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MITIGATION OF HUMAN-ELEPHANT CONFLICT FOLLOWING HYDROMETEOROLOGICAL DISASTERS IN CENTRAL ACEH REGENCY

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Abstract

This study aims to analyze the characteristics and driving factors of post-disaster human-elephant conflict and to formulate mitigation strategies integrated with Disaster Risk Reduction (DRR). Employing a qualitative approach with an exploratory case study design, the research was conducted in Karang Ampar Village, Central Aceh Regency, an area that experienced severe isolation following the impact of Tropical Cyclone Senyar in November 2025. Data were collected through field observations, in-depth interviews with affected communities and key stakeholders, and supporting documentation, and were analyzed using Miles and Huberman's interactive analysis model. The findings indicate that the intensification of post-disaster human-elephant conflict is driven by four main factors: habitat degradation and scarcity of natural forage, alterations in elephant migration corridors, damage to conflict mitigation infrastructure, and increased socio-economic vulnerability of local communities following the disaster. Hydrometeorological disasters function as trigger events that accelerate shifts in elephant movement patterns toward human settlements, while simultaneously reducing community capacity to respond to conflict in a safe and adaptive manner. This study recommends an integrated mitigation strategy encompassing habitat rehabilitation through Nature-based Solutions, strengthening disaster-resilient mitigation infrastructure, community empowerment based on conservation and disaster resilience, and the reinforcement of institutional and spatial policy frameworks. Such an integrated approach is essential not only to reduce the intensity of human-elephant conflict but also to enhance post-disaster socio-ecological resilience in Central Aceh.

Keywords: Central Aceh; disaster risk reduction; human-elephant conflict; hydrometeorological disaster; socio-ecological resilience.

INTRODUCTION

The Sumatran Elephant (*Elephas maximus sumatranus*) is one of the Asian elephant subspecies and plays a vital role in maintaining the balance of the tropical forest ecosystem of Sumatra. These animals act as guardians of ecological dynamics through roaming patterns, seed dispersal, and the formation of natural corridors in forest areas. However, the Sumatran elephant population is currently very worrying. Its status is critically endangered, with a particularly sharp population decline in recent decades. If, in the mid-1980s, the population was estimated at 2,800–4,800 individuals spread across 44 habitat pockets, then in 2020 this number will decrease to around 924–1,359 individuals across 22 habitat pockets (Imron et al., 2023). This decline is mainly driven by deforestation, habitat fragmentation, the conversion of forest areas to plantations, and increasing pressure on interactions between elephants and humans. This condition shows that the conservation problem of Sumatran elephants cannot be understood solely as a wildlife issue but also as an interrelated ecological and social problem.

Among the various elephant habitat areas in Sumatra, Aceh Province occupies a strategic position because it has the largest population of Sumatran elephants in Indonesia, estimated at 475–550 individuals (wwf.id, 2017). One of the important habitat pockets is in the Peusangan watershed area, which includes the Central Aceh Regency. However, these habitats face serious threats from habitat fragmentation, plantation expansion, illegal deforestation, and the intensification of elephant-human conflicts (Mobrucker et al., 2016). The situation became even more complex after a major hydrometeorological disaster in November 2025 that hit the Sumatra region. The disaster triggered by Tropical Cyclone Senyar caused flash floods, landslides, infrastructure damage, village isolation, and significant landscape changes in Central Aceh. Post-disaster ecological changes have direct implications for elephant habitats, including the destruction of food sources, disruption of migration corridors, and increased pressure on elephants to enter residential areas and farmland (Sarker & Adnan, 2024). Thus, the elephant-human conflict in Central Aceh cannot be separated from the context of disasters, climate change, and the social vulnerability of local communities.

Several previous studies have shown that a combination of ecological and anthropogenic factors influences elephant-human conflict. *First,* Human-elephant conflicts in the TNTN have increased due to forest shrinkage and plantation dominance (>78%), triggered by settlement

distance (34.4%), altitude (27.3%), and river distance (15.9%), with high-risk areas reaching 46,381.64 ha in lowlands near settlements and rivers (Elfi & Iskarni, 2025). *Second,* The intensity of crop damage by elephants increases due to land conversion and preferred crop types, with 65% of the affected land being <250 m from the water source, and the predicted damage increases from 17% to 54–63% as palatable crops increase, although the drought scenario is estimated to reduce the affected area by 46% but increase human-elephant competition for water (Montero-Botey et al., 2024). *Third*, human-elephant conflicts in Aceh reached 262 cases (2012–2017), with the highest contribution in East Aceh (47 cases) and Aceh Jaya (44 cases), which are mainly influenced by distance from settlements (84.7%) and primary forest loss (14.1%)(Qomariah et al., 2018).

Fourth, human-elephant conflict in Aceh shows that 64% of people reject conservation when livelihoods are threatened, although 36% support elephant protection and 86% view forests positively, while 83% rate conservation authorities negatively, with attitudes influenced by proximity to forests, employment, and education levels (Abdullah et al., 2019). *Fifth,* human-elephant conflict mitigation in Way Kambas National Park involves 11 stakeholders divided into three main groups (subject, key players, and context setters) with a pattern of collaborative relationships, so it is necessary to strengthen communication forums and cross-party cooperation to achieve the effectiveness of conflict mitigation (Andyono et al., 2018). In addition, other studies affirm the importance of local community involvement in conservation, as the presence of elephants around settlements can lead to recurring conflicts.

Although these studies have provided an important knowledge base, there are still clear gaps in the study. Most previous research has focused on the effects of habitat fragmentation, settlement proximity, forest loss, and conflict patterns in specific regions. However, it has not specifically examined the dynamics of elephant-human conflict in the context of hydrometeorological post-disasters. In fact, disasters can suddenly alter the ecological landscape, disrupt food resources, cut off migration routes, and increase pressure on animals moving into human living spaces. In Indonesia, especially in Central Aceh Regency, which has a mountainous terrain and is highly vulnerable to climate disasters, this kind of study remains very limited. On that basis, the novelty of this research lies in its effort to analyze elephant-human conflicts following hydrometeorological disasters, specifically, while integrating the perspective of wildlife conservation with a disaster risk reduction approach. This approach is important because it offers

a mitigation framework that is not only reactive to conflict but also adaptive to environmental changes and societal vulnerabilities.

Based on this description, this study aims to analyze the characteristics of elephant-human conflict following hydrometeorological disasters in Central Aceh Regency, identify factors that affect conflict intensity, and formulate effective, integrated mitigation strategies that integrate disaster risk reduction. This goal is important because post-disaster elephant-human conflict is not only a matter of species conservation but also concerns the protection of community living space, the sustainability of livelihoods, and the region's resilience to future disasters. By comprehensively understanding the characteristics of conflicts and their triggers, this research is expected to produce relevant recommendations for local governments, conservation managers, and local communities. Furthermore, the results of this study are expected to strengthen the development of an adaptive, participatory, and contextual conflict mitigation model, so that the protection of Sumatran elephants can go hand in hand with efforts to build socio-ecological resilience of communities in disaster-prone areas.

METHOD

This study uses a qualitative approach with an exploratory case study design (*Exploratory Case Study Design*) to study in depth the dynamics of elephant-human conflict after hydrometeorological disasters in Central Aceh Regency(Yin, 2009). This approach was chosen because the research seeks to understand events in a contextual, holistic, and in-depth manner, based on the experiences of parties directly involved in the field. The study was conducted in Karang Ampar Village, an area bordering the Peusangan Watershed (DAS), which was one of the pockets of elephant habitat affected by Tropical Cyclone Senyar in November 2025. The location was selected purposively based on three main criteria: the level of disaster impact, the frequency of elephant-human conflicts before and after the disaster, and the area's accessibility for implementing the research. The research focuses on understanding the characteristics of conflicts, their triggering factors, and the mitigation needs relevant to the local community's socio-ecological conditions.

The research data consists of primary data and secondary data. Primary data were collected through field observations, in-depth interviews, and documentation. In contrast, secondary data

were obtained from supporting documents, agency reports, and archives relevant to elephant-human conflicts and disasters. Data sources include conflict victims, village heads, community leaders, farmers, and key stakeholders, including the Forestry Service, the Central Aceh Regional Disaster Management Agency (BPBD), and conservation NGOs in Central Aceh. The collected data were analyzed using the Miles and Huberman interactive analysis model, which comprises three main stages: data condensation, data presentation, and conclusion drawing and verification. The analysis is carried out simultaneously and iteratively from the beginning of data collection through the completion of the research, allowing researchers to gain a more comprehensive understanding. (Huberman, 2019). Through this method, the research is expected to yield findings that can contribute to the practical formulation of more effective elephant-human conflict mitigation policies.

RESULT AND DISCUSSION

Results

The results of this study are compiled based on a problem formulation that focuses on the factors driving the intensification of human-elephant conflicts following hydrometeorological disasters in Central Aceh Regency. The data presented are the results of field observations, in-depth interviews, and spatial analysis that describe the empirical conditions in Karang Ampar Village. The presentation of the results begins with a table summarizing the data to provide an overview of changes in conditions before and after. This was followed by a descriptive elaboration of each of the main factors: habitat degradation, changes in migration corridors, damage to mitigation infrastructure, and increased socio-economic vulnerability of the community. This structure aims to show the causal relationships among factors systematically.

Table 1. Factors of Intensifying Human–Elephant Conflict Post-Disaster

Factors	Indicator	Findings
Habitat degradation	Damage to feed vegetation	40–60%
Scarcity of feed	Availability of natural resources	Significant decline
Corridor changes	Habitat–settlement distance	6–8 km → 2–4 km
Mitigated infrastructure	Electric fence & trench	Damaged/non-functional
Socio-economic vulnerability	Decreased income	50–70%
Intensity of conflict	Frequency of elephant appearances	Increased 2x

Description: Data from observations, interviews, and field analysis (2025–2026)

Habitat Degradation and Feed Scarcity

The study's results show that habitat degradation is the main driver of the intensification of human-elephant conflicts after disasters. Vegetation damage from landslides and flash floods has led to the loss of most of the elephants' natural food sources, especially in buffer forest areas adjacent to settlements. Observation data showed that the damage rate to feed vegetation reached 40-60%, especially to bamboo plants and grass, which are the main food of elephants. This creates significant ecological stress, so elephants lose access to adequate food sources in their natural habitat.

In addition to vegetation damage, changes in hydrological conditions also affect the availability of water sources for elephants. Flash floods and river sedimentation cause some natural water sources to experience blockages or changes in flow. This reduces the elephant's access to water, a vital need throughout its life cycle. As a result, elephants are encouraged to leave forest areas and seek alternative water sources near human settlements, thereby increasing the potential for direct interaction between humans and elephants.

Interviews with the community show that after the disaster, the presence of elephants on farmland increased significantly. Agricultural land that is relatively not directly affected by disasters is an attractive alternative source of feed for elephants. Crops such as corn, bananas, and sweet potatoes are the main targets. This shows that habitat degradation not only reduces the carrying capacity of the natural environment but also shifts ecological pressure into human living spaces, thereby increasing the likelihood of direct conflict.

Changes in the Elephant Migration Corridor

Changes in elephant migration corridors are another important factor in the intensification of conflicts. The results of the spatial analysis showed that the traditional elephant roaming route was disrupted by landslide material that blocked natural access. Previously, consistently used paths became impassable, so elephants had to find alternative routes to move between regions. These changes directly affect elephants' movement patterns, making them more unpredictable.

The data show that the distance between elephant habitat and community settlements decreased significantly, from about 6–8 km to 2–4 km after the disaster. This decrease in distance increases the likelihood of interactions between humans and elephants. In addition, some alternative routes used by elephants actually pass through agricultural areas, increasing the risk of

land damage and direct conflict. This change in the corridor also caused elephants to enter areas that were previously rarely traveled. People who are not used to encountering elephants are less prepared to respond to the situation. This exacerbates conflict conditions due to the lack of experience or adequate mitigation measures in the new areas through which elephants pass. Thus, corridor changes not only affect the ecological aspect but also the community's social readiness.

Damage to Mitigation Infrastructure

Damage to mitigation infrastructure accelerates the escalation of post-disaster conflicts. The solar electric fence, which previously served as the main barrier, was damaged by landslide material and flooding. In addition, at some points, barrier trenches are covered with sediment, making them ineffective at inhibiting elephant movement. This condition causes a loss of physical protection for the community against the threat of elephants. Community-based early warning systems are also disrupted due to damage to communication devices and limited access to transportation. The area's isolation makes coordination between the community and related parties suboptimal. As a result, effective early detection of elephant presence is not possible, so responses to conflicts tend to be delayed. This infrastructure damage shows that existing mitigation systems were not designed to withstand post-disaster extremes. Infrastructure that was previously effective under normal conditions becomes dysfunctional in emergencies. This indicates weaknesses in mitigation planning that fail to account for disaster risk comprehensively.

Socio-Economic Vulnerability of Communities

Increasing the socio-economic vulnerability of communities is an important factor in intensifying conflict. The interviews showed that most people experienced a 50-70% decrease in income due to damage to agricultural land and disrupted market access. This condition makes the community highly dependent on the remaining crops, thereby increasing the significance of losses due to elephant disturbances.

In this situation, the community's tolerance for elephants decreases sharply. Crop loss not only affects the economy but also household food security. This encourages the community to take more aggressive measures in evicting elephants, including the use of high-risk methods. High economic pressure also affects the community's psychological well-being. Post-disaster anxiety and uncertainty exacerbate the response to conflict. This shows that socio-economic vulnerability

affects not only material aspects but also people's behavior and decision-making patterns in dealing with wildlife conflicts.

Discussion

Habitat Degradation and Ecological Stress

The study's findings show that post-disaster habitat degradation is the main factor driving changes in elephant habitat behavior towards human settlements. From an ecological perspective, the scarcity of food sources is a major determinant of spatial shifts in the distribution of large species such as elephants. Vegetation damage of 40–60% can significantly reduce habitat carrying capacity, prompting elephants to seek alternative food sources. This aligns with the ecological carrying capacity theory, which states that when environmental capacity decreases, animals will move to areas with higher resource availability. Thus, the conflict that occurs is not elephant deviant behavior but an adaptive response to ecological pressures that suddenly increase following disasters (Maurer et al., 2021; Mumby & Plotnik, 2018; Pretorius et al., 2023).

These findings confirm previous studies showing that habitat degradation is a dominant factor in human-wildlife conflicts. Studies in Asia and Africa have shown that the loss of feed vegetation significantly increases the frequency of negative interactions between humans and elephants (Batrisyia et al., 2026; Cabral De Mel et al., 2022; Gross et al., 2018; Guarnieri et al., 2024). However, this study makes a new contribution by showing that hydrometeorological disasters accelerate the degradation process in a relatively short time. If, under normal conditions, habitat change occurs gradually, then post-disaster change occurs abruptly and simultaneously. This shows that disasters function as ecological stressors that accelerate pressure on wildlife, thereby increasing conflict intensity more rapidly than natural dynamics.

In addition, changes in hydrological conditions have exacerbated the ecological stress elephants experience. Reduced access to natural water sources forces elephants to seek alternative sources near settlements (Buchholtz et al., 2021; Shiweda et al., 2023). In the study of animal behavior, water needs are an important factor that affects daily and seasonal movement patterns. These findings reinforce the argument that human–elephant conflict is not only triggered by food-related factors but also by other basic needs, such as water. Thus, mitigation approaches must not focus solely on spatial management; they must also consider the restoration of ecosystem functions as a whole, including water sources as an integral part of wildlife habitats.

Changing Corridors and Conflict Landscapes

Changes in elephant migration corridors suggest that the spatial dynamics of the post-disaster landscape also influence human-elephant conflict. Traditional cruising routes covered by landslide materials forced elephants to use alternative routes closer to human settlements. In landscape ecology theory, changes in landscape structure can disrupt habitat connectivity and force wildlife to adapt to new conditions (Cumming & Epstein, 2020; Doherty & Driscoll, 2018; Presley et al., 2019). Reducing the distance between habitat and settlement from 6–8 km to 2–4 km significantly increases the probability of interaction. This shows that conflict is not only triggered by ecological pressures but also by changes in spatial configuration that bring humans and animals into closer proximity.

These findings confirm previous research that spatial proximity between animal habitats and human settlements is a major predictor of conflict. However, this study makes an additional contribution by showing that disasters can quickly and drastically reconfigure the conflict landscape. Changes that usually occur over the long term can occur in a short period due to large-scale environmental disturbances. This suggests that human-animal conflict analysis needs to consider the temporal dynamics triggered by extreme events, rather than the static conditions of the landscape (Abrahms et al., 2023; Bagheriyan et al., 2023; MustăţEa & Pătru-Stupariu, 2021).

In addition, the entry of elephants into previously rarely traveled areas indicates the expansion of conflict areas. Communities in the region tend to lack experience or capacity to address conflicts with elephants, so responses are often ineffective or even make the situation worse (Sampson et al., 2019; Shaffer et al., 2019). This shows that the change in the corridor not only affects the ecological aspect but also the community's social readiness. Therefore, conflict mitigation must consider the spatial distribution of risk and the readiness of communities in areas with the potential to become new elephant movement routes.

Weaknesses of Mitigation Infrastructure

Damage to post-disaster mitigation infrastructure shows weaknesses in existing conflict management systems. Solar electric fences and barrier ditches that were previously effective became dysfunctional due to landslides and flooding. From a risk management perspective, this condition reflects the low level of resilience of infrastructure to external disturbances (Bagnoli & Cavallo, 2025; Soltaninejad et al., 2025). Mitigation infrastructure that is not designed to withstand

extreme conditions tends to fail when needed, increasing the risk of conflict. This shows that the effectiveness of mitigation systems largely depends on their adaptability to changing environmental conditions.

These findings criticize conventional approaches to human–animal conflict mitigation that tend to focus on technical solutions without considering disaster risk factors. Previous studies have shown that electric fencing and early warning systems are effective in reducing conflicts, but this study shows that their effectiveness is contextual. When a disaster occurs, the system becomes dysfunctional, so it is unable to provide adequate protection (Barten et al., 2021; Mahadevia Ghimire, 2021; Roy, 2023). Thus, a new approach is needed that integrates disaster resilience into the design of mitigation infrastructure.

In addition to the physical aspect, damage to the communication system also affects the effectiveness of conflict mitigation. Disruptions in the early warning system led to delays in detecting elephant presence and in community response. In this context, coordination between the community and related institutions becomes suboptimal. This shows that conflict mitigation depends not only on physical infrastructure, but also on the institutional and communication systems that support it. Therefore, strengthening mitigation infrastructure must be carried out holistically, taking into account both technical and institutional aspects.

Socio-Economic Vulnerability and Community Response

The increase in socio-economic vulnerability of post-disaster communities is an important factor in the escalation of human-elephant conflicts. A 50–70% decrease in income causes people to lose their main source of livelihood, resulting in increased dependence on agricultural products. In the theory of livelihood vulnerability, this condition increases people's sensitivity to external disturbances, including conflicts with wildlife. Losses due to elephant disturbances are more significant because they directly affect household economic resilience. This shows that conflict is influenced not only by ecological factors but also by the community's socio-economic conditions.

These findings affirm previous research that economic conditions influence people's tolerance for wildlife. In a stable economic situation, people tend to be more tolerant of animal disturbances. However, in post-disaster crisis conditions, this tolerance decreases drastically. The study adds that high economic pressures not only lower tolerance but also encourage people to use more aggressive, risky eviction methods a(Azzam et al., 2022; Iyer-Raniga & Vahanvati, 2021;

Warner & Wiegel, 2021). In addition to the economic aspect, post-disaster psychological stress also affects people's responses to conflicts. Anxiety and uncertainty increase people's tendency to make reactive decisions. This shows that human-elephant conflict is a multidimensional phenomenon that involves ecological, economic, and psychological aspects. Therefore, mitigation strategies should include a community empowerment approach that focuses not only on the economy but also on building adaptive capacity and psychosocial resilience.

Disaster as a DRR Trigger and Integration

Overall, this study's findings show that hydrometeorological disasters serve as trigger events that accelerate the intensification of human-elephant conflicts. Within the framework of Disaster Risk Reduction (DRR), disasters not only increase human vulnerability but also trigger changes in ecological systems that affect wildlife behavior (Klein et al., 2019). This shows that the conflicts that occur are part of a complex and interrelated socio-ecological risk.

These findings reinforce the literature's argument that human–wildlife conflict needs to be understood within an integrated system. Approaches that separate conservation and disaster management have proven ineffective in addressing post-disaster conflict (Gaillard et al., 2019; Peters, 2021). This study confirms the importance of integration between the two approaches to create a more adaptive and sustainable system. Thus, the proposed mitigation strategy should include habitat rehabilitation based on Nature-based Solutions, strengthening disaster-resistant infrastructure, community empowerment, and cross-sectoral policy integration. This approach aims not only to reduce short-term conflict but also to increase long-term socio-ecological resilience (Sáenz De Tejada et al., 2024). This is key in facing the challenges of climate change and the increasing frequency of disasters in the future.

CONCLUSION

This study concludes that the intensification of human-elephant conflicts after hydrometeorological disasters in Central Aceh is influenced by four main factors, namely habitat degradation and feed scarcity, changes in migration corridors, damage to mitigation infrastructure, and increasing socio-economic vulnerability of communities. Disasters act as *trigger events,* accelerating elephants' movement into settlements while reducing communities' adaptive capacity to respond to conflicts safely. Therefore, conflict management requires an integrated approach

that includes habitat rehabilitation based *on Nature-based Solutions*, strengthening disaster-resistant infrastructure, community empowerment grounded in conservation and resilience, and strengthening institutional and spatial policies to improve socio-ecological resilience sustainably.

This research has the strengths of an integrative approach between conservation and *Disaster Risk Reduction,* as well as the use of qualitative methods that can explore local dynamics in depth. However, it has limitations in narrow-area coverage and lacks support for quantitative data and animal monitoring technology. Therefore, further research is recommended using *a mixed-methods approach,* with support from technologies such as GPS tracking and satellite imagery, and conducting cross-regional comparative studies to improve the validity and generalizability of findings and to evaluate the effectiveness of implementing the proposed mitigation strategies.

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