice paddies, vegetables, and bamboo among damaged crops reflects elephants' dietary preferences for high-calorie foods and their seasonal dependency on agricultural landscapes (Sukumar, 1990). These findings are consistent with studies conducted in similar agro-forest interface regions, which note that elephants often target human crops during periods of natural food scarcity, particularly during dry or lean seasons (Fernando et al., 2008; Hopker et al., 2020). The patterns

observed in this study underscore the urgent need for targeted mitigation measures—such as buffer zones, strategic fencing, and community-based monitoring—in high-risk villages located near critical elephant habitats.

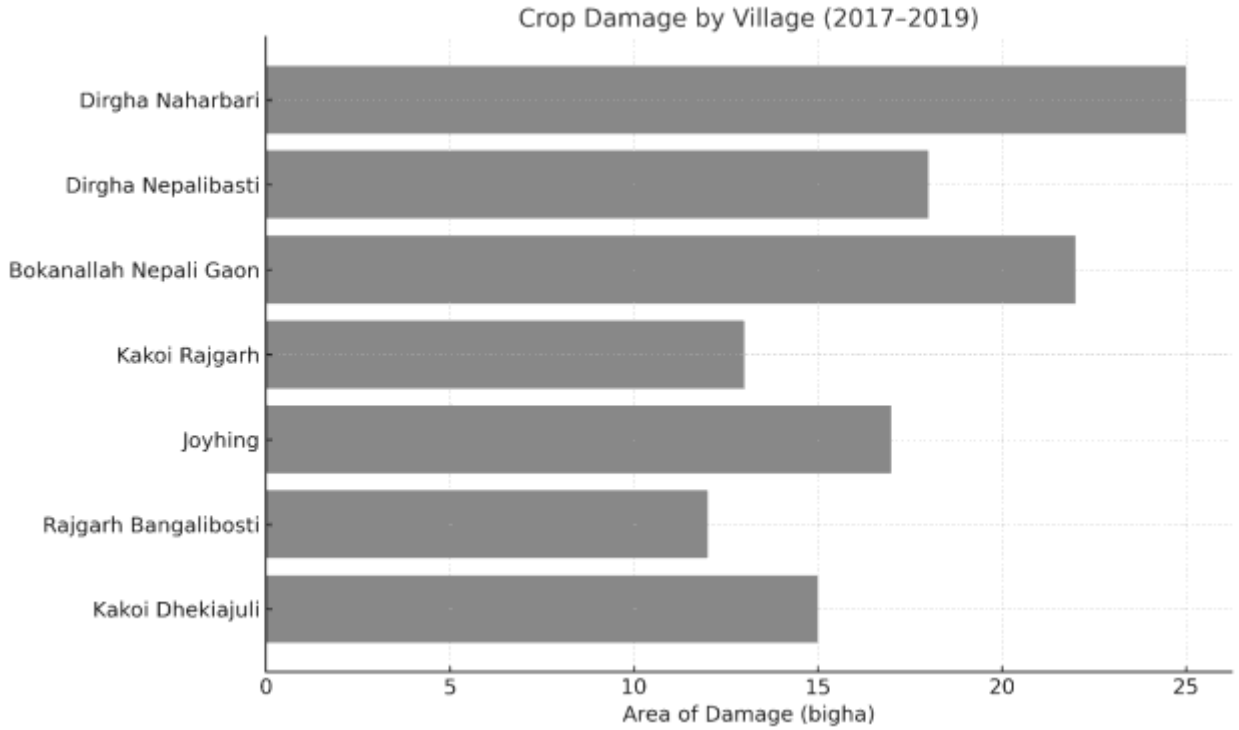

Fig 1: Area of crop damage (in bighas) recorded from 2017 to 2019 across seven fringe villages of Kakoi Reserve Forest, with Dirgha Naharbari reporting the highest loss.

4.1.4 Frequency of Plant Parts Damaged or Consumed by Elephants

Analysis of the field survey data reveals a clear pattern in the types of plant parts most frequently targeted by elephants. As depicted in the Fig 2, the entire plant was the most commonly affected category, indicating the destructive foraging behavior of elephants that often results in total uprooting or trampling (Williams et al., 2020). This was followed by damage specifically to fruits, leaves, and roots, particularly in crops such as jackfruit, pineapple, and tapioca. Additionally, a significant number of entries were categorized under "trampled" or "damaged", reflecting instances where the elephants did not consume the plant but still rendered it unharvestable (Gubbi et al., 2014). The prevalence of whole plant destruction aligns with earlier findings by Ramakrishnan and Häger (2020), who noted that elephants often cause collateral damage far beyond their nutritional needs, exacerbating the economic losses suffered by subsistence farmers. Such indiscriminate foraging not only intensifies the human–elephant conflict but also increases the risk of retaliatory actions in affected regions (Sarma et al., 2020).

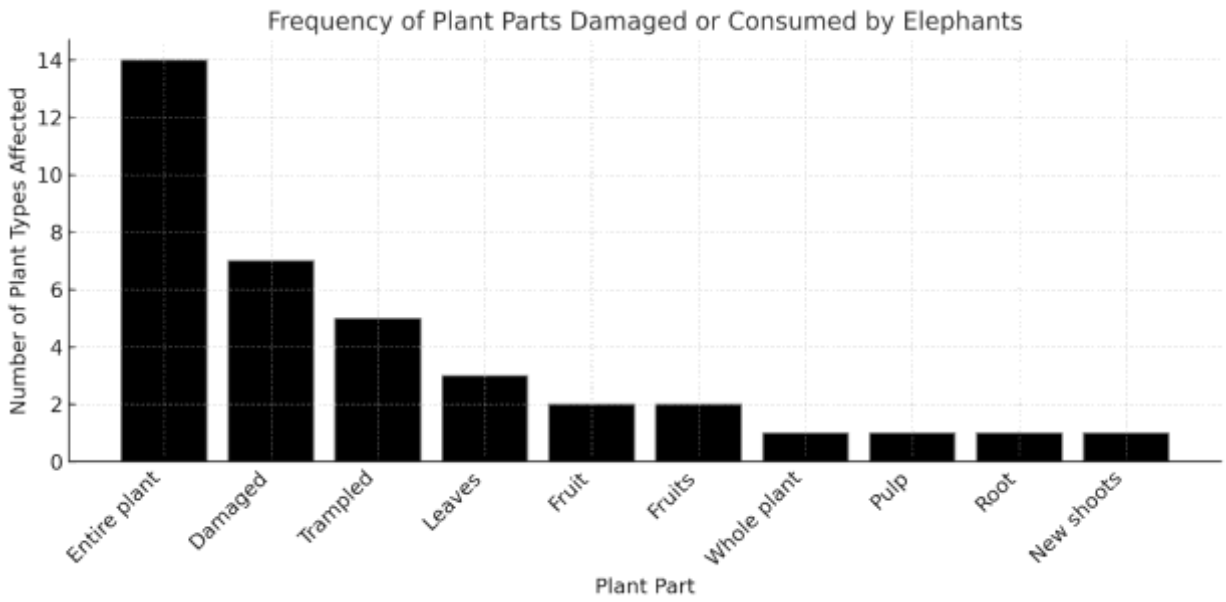

Fig 2: Frequency of plant parts damaged or consumed by elephants, with entire plants being the most frequently affected, followed by generalized damage and trampling.

4.1.5. Raiding Group Size

Analysis of field data and Forest Department records reveals a clear distinction in raiding behavior between solitary elephants and family herds. Lone males, commonly referred to as makhnas, were found to raid crop fields year-round and at higher frequencies compared to family groups led by females. By contrast, family herds, typically comprising 15 to 25 individuals, were observed raiding less frequently, though occasional incursions involved up to 33 elephants. These observations corroborate findings from Sharma et al. (2021) and Hussain & Bhat (2022), who similarly report that solitary males are more adaptable and often more willing to enter agricultural landscapes in search of food, while family herds tend to avoid prolonged interactions with humans. The data suggest that targeted management efforts, such as deploying deterrents and waterholes at potential entry points, may be particularly effective against these solitary raiders.

4.2. Human Casualties from Elephant Conflict

Between 2017 and 2019, the Kakoi Reserve Forest and its adjoining villages recorded a total of eight human fatalities and an equal number of injuries attributed to human-elephant conflict. These incidents were distributed across several fringe settlements, including Kakoi Dhekiajuli, Bokanallah, Rajgarh Bangalibasti, and fields within Johying. As depicted in Fig 3, fatalities were not confined to a specific type of landscape—some occurred in densely inhabited village areas such as Rajgarh and Johying Line no.27, while others took place within the forest boundaries, highlighting both the spatial unpredictability and intensity of these encounters. Notably, all recorded fatal and non-fatal incidents involved solitary male elephants, or makhnas, often in a state of musth or suffering from prior injuries. Of the eight injury cases, 66% were classified as minor, while 34% involved severe trauma including bone fractures and head injuries. A few incidents also resulted from accidental nighttime encounters where both humans and elephants were unaware of each other's presence. Although the annual number of such cases is relatively low, they hold disproportionate emotional and economic consequences for affected families

and generate community resentment towards conservation initiatives. These findings reflect similar patterns observed in other conflict-prone regions of India, such as West Bengal and Odisha, where gender-diverse vulnerability, limited mitigation infrastructure, and marginal agrarian livelihoods increase local susceptibility to elephant aggression (Gore et al., 2020; Das & Dey, 2022). The need for early-warning systems, habitat restoration, and community-level preparedness becomes all the more urgent in light of these recurring incidents.

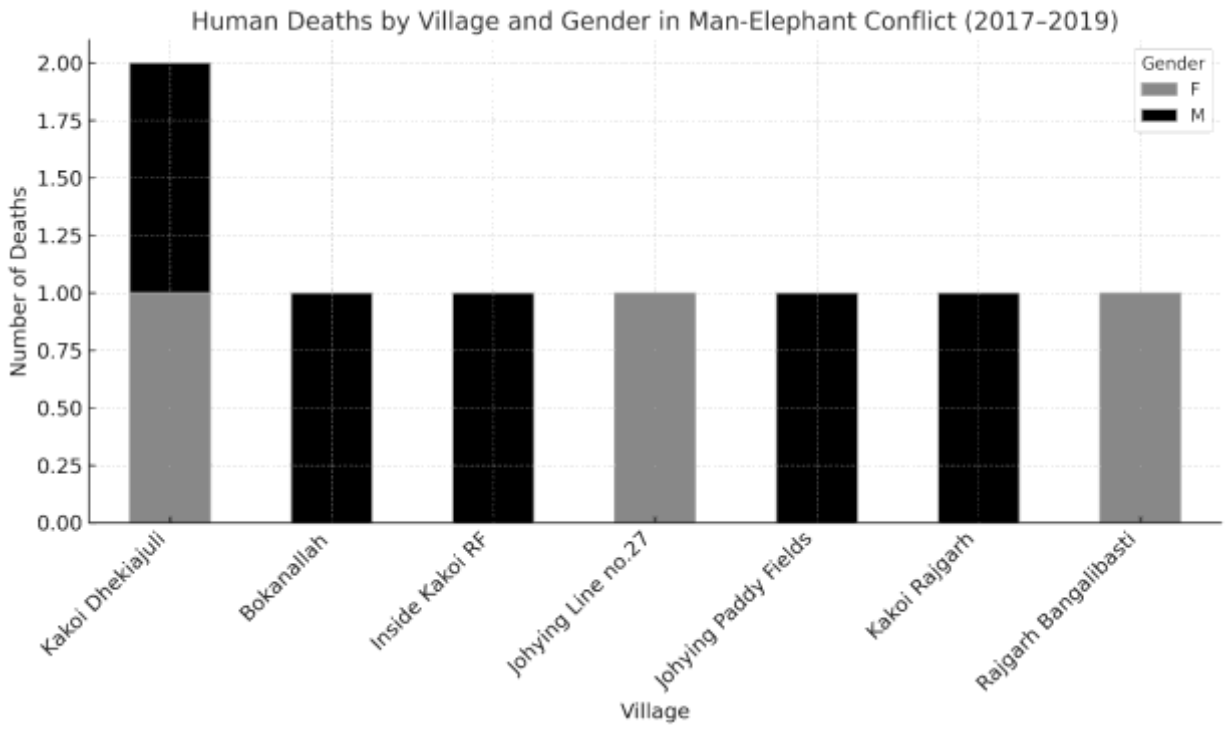

Fig 3: Human fatalities from man-elephant conflict in Kakoi region villages (2017–2019), showing a nearly equal distribution between male and female victims, with Kakoi Dhekiajuli reporting the highest number of deaths.

4.3. Household and property damage:

Between 2017 and 2019, the estimated economic loss due to human-elephant conflict in the study villages amounted to approximately ₹1.41 lakh, encompassing damage to livestock, poultry, and sericulture infrastructure. These figures are derived from conservative market valuations based on Assam's prevailing compensation standards at the time. Cattle losses were valued at ₹15,000–₹25,000 per adult head, with injuries estimated at ₹5,000 per case (Dutta & Singh, 2018), while pigs averaged ₹6,000 each, and poultry at ₹250 per bird (Ramakrishnan & Häger, 2020). In Kakoi Rajgarh, a household sericulture unit—comprising Persea bombycina plantations and rearing structures—was completely destroyed, incurring an estimated loss of ₹35,000 in accordance with norms from the Assam Sericulture Mission (2018).

Beyond economic loss to livestock and cottage industries, wild elephants frequently damaged homes and personal property. These incidents were largely triggered by elephants seeking salt and stored grain within households, though in several cases, defensive responses from agitated residents escalated the damage. Property damage was reported nearly year-round, with a noticeable spike during the paddy

harvest season and winter months. Villages such as Bokanallah, Dirgha Naharbari, Dirgha Nepalibosti, and Kakoi Rajgarh were among the worst affected. Observations revealed that solitary bull elephants (makhnas) were responsible for approximately 70% of such incidents, while family herds accounted for the remaining 30%. According to the Government of India's ex-gratia compensation guidelines, affected families may be eligible for ₹500,000 in the case of human death, ₹200,000 for grievous injuries, and up to ₹25,000 for minor injuries (MoEFCC, 2021). Nonetheless, such restitution often falls short of covering the full socio-economic and psychological burden of crop failure, property destruction, and long-term displacement (Vasudev et al., 2020).

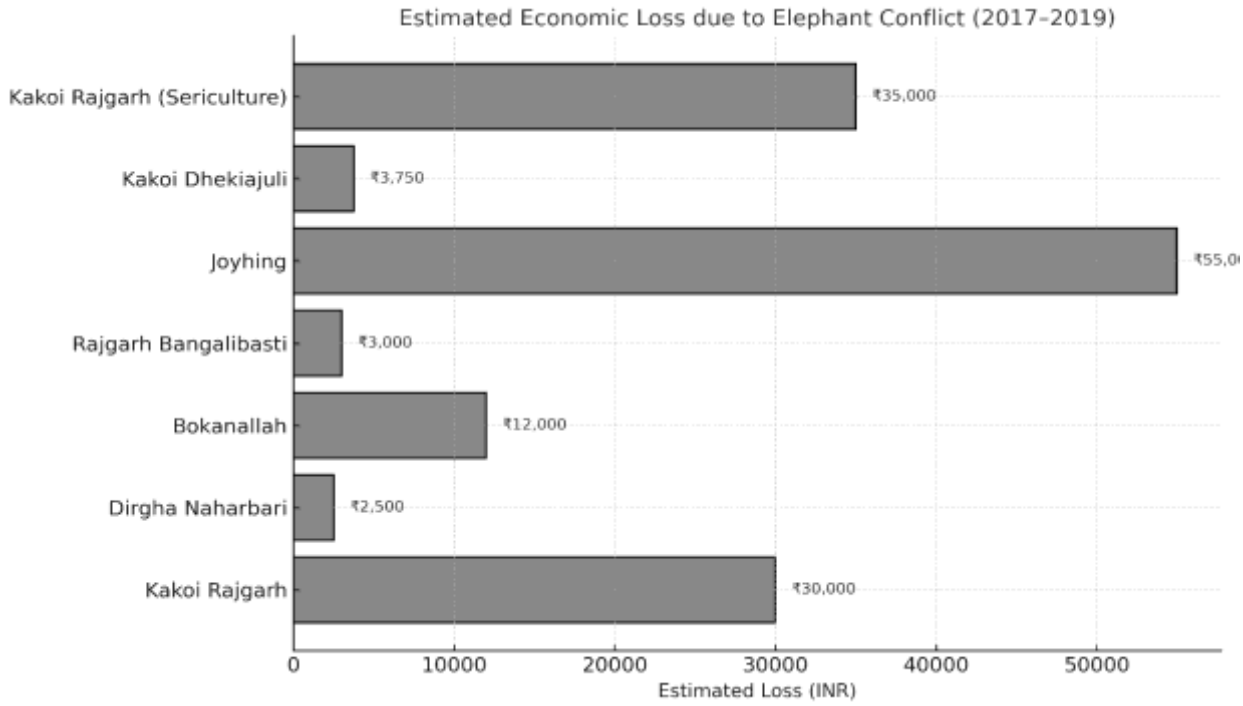

Fig 4: Estimated economic losses incurred due to elephant conflict in Kakoi fringe villages (2017–2019), with Joyhing and Kakoi Rajgarh (Sericulture) reporting the highest monetary damages.

4.4 Strategies for Mitigating Human–Elephant Conflict

In the fringe villages surrounding Kakoi Reserve Forest, traditional drive-away techniques remain the primary method of deterring wild elephants. These include shouting, drumming, bursting firecrackers, firing blanks, waving torches, pelting stones, and throwing burning logs—strategies that rely on sensory deterrence. Depending on the severity of intrusion, the Forest Department may initiate Kunki operations, wherein trained captive elephants are used to repel crop-raiding herds. During the cropping and harvesting seasons, farmers construct temporary tree-platform shelters known as tongis or machans near their fields, allowing them to guard their crops overnight.

Interviews with affected residents consistently revealed that no single mitigation strategy was entirely effective on its own. While each method may offer partial relief, it is their combined application—or "synergistic deployment"—that provides a more comprehensive deterrent effect. Similar findings have been documented by Chaudhury (1992), who emphasized that persistent, multi-pronged deterrence can often frustrate even the most determined problem elephants. According to local informants, family herds

were generally easier to repel, whereas solitary bulls, especially makhnas, were significantly more difficult and resource-intensive to deter, often requiring coordinated community action.

4.4.1 Community Perspectives on Conflict and Compensation

Despite experiencing recurrent loss and hardship due to elephant incursions, communities in the study area often retain a respectful—though increasingly strained—view of elephants. This cultural tolerance is rooted in India's rich religious and philosophical traditions, where animals, including elephants, hold symbolic and sacred significance (Gurung, 2000; Williams, 2006). However, tolerance is not unlimited. Nearly all respondents (98%) expressed frustration with the Assam Forest Department's current compensation mechanisms. Many described the process as slow, bureaucratic, and insufficient in providing fair redress. In some cases, villagers reported receiving no compensation even after repeated follow-ups.

When asked to suggest effective mitigation strategies, 48% of respondents recommended installing electric fences along the forest perimeter. Concrete boundary walls were the second most popular suggestion (25%), while 15% emphasized the need for increased Forest Department patrolling and Joint Forest Management Committee (JFMC) involvement during peak crop-raiding months. A smaller proportion of villagers proposed more extreme or creative measures, including complete relocation (8%) or installing perimeter lighting at night (7%).

4.4.2 Alternative Cropping and Bio-Fencing as Preventive Measures

An increasingly advocated mitigation strategy involves modifying traditional cropping patterns by introducing elephant-repellent cash crops such as lemon and chilli. Successful trials of these "bio-fence" crops have been reported in the buffer zones of Manas National Park and other high-conflict areas in India (Menon et al., 2013; Sukumar & Santiapillai, 2020). In the Kakoi Reserve Forest area, small-scale tea cultivation along forest edges was observed during fieldwork and appears to serve a dual purpose—as both a deterrent and an economically viable alternative to rice. Given its dense foliage and low palatability for elephants, tea cultivation could serve as a natural barrier, reducing both the frequency and severity of elephant incursions. Diversifying toward such deterrent crops could help farmers offset their annual losses while reinforcing ecological boundaries between human settlements and elephant habitats.

5. Conclusion

The intensifying human–elephant conflict (HEC) in the fringe villages of Kakoi Reserve Forest, Assam, reflects the broader crisis facing Asian elephants (Elephas maximus) across South Asia. Between 2017 and 2019 alone, the study area recorded eight human fatalities, multiple serious injuries, loss of livestock, destruction of infrastructure, and widespread crop damage. Over 67 incidents of crop-raiding, seven fatal encounters, and an estimated economic loss of ₹1.41 lakh from livestock and sericulture damage were documented. Additional losses from crop destruction—especially of paddy, banana, coconut, and vegetables—would likely push the total annual loss well beyond ₹5–6 lakhs per cluster of villages, depending on seasonality and intensity (Ramakrishnan & Häger, 2020; Dutta & Singh, 2018).

These damages, both tangible and emotional, are exacerbated by the fragmentation of migratory corridors, increasing anthropogenic pressures, and delays in compensation mechanisms. Notably, elephants in this landscape prefer paddy crops, with attacks peaking in June–August and October–December—critical agricultural seasons for Ahu and Sali paddy. Despite seasonal trends, elephants were

found to raid year-round, often within 3 km of the forest edge, demonstrating both spatial persistence and behavioral adaptability (Sukumar, 2013; Naha et al., 2020).

Most raiding events were attributed to solitary male elephants or Makhnas, known for their aggressive crop-foraging behavior. Additionally, damage to livestock (including pigs and cattle), poultry houses, and even sericulture infrastructure indicates that the scope of conflict has widened from just food security to household economy and agrarian sustainability. The Government of India's ex-gratia compensation of ₹5 lakh for human deaths and capped reimbursements for crop/property losses remains insufficient to address the broader social and psychological toll (Vasudev et al., 2020; Singha, 2022).

Yet, amidst these challenges, local communities continue to employ traditional drive-away methods, construct "machans" (crop-watch platforms), and express residual cultural reverence for elephants, despite repeated losses. The support for electric fences, regular patrols, and bio-fencing with deterrent crops like lemon and tea reflects a willingness to collaborate in mitigation if institutional responsiveness improves (Menon et al., 2013; Chaudhury, 1992).

Effective HEC management in regions like Kakoi demands a comprehensive, region-specific strategy. This includes:

Rapid-response compensation frameworks,

Habitat and corridor restoration,

Deployment of alternative cropping and agroforestry,

And community co-management structures.

Only by acknowledging the socioeconomic and ecological interconnectedness of the problem can long-term coexistence between humans and elephants be achieved.

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