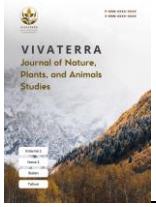

Vivaterra:
Journal of Nature, Plants and Animals Studies
Vol 1 No 1 August 2025, Hal 27-35
ISSN: XXXX-XXXX (Print) ISSN: XXXX-XXXX (Electronic)
Open Access: https://scriptaintelektual.com/vivaterra/

The Impact of Deforestation on Protected Animal Populations in Sumatra: Analysis of Global Forest Watch and IUCN Red List Data

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Article Info :
Received:
15-7-2025
Revised:
29-7-2025
Accepted:
24-8-2025

Abstract

Deforestation in Sumatra has become one of the most critical environmental challenges in Indonesia, threatening both ecological balance and the survival of key wildlife species. This study examines patterns of primary forest loss using Global Forest Watch datasets alongside population assessments from the IUCN Red List. Findings reveal that deforestation is concentrated in lowland and peat swamp ecosystems, particularly in Riau, Jambi, and South Sumatra, where industrial expansion of oil palm and acacia plantations has transformed landscapes on a large scale. The fragmentation of forest cover has disrupted ecological corridors, weakened hydrological functions, and increased carbon emissions, creating cascading impacts on biodiversity and ecosystem services. The consequences are most severe for protected species such as the Sumatran orangutan (Pongo abelii), the Sumatran tiger (Panthera tigris sondaica), and the Sumatran elephant (Elephas maximus sumatranus), all of which are listed as Critically Endangered. Population estimates suggest fewer than 8,000 orangutans, 600 tigers, and 1,700 elephants remain in fragmented habitats vulnerable to hunting, genetic isolation, and human-wildlife conflict. Conservation efforts through national parks and wildlife reserves provide limited protection due to spatial restrictions and weak law enforcement. The results highlight the urgent need for integrated landscape-based strategies, stronger governance mechanisms, and community-based initiatives to ensure long-term habitat connectivity and reduce extinction risks. Ultimately, protecting Sumatra's remaining forests is not only a regional ecological priority but also a crucial contribution to global biodiversity conservation.

Keywords: Deforestation, Sumatra, Primary Forest Loss, Sumatran Orangutan, Sumatran Tiger.

INTRODUCTION

The tropical rainforests on the island of Sumatra are part of the Sundaland ecosystem, which is home to high biodiversity and many endemic species, making its ecological function critical to regional balance (Helmizuryani et al., 2024). Forest areas in Sumatra have undergone massive conversion and loss of cover throughout the 21st century, reducing habitat connectivity and causing significant landscape fragmentation (Supriatna & Lenz, 2025). The decline in primary forest area and habitat degradation has not only reduced the amount of living space but also decreased the availability of food, migration routes, and breeding areas for large animals that depend on continuous forest areas (Hardiwinoto et al., 2024). Spatial analysis from previous studies shows that accumulated deforestation in Sumatra has reached tens of thousands of square kilometers over the past two decades, and this trend correlates with a decline in population indicators for many large mammal species (Calyx et al., 2023). This situation highlights the need for research that quantifies the relationship between forest cover loss and changes in the population status of protected species in measurable terms.

Deforestation in Sumatra is driven by several key interacting factors, including the expansion of plantation land (especially oil palm), illegal logging, land fires, and infrastructure development such as roads and mines (Ramadhan, 2025). Small-scale activities by smallholder farmers and large-scale land conversion often occur simultaneously; this pattern accelerates the fragmentation of large forest blocks into small patches that can no longer support large species populations in the long term. The practice of clearing land by burning exacerbates land degradation, increases vulnerability to repeated fires, and prolongs negative effects on vegetation structure and soil nutrient cycles (Kumar et al., 2024). The

ecological consequences of this combination of drivers are not only loss of area but also increased human-wildlife contact, which fuels conflict and poaching. Therefore, understanding the spatial and temporal drivers of deforestation is a prerequisite for assessing the real impact on protected wildlife populations.

The impact of fragmentation is clearly evident in the decline in habitat quality even in large conservation areas; case studies show the loss of primary cover in legally protected areas, thereby increasing population isolation (Setyanto, 2021). Satellite data and landscape analysis report significant damage in several national parks and nature reserves in Sumatra, with specific examples showing the loss of tens of thousands of hectares over a two-decade period. The loss of correlation between forest patch size and population carrying capacity has resulted in many sub-populations becoming small, vulnerable to demographic fluctuations, and at risk of local extinction (Paramita & Michiani, 2021). In some large parks, the rate of forest loss has increased in recent years, indicating that formal protection does not always prevent land leakage due to economic pressures and weak enforcement. This situation makes the evaluation of forest cover change at the local-protection scale critical as a basis for analyzing impacts on wildlife populations.

The presence and population trends of several flagship species in Sumatra reflect strong habitat pressures. The following summary table shows the conservation status, population estimates, and main threats to three selected species that are highly dependent on forest habitat continuity in Sumatra:

Table 1. Population Data and Threats to Sumatran Endemic Species Based on the IUCN Red List

Species (scientific name)	IUCN Status	Estimated Population (range/latest)	Main Threats
Sumatran Orangutan (*Pongo abelii*)	Critically Endangered	7,500 (estimated island-wide population; combined survey sources)	Habitat loss, fragmentation, hunting
Sumatran Tiger (*Panthera tigris sondaica*)	Critically Endangered / Endangered (subsp. threatened)	568–618 individuals (island-wide estimate, survey-based)	Habitat loss, hunting, low prey availability
Sumatran Elephant (*Elephas maximus sumatranus*)	Critically Endangered	Estimated range between 924–2,400+ (varies across studies/conservation documents)	Habitat loss, human–elephant conflict, population fragmentation

Source: IUCN Red List

The figures in the table above show a relatively small and fragmented population, and differences in estimates between sources indicate methodological uncertainty and the need for integrated field and remote-sensing data. Uncertainty in population estimates also reflects gaps in long-term monitoring and differences in survey coverage between areas. Linking data on forest cover loss with population trends at the sub-regional level will provide stronger quantitative evidence of a causal relationship (Borja, 2024), making the combination of Global Forest Watch data on forest cover and IUCN data on species status an appropriate approach for this analysis.

The decline in primary habitat area and changes in patch size have serious demographic implications; populations confined to small patches show lower effective reproduction rates and are more vulnerable to genetic loss. Historical data and trend analysis show that the loss of primary habitat in the last decade has not only reduced its area, but also changed its quality, for example, through a reduction in large trees and food sources, which has reduced the carrying capacity for frugivorous species and apex predators (Sugiharto, 2020). In addition, small fragments are often connected by

damaged or non-existent corridors, hindering interbreeding between sub-populations and triggering genetic isolation. These cumulative effects increase the risk of local extinction, especially for species with large home ranges such as elephants and tigers, which require a minimum area for populations to be sustainable. Therefore, spatial analysis linking patch size, distance between patches, and forest cover trends is an important tool for estimating the carrying capacity of habitats for each species.

The scale of forest cover loss in Sumatra during the early 21st century has reached tens of thousands of square kilometers, a figure that indicates significant anthropogenic pressure on the forest landscape. A summary of multi-source analysis reports that the total loss of primary forest on the island during a specific study period reached tens of thousands of km^2, with annual variations reflecting peaks in land clearing activity in certain years. The cumulative value of this forest loss is further linked to carbon release and changes in the local microclimate, which reduce habitat quality in addition to simply reducing its quantity. These developments confirm that research that only looks at the percentage of loss should not stand alone; studies must link the magnitude of loss to the spatial distribution of animal populations in order to identify hotspots of ecological impact. Temporal data analysis from Global Forest Watch, together with species status assessments, enables the identification of priority periods and locations for conservation interventions.

The practical impact of conservation has manifested itself in the form of increased human-wildlife conflicts, decreased reproduction rates, and behavioral changes to avoid degraded areas. Documented cases show that legally protected areas are not immune to encroachment or land use changes that cut off important corridors; several large areas have experienced significant land loss over the past two decades, indicating that formal protection does not always translate into effective protection on the ground. Furthermore, palm oil production and short-term economic gains often drive irreversible conversion, requiring comprehensive recovery strategies for declining populations, including corridor restoration, zoning arrangements, and conflict reduction. Interventions combining satellite monitoring, field patrols, and local community engagement have proven more effective than approaches relying solely on administrative protection zones. Studies combining spatial evidence from GFW and IUCN population data can help design evidence-based conservation priorities.

Scientific and managerial needs drive the need for research that integrates high-resolution land cover data (Global Forest Watch) with population status and trend data from the IUCN and field surveys to produce operationalizable impact indicators. The proposed research should develop quantitative methodologies to test the spatial-temporal correlation between habitat loss and changes in population estimates, controlling for intermediate variables such as fragmentation, road access, and hunting pressure. Expected results include risk hotspot maps for protected species, regression figures estimating the contribution of habitat loss to population decline, and recommendations for priority locations for ecological corridor restoration. Given the trends in deforestation and the latest episodic and rapidly changing threats, the outputs of this study will provide a basis that can be directly used by policymakers, conservation agencies, and local stakeholders to design focused and measurable mitigation actions. Thus, this research not only addresses a scientific gap but also provides the decision-making tools needed to limit the rate of decline in protected animal populations in Sumatra.

RESEARCH METHOD

This study uses a qualitative-descriptive approach based on spatial analysis and literature review. The main data used comes from Global Forest Watch to map changes in primary forest cover in Sumatra and from the IUCN Red List to obtain the conservation status and population trends of protected animals. This data was combined with the results of previous studies, conservation reports, and official documents related to forest area management in Sumatra. The analysis was conducted by comparing patterns of forest loss with the habitat distribution of target species such as Sumatran orangutans, Sumatran tigers, and Sumatran elephants, thereby obtaining an overview of the relationship between deforestation, habitat fragmentation, and pressure on animal populations.

This study also examines the ecological and social contexts that influence the survival of protected species. Drivers of deforestation, such as plantation expansion, logging, fires, and infrastructure development, are examined to see how human interactions with forest landscapes accelerate habitat degradation. The results of the analysis are then interpreted descriptively to highlight locations at high risk of species extinction and to formulate evidence-based conservation

recommendations. With this approach, the study not only describes forest loss in numbers, but also explains the ecological impacts and managerial implications that need to be addressed immediately.

RESULTS AND DISCUSSION

The Dynamics of Primary Forest Loss in Sumatra

Primary forest loss in Sumatra over the past two decades has shown an uneven pattern across provinces, due to differences in land pressure triggered by plantation expansion and infrastructure needs (Berutu et al., 2025). Satellite data shows that lowland forest areas are most vulnerable to land clearing, while mountainous areas are relatively more protected due to limited accessibility. This condition indicates that the most serious habitat degradation occurs in ecosystems with the highest biodiversity, such as peat swamp forests and wet lowland forests (Rohmatin et al, 2025). The increasing rate of forest cover loss is also linked to high demand for timber and land conversion for commercial crops. These changes have ecological consequences in the form of habitat fragmentation, which worsens the survival chances of endemic species (Ramadhan, 2025).

Spatial analysis shows that most of the forest loss is in South Sumatra, Riau, and Jambi, areas that have undergone massive transformation into oil palm and acacia plantations over the past two decades (Maruddani, et al., 2024). This trend has led to a reduction in the integrity of ecological corridors connecting one forest area to another, making it difficult for large animals that require extensive roaming to find continuous living space. The loss of forest landscape connectivity has led to an increase in human-animal conflict, especially in areas directly adjacent to villages and plantation land. This impact is evident in the high incidence of encounters between large animals and humans around industrial forestry concessions (Bista & Song, 2022). This situation reinforces the fact that forest loss is not only a matter of area, but also of spatial structure and ecosystem function.

Changes in forest cover in Sumatra cannot be separated from the land management system that provides ample space for extractive industry permits (Nabila, 2023). Spatial planning instruments often place forested areas at a low priority, so that the sustainability of ecological functions is not taken into account. This means that even protected forests are not entirely safe, as encroachment and illegal logging still occur in many locations. Weak field supervision and limited law enforcement agencies provide opportunities for illegal land conversion to continue (Amanda, 2024). In the long term, this condition demonstrates the failure of the regulatory system to maintain the sustainability of primary forests.

The pattern of primary forest loss also shows an upward trend during certain periods, especially when plantation commodity prices rise on the global market. This encourages large-scale land clearing, thereby intensifying pressure on the ecosystem. Meanwhile, forest and land fires are an additional trigger that accelerates forest loss, especially in areas with highly flammable peat ecosystems. The impact of fires not only destroys vegetation, but also leaves long-term damage in the form of soil degradation and carbon emissions. This situation makes recovery efforts even more complex because the ecosystem loses its natural ability to recover.

The presence of road infrastructure, both legal and illegal, is a factor that accelerates forest fragmentation (Berenguer et al., 2024). Roads open up access to previously inaccessible areas, facilitating logging, hunting, and land clearing activities. Landscape studies by (Larrea-Gallegos & Vázquez-Rowe, 2022), (Engert et al., 2025), (Hussain, et al., 2022) and (Arias-Gaviria et al., 2021) show that road construction is often the starting point of a cycle of sustainable deforestation. Transportation routes that cross primary forests disrupt the migration paths of large animals and increase the risk of conflict as the boundaries between human and animal habitats become blurred. This phenomenon makes infrastructure one of the main drivers of the loss of forest ecosystem integrity in Sumatra.

Table 2. Changes in Primary Forest Cover in Selected Provinces of Sumatra (2001–2022)

Province	Primary Forest Area 2001 (million ha)	Forest Loss 2001–2022 (million ha)	Percentage Loss (%)
Riau	3.4	1.9	55.9
South Sumatra	2.7	1.4	51.8

Jambi	2.1	1.0	47.6
Aceh	3.2	0.8	25.0
North Sumatra	2.0	0.6	30.0

Source: Global Forest Watch (2023); Ministry of Environment and Forestry Forestry Statistics (2022)

The data in the table shows that Riau is the province with the most extensive loss of primary forest, reaching more than half of its original total cover. This condition indicates that areas with a strong industrial plantation base are highly vulnerable to forest conversion. Jambi and South Sumatra also show similar patterns, with loss percentages almost equal to Riau's, despite their smaller original areas. In contrast, Aceh shows a lower rate of loss, as it still has relatively large conservation areas protected by special legal status. These figures underscore the importance of protecting the remaining forest areas throughout Sumatra.

Such massive forest loss has a serious impact on the regional hydrological cycle. Lost forests reduce the ecosystem's ability to absorb rainwater, thereby increasing the risk of flooding in the rainy season and drought in the dry season. Downstream areas of large rivers in Sumatra are now more prone to flash floods due to the decline in the function of water catchment areas. In addition, sedimentation increases due to soil erosion from upstream areas, which ultimately damages water quality and affects people's livelihoods. These impacts demonstrate the direct link between deforestation and the freshwater ecosystem crisis.

Forest degradation also reduces the ecosystem's ability to absorb carbon, thereby accelerating the rate of climate change. Sumatra, previously known as one of the largest carbon sinks in the tropics, has now become a source of emissions due to deforestation. International reports have identified this region as a significant contributor to greenhouse gas emissions from the forestry sector. The resulting emissions not only have a local impact, but also exacerbate global climate issues. This makes the protection of primary forests a crucial climate change mitigation strategy.

The link between deforestation and the vulnerability of large animals is increasingly evident in the context of Sumatra. Orangutans, tigers, and elephants are losing most of their habitat, causing their populations to become increasingly isolated in small pockets of forest. This isolation affects genetic diversity because mating occurs within a limited scope, increasing the risk of inbreeding. As a result, the resilience of populations to disease and environmental change is significantly reduced. This situation places Sumatra's endemic species at a greater risk of extinction.

Deforestation also impacts indigenous and local communities that depend on forest resources. Many communities lose access to food sources, traditional medicines, and building materials that were previously abundant. As forests decline, they are forced to rely on external economic resources that are not always compatible with local culture and knowledge. This shift has weakened the social ties between communities and forests, so that conservation values are no longer a top priority. The loss of these traditional relationships exacerbates the cycle of deforestation because communities lose their reason to protect forests.

Conservation efforts in Sumatra have so far focused on formal protected areas, even though much of the forest loss occurs outside conservation areas. This creates a major gap in biodiversity protection strategies, as wildlife does not recognize administrative boundaries. Large animals require space that extends far beyond conservation areas, so limited protection is not enough to ensure their survival. A landscape approach is needed that integrates conservation areas with cultivated land, so that ecological corridors are maintained. Such an approach requires cross-sector collaboration, which has not yet been optimally implemented.

Analysis of the dynamics of primary forest loss in Sumatra confirms that threats to biodiversity cannot be separated from global economic pressures, national governance, and local practices. Massive deforestation patterns reveal the weaknesses of the current ecological protection system. Although some areas have managed to preserve most of their forests, the long-term trend continues to point toward a decline in natural habitats. This situation requires stronger, evidence-based policies that involve all stakeholders. Only in this way can the sustainability of Sumatra's ecosystems be protected from increasingly apparent collapse.

The Impact of Forest Loss on the Survival of Key Species

Key species in Sumatra such as orangutans, tigers, and elephants face enormous pressure due to the shrinking of primary forest habitats, which are their main living spaces (Gaffar et al., 2024). Orangutans depend on large trees as a source of food and nesting sites, while tigers need large areas to roam for hunting. Elephants, with their enormous space requirements, often become victims of conflict when they enter agricultural land as their habitat shrinks. These three species play a vital role in maintaining the balance of the forest ecosystem, so a decline in their populations will have systemic impacts. The conditions in Sumatra demonstrate the close link between deforestation and the threat of extinction of key species.

The Sumatran orangutan population has declined dramatically because the lowland forests that are their primary habitat are almost gone. Habitat fragmentation has isolated orangutan groups in small pockets, hindering movement between groups. This not only affects food availability, but also reduces opportunities for natural mating, which is important for maintaining genetic diversity. Field studies show that many orangutans are forced to enter oil palm plantations in search of food, even though this increases the risk of conflict with humans. This situation reflects the enormous pressure this species faces in order to survive (Tanjung, et al., 2025).

Sumatran tigers face more complex challenges because they require vast roaming areas that are now increasingly fragmented. When forest corridors are cut off, tigers lose their natural routes for hunting prey, often leading them to enter residential areas. Conflicts with humans often result in the death of animals and economic losses for communities. The decline in prey populations due to deforestation also exacerbates the situation as tigers struggle to find food. This shows how closely linked habitat availability and the survival of apex predators are.

Sumatran elephants are a clear example of the impact of deforestation, as their vast roaming grounds often overlap with human land. When forest habitats are reduced, herds of elephants are forced to enter fields and gardens in search of food, leading to crop damage and prolonged conflict. Many elephants are injured or killed as a result of repressive measures taken to protect agricultural land. This conflict highlights the failure to manage interactions between humans and large animals. Such conditions place elephants in a very vulnerable position in their natural habitat.

Table 3. Population Estimates of Key Species in Sumatra

Species	IUCN Status	Latest Population Estimate	Main Threats
Sumatran Orangutan (*Pongo abelii*)	Critically Endangered	7,500 individuals	Habitat loss, fragmentation, hunting
Sumatran Tiger (*Panthera tigris sondaica*)	Critically Endangered	600 individuals	Habitat loss, human conflict, hunting
Sumatran Elephant (*Elephas maximus sumatranus*)	Critically Endangered	1,700 individuals	Habitat loss, human–elephant conflict, hunting

Source: IUCN Red List (2023); Forum HarimauKita (2022); WWF Indonesia (2023)

The table above shows the critical status of three major species in Sumatra, all of which are classified as Critically Endangered according to the IUCN. The remaining orangutan population is estimated to be no more than eight thousand individuals, while there are only about six hundred tigers left. These figures paint a very worrying picture, as such small populations are vulnerable to extinction due to random factors. Elephants, numbering around 1,700 individuals, also face significant pressure from conflicts with humans. These data confirm that without serious conservation efforts, these three species are at risk of disappearing from Sumatra's wild.

Habitat fragmentation is a major threat because it hinders the movement of large animals that require large spaces. When habitats are divided into small pockets, populations become isolated and experience a decline in genetic resilience. This process accelerates the risk of inbreeding, which reduces offspring quality, making them vulnerable to disease and environmental change. Isolation also limits

access to more varied food sources, forcing animals to survive in increasingly resource-poor habitats. This creates a vicious cycle that is difficult to break without conservation intervention.

Poaching pressure remains a major problem for key species in Sumatra. Black market demand for tiger parts, elephant tusks, and illegal trade in orangutan babies continues to drive poaching. This practice is exacerbated by weak law enforcement and the involvement of international networks that are difficult to eradicate. Poaching not only reduces the number of individuals, but also destroys the social structure within animal groups. When key individuals are lost, such as adult females or dominant males, the balance of the population is further disrupted.

Land use change also affects the availability of natural prey, especially for apex predators such as tigers. The decline in deer, antelope, and wild boar populations due to poaching and habitat loss worsens conditions for tigers. Predators that lose their natural prey are forced to prey on livestock, which then triggers conflict with humans. This creates a cycle of conflict that is difficult to stop because communities suffer economic losses. In this context, conservation efforts must not only protect predators, but also maintain their prey populations.

Conservation efforts to date have included the establishment of national parks, wildlife refuges, and anti-poaching patrol programs. However, the effectiveness of these programs remains limited because conservation areas are not large enough to accommodate the roaming needs of large animals. Many animals still leave protected areas and enter areas at high risk of conflict. Elephant translocation or orangutan release programs are also not always successful due to limited suitable habitat. This shows that conservation cannot rely solely on formal protected areas.

A landscape-based approach is needed to maintain habitat connectivity outside conservation areas. Ecological corridors connecting national parks with production forests or environmentally friendly plantations can be a solution. Such programs require the involvement of concession owners, local governments, and local communities. Without cross-sector integration, conservation efforts will only be limited to a small scale that does not have a significant impact on animal populations. The actual implementation of a landscape approach remains a major challenge in Sumatra.

The socio-economic aspects of society also play an important role in determining the success of conservation. When communities derive direct benefits from the existence of wildlife and forests, the level of participation in protecting ecosystems will increase. Community-based ecotourism programs can be a concrete example of how the local economy can grow without damaging habitats. However, such programs require infrastructure support, capacity, and a stable market so that they do not remain mere ideas. Integrating the economic interests of communities with conservation goals is key to long-term sustainability.

Discussions on the impact of forest loss on key species in Sumatra show that the conservation crisis cannot be delayed any longer. The populations of endemic animals are very small and at a critical point, so intervention must be carried out immediately. Efforts to protect remaining primary forests, develop ecological corridors, enforce laws against poaching, and empower communities are urgent priorities. Without concrete action, Sumatra risks losing one of the world's most important biological legacies. This situation demands a much stronger political, scientific, and social commitment than currently exists.

CONCLUSION

The loss of primary forests in Sumatra over the past two decades shows a serious and complex pattern, especially in areas with massive industrial plantations such as Riau, Jambi, and South Sumatra. The main driving factors include the expansion of oil palm and acacia plantations, infrastructure development, and forest fires that exacerbate the degradation of peat ecosystems. This situation not only reduces forest area, but also damages landscape connectivity, which is important for the survival of large animals and regional ecological cycles. Forest fragmentation worsens the hydrological cycle, accelerates carbon emissions, and increases the risk of human-wildlife conflict. This shows that the problem of deforestation in Sumatra is not just a matter of area, but also concerns spatial structure, land management, and weak regulations and supervision.

The impact of deforestation is increasingly evident in key species such as orangutans, tigers, and elephants, which are now trapped in fragmented habitats with small and vulnerable populations. Their shared Critically Endangered status indicates that without real intervention, the risk of extinction is increasing. Population isolation, reduced natural prey, and rampant conflict with humans are

accelerating the decline in genetic and socio-ecological resilience. Existing conservation efforts are still limited to formal protected areas that do not meet the roaming needs of large animals. Therefore, an integrated landscape approach, strengthened law enforcement against poaching, the development of ecological corridors, and community involvement in conservation-based economies are needed. Without these measures, Sumatra risks losing its biodiversity, which is an important pillar of global ecology.

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