

ANALYSIS OF HUMAN–ELEPHANT CONFLICT AND ITS ECONOMIC IMPACTS USING A COMMUNITY-BASED APPROACH IN THE PEUSANGAN WATERSHED, ACEH

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Abstract

Human–elephant conflict has become an increasingly significant environmental issue in Indonesia, particularly in the Peusangan Watershed, Aceh, affecting ecological, social, and economic aspects of local communities. This study aims to identify the main factors causing human–elephant conflict, analyze its economic impacts, and examine community-based mitigation efforts implemented at the local level. The research employed a descriptive exploratory approach using an ex-post facto method through interviews and field observations involving communities in Pantan Lah, Blang Rakal, and Karang Ampar villages. The results indicate that the conflict is primarily driven by habitat loss and fragmentation, microclimate changes, resource competition, and negative community perceptions toward elephants. The highest number of conflict cases was recorded in Karang Ampar Village (53 cases), followed by Blang Rakal (14 cases) and Pantan Lah (9 cases). The economic losses resulting from damage to agricultural and plantation land were estimated at IDR 2,733,800,000, leading to decreased productivity and community welfare. Community-based mitigation efforts include patrol activities, elephant deterrence measures, and participatory mapping of elephant movement corridors. These findings highlight that a community-based approach plays a crucial role in supporting sustainable conflict mitigation.

Keywords: *community-based mitigation, economic impact, human–elephant conflict, Peusangan watershed, Sumatran elephant.*

INTRODUCTION

Human–elephant conflict is an escalating global environmental issue, particularly in regions experiencing habitat fragmentation and land-use change (Nyhus, 2016). In Indonesia, especially on the island of Sumatra, this conflict has significant ecological, social, and economic consequences for communities living near elephant habitats (Kuswanda & Barus, 2018; Pratiwi et al., 2022). Elephants frequently leave their natural habitats and enter agricultural areas and human settlements, resulting in crop damage, economic losses, and increased risks to human safety. In Aceh Province, the intensity of human–elephant conflict has shown a rising trend over time. Previous studies report numerous conflict cases, largely driven by habitat loss due to deforestation and land conversion into agricultural and plantation areas (Qomariah et al., 2019; Kuswanda & Barus, 2018). Additional contributing factors include the proximity of human settlements to elephant habitats, microclimate changes, resource competition, and limited community participation in mitigation efforts, all of which exacerbate the conflict.

The Peusangan Watershed represents one of the key habitats of the Sumatran elephant (*Elephas maximus sumatranus*) in Aceh, currently under significant pressure from human activities such as agricultural expansion, plantation development, and infrastructure growth (Qomariah et al., 2019). These pressures have led to habitat fragmentation, forcing elephants to move into human-dominated landscapes. As a result, recurring conflicts occur, causing substantial economic losses for local communities. Specifically, the villages of Pantan Lah, Blang Rakal, and Karang Ampar exhibit varying levels of conflict intensity, with considerable impacts on agricultural productivity. Damage to crops and plantations caused by elephant incursions often leads to crop failure and significant financial losses, thereby affecting local livelihoods. Furthermore, these conflicts contribute to negative community perceptions of elephants, which may hinder long-term conservation efforts. Various mitigation measures have been implemented,

including both structural and non-structural approaches such as fencing, patrols, and deterrent techniques. However, their effectiveness remains limited and often lacks sustainability (Nugraheni et al., 2023). Therefore, community-based approaches have emerged as a promising alternative, emphasizing the active involvement of local communities in conflict mitigation strategies (Nyhus, 2016). This approach enhances community participation, fosters local ownership, and integrates local knowledge with scientific practices to support sustainable conservation outcomes. Based on these considerations, this study aims to analyze the factors driving human–elephant conflict, assess its economic impacts, and examine community-based mitigation efforts in the Peusangan Watershed. The findings are expected to contribute to both scientific knowledge and practical strategies for sustainable human–wildlife conflict management.

LITERATURE REVIEW

Human–elephant conflict is a growing global phenomenon, particularly in regions experiencing rapid land-use change and habitat fragmentation (Nyhus, 2016). In Indonesia, especially on the island of Sumatra, this conflict is primarily driven by the overlap between elephant habitats and human activities such as agriculture and plantation expansion (Kuswanda & Barus, 2018; Nugraheni et al., 2023). Previous studies indicate that when elephant habitats are reduced or degraded, elephants tend to move into agricultural areas in search of alternative food sources, leading to crop damage and increased conflict with local communities. These findings highlight that landscape transformation is a key driver of human–wildlife conflict. From a theoretical perspective, human–wildlife conflict can be explained through landscape ecology and human–environment interaction frameworks, which emphasize that changes in ecosystem structure and function influence wildlife behavior (Rood et al., 2010; Pirmansyah et al., 2024). The Sumatran elephant (*Elephas maximus sumatranus*) is a wide-ranging species with high dependency on food availability and water sources.

Consequently, habitat fragmentation caused by deforestation and land conversion disrupts elephant movement patterns and increases the likelihood of encounters with humans. In this context, ecological sustainability theory underscores the importance of maintaining a balance between human needs and wildlife conservation. Several studies have also identified that the drivers of human–elephant conflict are not solely ecological but also involve social and economic dimensions. Factors such as negative community perceptions toward elephants, low participation in conservation programs, and dependence on agricultural livelihoods further exacerbate the conflict (Pratiwi et al., 2022; Qodriyatun, 2019). Additionally, microclimate changes resulting from land conversion may affect water and food availability, forcing elephants to move beyond their natural habitats. This indicates that human–elephant conflict is a multidimensional issue that requires an interdisciplinary approach.

Various mitigation strategies have been implemented to address human–elephant conflict, including both structural and non-structural approaches. Structural measures involve the construction of fences, canals, and watchtowers, while non-structural approaches include patrols, deterrent tools, and monitoring of elephant movements (Nugraheni et al., 2023). However, existing studies suggest that these strategies are often short-term and lack sustainability, particularly due to limited community involvement in conflict management (Berliani et al., 2015). This limitation represents a major weakness in conventional mitigation practices. As an alternative, community-based approaches have gained increasing attention in human–wildlife conflict management. This approach emphasizes the active involvement of local communities in designing and implementing mitigation strategies, thereby enhancing local ownership and long-term sustainability (Nyhus, 2016; Naha et al., 2020). Empirical studies show that community participation in activities such as patrols, monitoring, and habitat management can significantly reduce conflict intensity and improve community perceptions of wildlife conservation. Furthermore, integrating local knowledge with scientific approaches is considered a key factor in the success of such strategies.

Despite the growing body of research on human–elephant conflict, significant gaps remain in the literature. Most previous studies tend to focus on ecological factors or technical mitigation strategies, with limited integration of socio-economic impacts and community-based approaches within a comprehensive analytical framework. In addition, there is a lack of context-specific studies that examine these issues in the Peusangan Watershed. Therefore, this study seeks to address these gaps by integrating the analysis of conflict drivers, economic impacts, and community-based mitigation efforts within a holistic framework. The study is expected to contribute to the development of more effective, participatory, and sustainable strategies for managing human–elephant conflict.

METHOD

Study Area and Research Period

This study was conducted in the Peusangan Watershed, Aceh Province, Indonesia, covering three villages: Pantan Lah, Blang Rakal, and Karang Ampar. These locations were purposively selected based on varying levels of human–elephant conflict intensity, categorized as low, moderate, and high. The research was carried out from January to June 2025, aligned with the agricultural activity cycle of local communities and the movement patterns of elephants in the study area. The spatial context of the study area is illustrated in *Figure 1*.

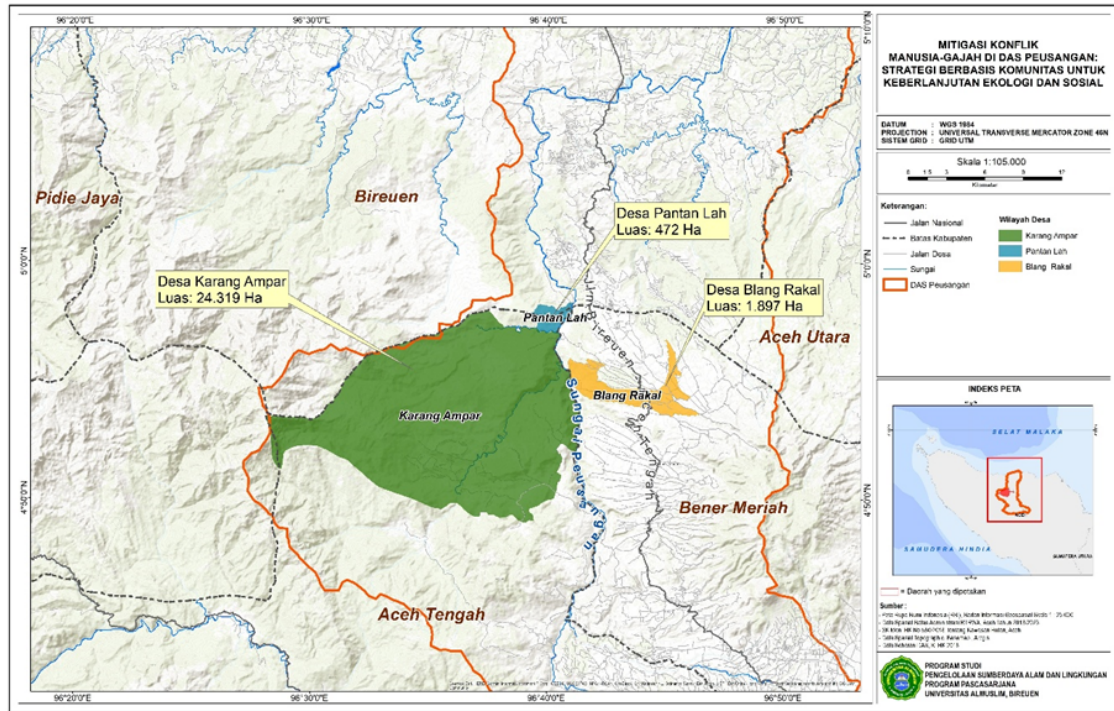


Figure 1. Study area map

Research Design and Data Collection Techniques

This study employed a descriptive exploratory approach using an ex-post facto method, which examines phenomena that have already occurred without manipulating research variables. Data collection was conducted through in-depth interviews, field observations, and documentation. In-depth interviews involved local communities, village authorities, and relevant stakeholders engaged in managing human–elephant conflict. Field observations were conducted to assess habitat conditions, types of land damage, and patterns of interaction between humans and elephants. Documentation included visual and spatial data collection using digital cameras and Global Positioning System (GPS) devices. The research instruments consisted of interview guidelines, voice recorders, digital cameras, and spatial analysis software (QGIS).

Data Analysis Techniques

1. Environmental Factor Analysis

Environmental factor analysis was conducted to identify the level of ecosystem changes contributing to human–elephant conflict. This analysis utilized the Naturalness Index to measure ecosystem naturalness and the Hemeroby Index to assess the degree of human-induced disturbance. The classification and scoring of these indices were based on *Table 1* and *Table 2*, respectively. These analyses were used to determine the level of habitat degradation at each study site.

Table 1. Naturalness index scoring

Score	Category	Human Impact & Ecological State
10	Virgin Natural System	Pure natural processes; negligible anthropogenic influence or external pollution.
9	Natural System	Minor exotic species (no ecological impact); minimal/temporary infrastructure; zero physicochemical pollution.
8	Sub-Natural System	Non-dominant exotic species; limited artificial elements; pollution within ecosystem tolerance; small-scale renewable extraction; natural hydrology; no fragmentation.
7	Quasi-Natural System	Widespread but low-impact human activity; scattered facilities; partially modified landscapes; rare artifacts/pollution; moderate extraction; low fragmentation; slightly altered hydrology.
6	Semi-Natural System	Sparse infrastructure; reduced natives, dominant wild exotics; low/biodegradable pollution; occasional energy input; minor physical changes; renewable extraction; low/moderate fragmentation; minimal water management.
5	Self-Maintained Cultural System	Extensive human use; altered/managed natives; naturally cultivated exotics; minor pollution; periodic energy input; sustainable extraction; passive water cycle management.
4	Assisted Cultural System	Mixed natives (corridors); dominant cultivated exotics; moderate pollution; energy-driven management; terraced/plotted landscapes; regular extraction; moderate fragmentation; active water management.
3	Highly Intervened System	Loss of select natives; abundant exotics & artifacts; intensive soil/water & moderate air pollution; high energy/material input; excavation-driven changes; intensive extraction; high fragmentation; controlled hydrology.
2	Semi-Transformed System	Rare natives; artifact-dominated; permanent water/air pollution; unplanned excavation & intensive fragmentation; no ecological corridors; fully regulated water systems.
1	Transformed System	Near-absent natives; garden-spread exotics; artifact-dominated; very high pollution; fully energy-dependent; complete physical alteration; maximal fragmentation; total water control.
0	Artificial System	No biological life; 100% artificial structures; incidental pollution; entirely dependent on external energy inputs.

Machado, 2004

Table 2. Hemeroby index scoring

Score	Category	Naturalness Level	Human Impact Summary
0	Ahemerobic	Undisturbed	No anthropogenic influence.
1	Oligohemerobic	Very low disturbance	Limited selective logging, low-intensity grazing, minor air/water emissions.
2	β -Mesohemerobic	Low disturbance	Occasional land clearing/tillage, clear-cutting, light fertilization.
3	α -Mesohemerobic	Moderate disturbance	Regular use of fertilizers, lime, pesticides; drainage ditch construction.
4	Euhemerobic	High disturbance	Intensive tillage, engineered drainage, systematic pesticide/fertilizer application.
5	Polyhemerobic	Very high disturbance	Single-event ecosystem destruction + habitat sealing with external materials.
6	Metahemerobic	Extremely disturbed	Ecosystem collapse; natural functions irreversibly lost.

Steinhardt et al., 1999

2. Economic and Social Impact Analysis

Economic impact analysis was carried out using a descriptive quantitative approach by calculating the economic losses resulting from damage to agricultural and plantation lands caused by elephant activities. Data were obtained from interviews and field observations and analyzed to estimate the magnitude of losses experienced by local

communities. This approach was further supported by identifying affected crop types and the extent of damage in each study location.

3. Habitat Quality and Vegetation Diversity Analysis

Habitat quality analysis was conducted using the Shannon–Wiener diversity index (H') to assess vegetation diversity within elephant habitat corridors. The classification of this index followed the criteria presented in *Table 3*.

Table 3. Shannon–Wiener diversity index (H') classification

H' Value	Category	Ecological Interpretation
< 1.5	Very Poor	Critically low diversity; ecosystem instability likely.
1.5 – 2.0	Poor	Low diversity; limited species richness or evenness.
2.1 – 2.5	Moderate	Balanced diversity; typical of disturbed or transitional habitats.
2.6 – 3.0	Good	High diversity; healthy, resilient community structure.
> 3.0	Very Good	Exceptional diversity; characteristic of pristine, complex ecosystems.

Vegetation data were collected using systematically arranged sample plots in the study area. The sampling design is illustrated in *Figure 2*.

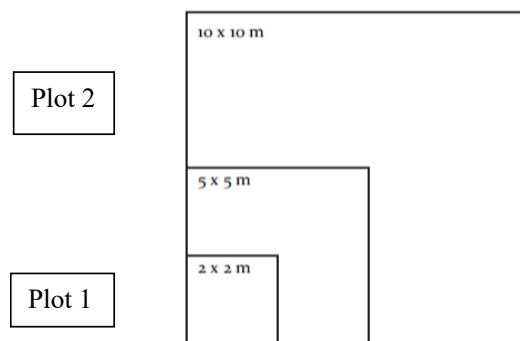


Figure 2. Systematic sampling plot design for vegetation analysis in elephant habitat

Spatial Analysis

Spatial analysis was performed to map habitat distribution and elephant movement patterns using ArcGIS software. This analysis aimed to identify potential elephant corridors and areas with a high risk of conflict. The results of the spatial analysis provided a basis for understanding the relationship between land-use changes and patterns of human–elephant conflict.

RESULTS AND DISCUSSION

A. Main Factors Causing Human–Elephant Conflict

The results of this study indicate that human–elephant conflict in the Peusangan Watershed does not occur randomly but is influenced by a combination of ecological, spatial, and anthropogenic factors. Based on empirical data, the number of conflict cases in 2025 shows significant variation across locations: Karang Ampar Village recorded 53 cases (high category), Blang Rakal Village recorded 14 cases (moderate category), and Pantan Lah Village recorded 9 cases (low category). These differences reflect variations in environmental pressure and land-use change intensity in each area. The distribution of conflict cases is closely related to regional characteristics such as area size, population density, and the intensity of local economic activities. These data are presented in *Table 4* :

Table 4. Area size, population, and human–elephant conflict cases

Desa Kelurahan	Kecamatan	Luas Total Area (Km ² /sq.km)	Jumlah Penduduk	Konflik Manusia dengan Gajah
Pantan Lah	Pintu Rime Gayo	6,6	195	9
Blang Rakal	Pintu Rime Gayo	16,56	1722	14
Karang Ampar	Ketol	99,00	517	53
Total				76

The table shows that Karang Ampar Village has a larger area with intensive land-use activities, including agriculture, plantations, and mining. These conditions increase pressure on elephant habitats compared to other villages. To understand the ecological drivers of conflict, analyses using the naturalness index and hemeroby index were conducted. The naturalness index measures ecosystem naturalness, while the hemeroby index reflects the level of human disturbance. The results indicate a gradient of environmental conditions ranging from relatively natural to highly degraded ecosystems, as shown in *Figure 3*.

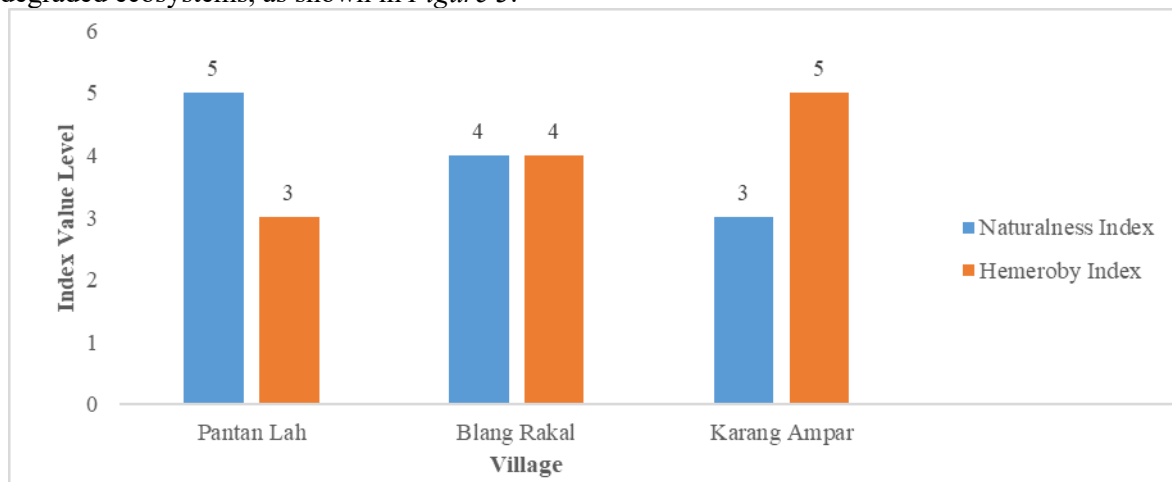


Figure 3. Naturalness and hemeroby indices in Pantan Lah, Blang Rakal, and Karang Ampar Villages

Based on the figure, Pantan Lah Village has the highest naturalness value (semi-natural system category) and the lowest hemeroby value (moderate disturbance), indicating relatively well-preserved habitat conditions with limited human activity. This condition contributes to the low intensity of conflict. In contrast, Karang Ampar Village shows low naturalness and very high hemeroby values (heavy to very heavy disturbance category), indicating significant ecosystem pressure due to land clearing, intensive pesticide use, and mining activities. These conditions destabilize elephant habitats and drive elephants out of their natural ranges. Blang Rakal Village represents a transitional condition, with moderate naturalness and high hemeroby, reflecting a mixture of natural and human-modified landscapes, resulting in moderate conflict levels.

One of the main causes of conflict is habitat loss due to forest conversion into agricultural land, plantations, and infrastructure. This reduces natural food availability and disrupts elephant migration routes. Additionally, habitat fragmentation exacerbates conflict by dividing habitats into isolated patches, limiting elephant movement. This increases the likelihood of encounters between elephants and humans, especially at forest–agriculture boundaries. This finding is supported by spatial analysis showing elephant distribution patterns in relation to land use, as presented in *Figure 4*.

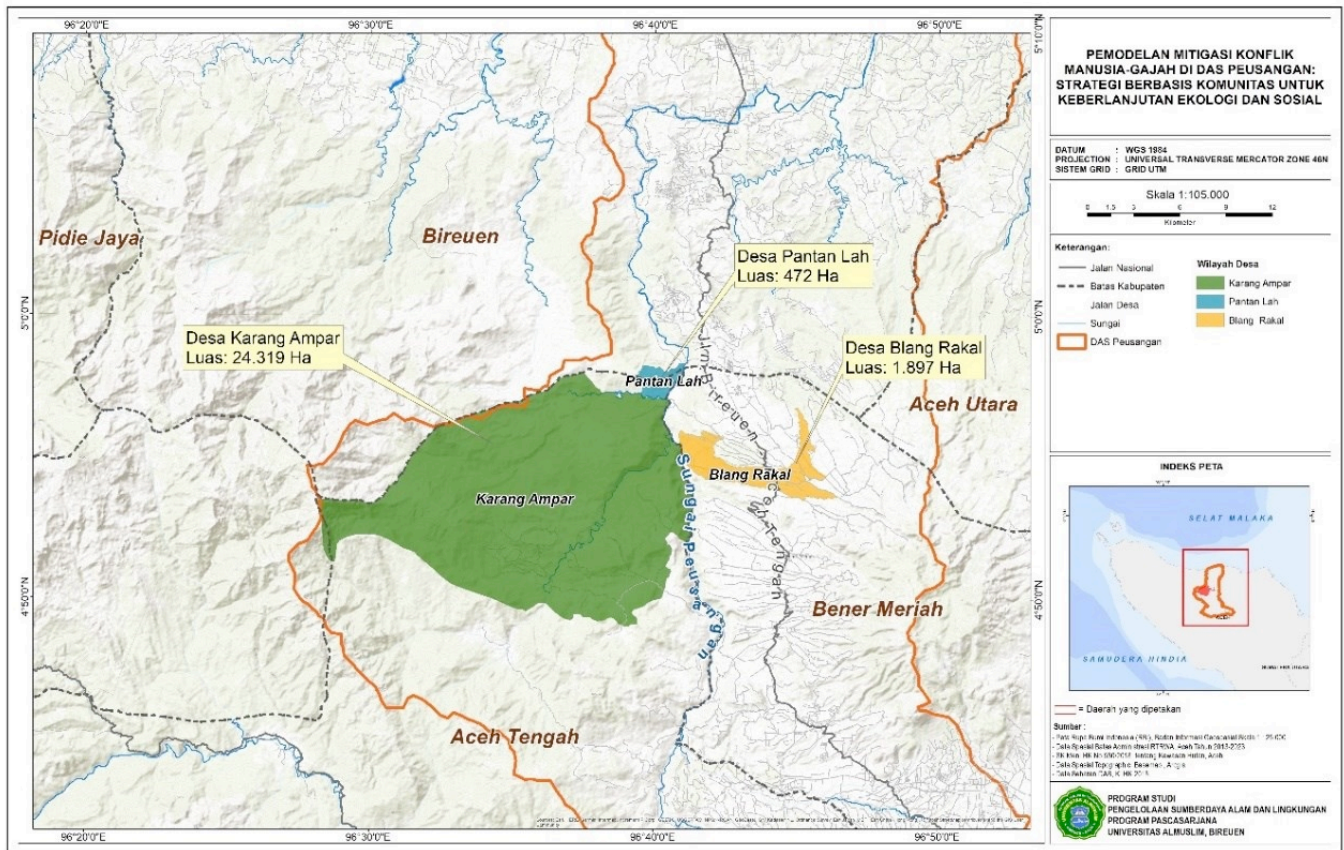


Figure 4. Spatial distribution map of elephants in the study area

The figure indicates that elephant distribution is concentrated near agricultural and plantation boundaries, suggesting that land-use changes have created intensive conflict zones. Microclimate changes due to deforestation also contribute to increasing conflict. Reduced vegetation cover leads to higher local temperatures and lower soil moisture, affecting water and food availability for elephants. As a result, elephants are forced to seek alternative resources outside their habitats, including agricultural lands. Their high dependence on water makes areas with water sources particularly vulnerable to conflict, especially during the dry season. Beyond ecological factors, social aspects also play an important role. Interviews reveal that local communities have negative perceptions of elephants due to crop damage and economic losses, leading to low tolerance and increased conflict potential. Low community participation in mitigation programs further complicates effective conflict management, indicating that human–elephant conflict is influenced not only by environmental factors but also by social and institutional dynamics.

B. Economic Impacts of Human–Elephant Conflict

Human–elephant conflict in the Peusangan Watershed not only affects ecological aspects but also causes significant economic losses for local communities. The study shows that damage to agricultural and plantation lands results in crop failures for key commodities such as oil palm, rice, corn, and horticultural crops. The total economic loss across all study sites reached IDR 2,733,800,000, indicating substantial economic pressure on local communities. The spatial distribution of these losses is illustrated in Figure 5.

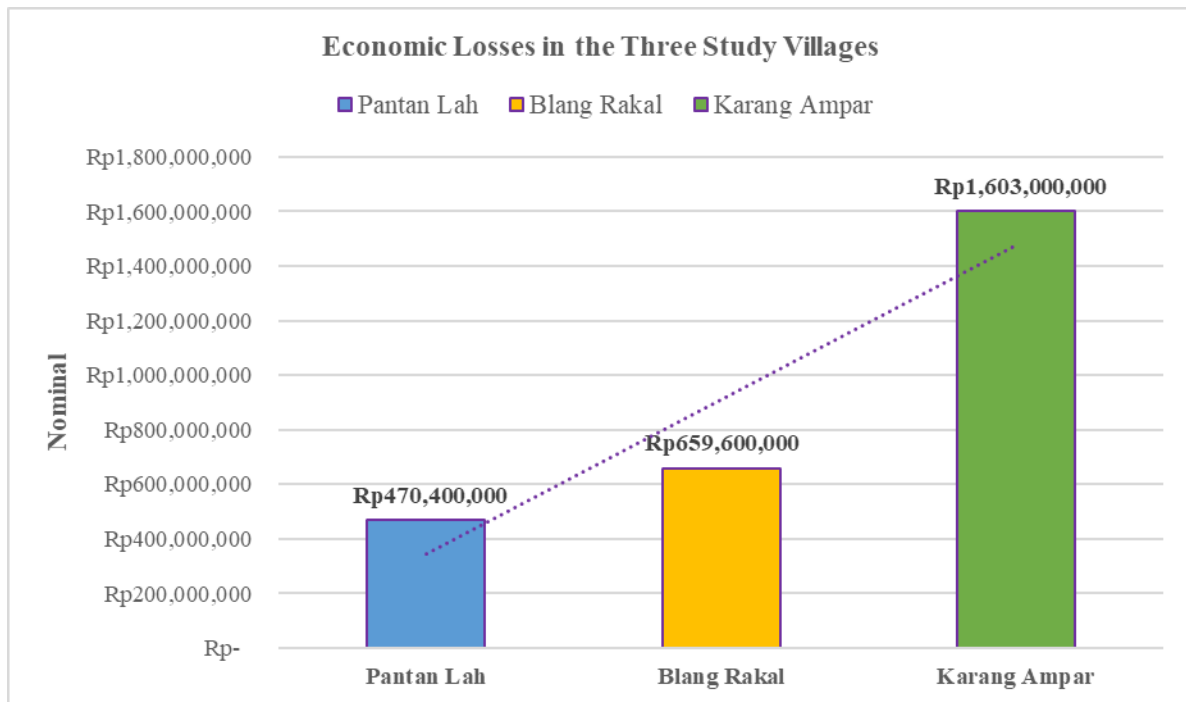


Figure 5. Total economic losses across the three study villages

Figure 5 shows that Pantan Lah Village experiences relatively low economic losses, consistent with its low conflict intensity and relatively intact habitat conditions, indicates that Blang Rakal Village experiences moderate economic losses due to increasing conflict frequency in agricultural areas, particularly during harvest seasons. Demonstrates that Karang Ampar Village experiences the highest economic losses, directly correlated with the highest number of conflict cases (53 cases). Elephant activities in this area are more frequent and recurring, causing large-scale and continuous land damage. Illustrates the cumulative economic losses, showing that Karang Ampar contributes the largest share, confirming a strong relationship between conflict intensity, habitat degradation, and economic impact. Economic losses are influenced not only by conflict frequency but also by crop types. Field observations indicate that crops with high economic value and nutritional content preferred by elephants are most affected, as shown in Figure 6.

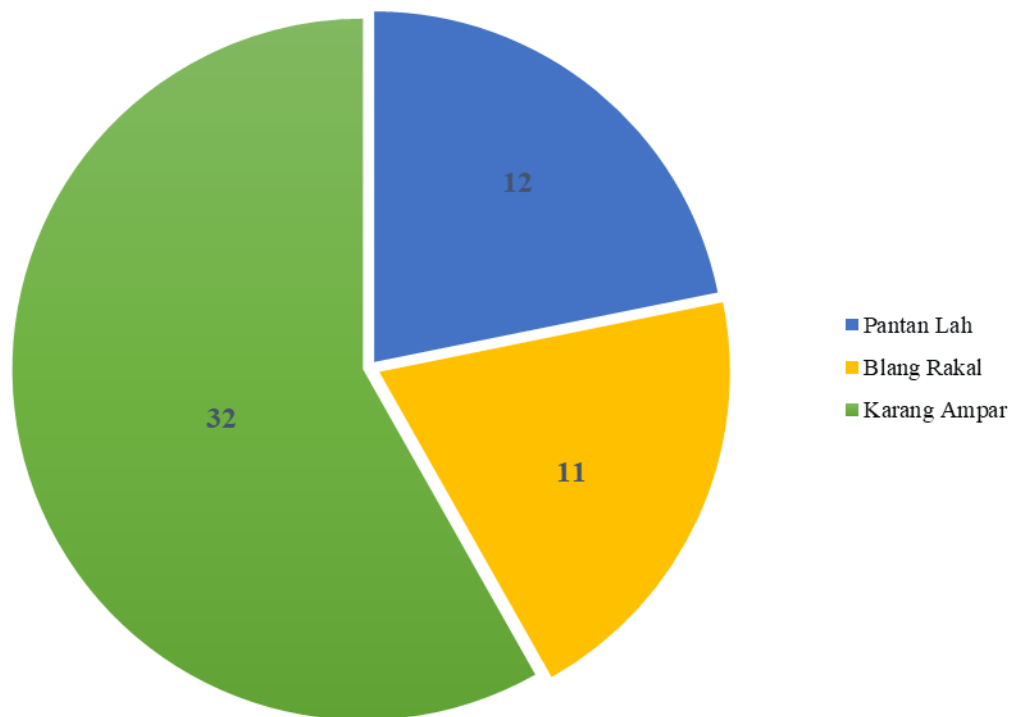


Figure 6. Total types of agricultural and plantation crops affected by conflict

The figure highlights that oil palm, banana, rice, and corn are the most frequently damaged crops due to their high water and nutrient content. Crops located near elephant habitats are particularly vulnerable. Damage includes not only yield loss but also structural damage to plants, root systems, and long-term productivity decline. In some cases, damaged land requires extended recovery periods before reuse. These economic impacts have broader implications for community livelihoods, especially for households dependent on agriculture. Repeated losses also reinforce negative perceptions of elephants, potentially hindering conservation efforts. The findings highlight a strong link between ecological conditions and economic impacts: areas with high habitat degradation, such as Karang Ampar, experience higher conflict intensity and greater economic losses, while areas with better habitat conditions show lower impacts. This emphasizes that conflict mitigation must go beyond technical deterrence and include sustainable habitat management and land-use planning through a holistic ecological–economic approach.

C. Community-Based Conflict Mitigation

The study shows that human–elephant conflict mitigation in the Peusangan Watershed depends not only on technical approaches but also on active community involvement. Community-based approaches are crucial because local people are both the most affected and possess valuable local knowledge about elephant movement patterns.

Based on interviews and field observations, communities in Pantan Lah, Blang Rakal, and Karang Ampar Villages implement mitigation measures such as:

1. Joint patrols to monitor elephant presence
2. Elephant deterrence using noise, fire, or natural repellents
3. Agricultural land monitoring, especially during harvest seasons

Although simple, these measures reduce short-term damage frequency. However, their effectiveness remains limited due to the lack of structured and sustainable systems. Spatial analysis is used to identify elephant ranges and potential movement corridors, as shown in *Figure 4*. This figure shows that elephant distribution follows patterns related to habitat and resource availability, particularly in forest–agriculture transition zones with high conflict potential. Further corridor modeling is presented in *Figure 7*.

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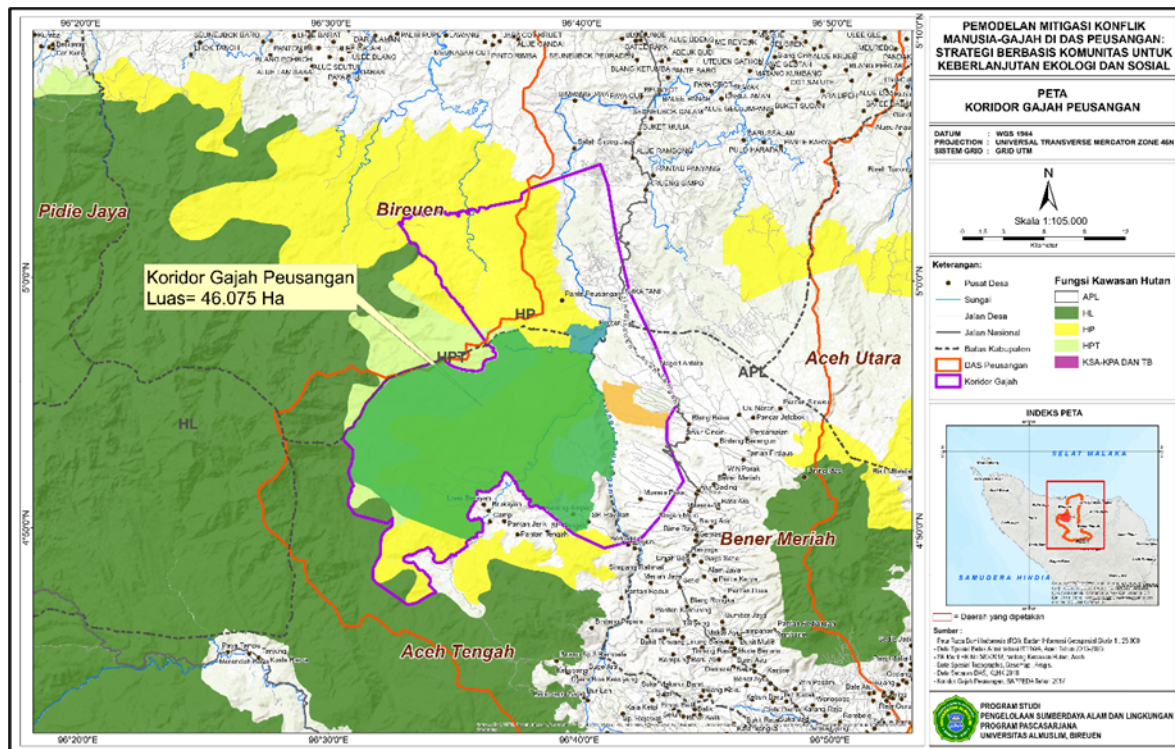


Figure 7. Elephant corridor model map in the study area

The map identifies potential movement pathways used by elephants, typically located in areas with remaining vegetation cover despite fragmentation. Corridor identification is essential for adaptive, ecology-based conflict mitigation planning. To support corridor analysis, vegetation diversity assessments were conducted, presented in *Table 5*.

Table 5. Vegetation diversity in elephant corridor pathways

No.	Plant Categories	Number of types	H ^p Score	Diversity Category
1.	Trees	72 types	2,91	Good diversity index.
2.	Understory Plants	82 types	3,54	Excellent diversity index.

The table indicates a relatively high diversity of plant species, supporting elephant habitat needs. However, some areas show reduced diversity due to human activities such as land clearing and resource exploitation. This suggests that corridor sustainability depends on habitat protection and regulation of human activities. Community-based approaches provide several benefits:

1. Improved real-time conflict monitoring
2. Reduced dependence on external intervention
3. Increased conservation awareness

However, challenges remain, including limited technical knowledge, lack of institutional support, and absence of integrated coordination systems. Overall, the study demonstrates that community-based mitigation has strong potential for sustainable conflict reduction. Integrating local knowledge with scientific approaches such as spatial analysis and corridor mapping can produce more adaptive strategies. This approach also supports participatory policy development, positioning communities as key actors in conflict management, ultimately balancing human needs and ecosystem conservation.

CONCLUSION

Human–elephant conflict in the Peusangan Watershed is primarily driven by habitat degradation and fragmentation, which force elephants into agricultural areas and increase conflict intensity. This conflict results in significant economic losses and negatively affects community welfare and perceptions toward conservation. Community-based mitigation approaches show strong potential in reducing conflict through active local participation. Future efforts should focus on strengthening habitat management, maintaining ecological corridors, and enhancing collaboration among stakeholders to ensure sustainable conflict mitigation.

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