

Invasive Alien Species: Their Impact on Degraded Mangrove Forest Ecosystems

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Abstract. Invasive Alien Species (IAS) plants in mangrove forests are plants that can reproduce rapidly and dominate mangrove forest areas due to their adaptability. This study aims to identify IAS species and analyze the impacts caused by their invasion in the mangrove forest area of the Air Telang Protected Forest (ATPF). The method used in this study is a survey method with sampling through a purposive sampling method. IAS plant samples were determined through a survey in the ATPF area, from land to the coast. This study succeeded in identifying three species of IAS plants, namely *Nypa fruticans*, *Acrostichum aureum*, and *Derris trifoliata*. These three plants are mainly found in degraded areas in the form of open shrub areas and secondary forests, both in land and coastal areas. The impacts caused by the presence of IAS in the ATPF area include reduce biodiversity, alter habitat structure, disrupt food chains, diminish fisheries productivity, reduced other ecosystem services and increase fire risk.

1 Introduction

Mangrove ecosystems are widely recognized as crucial coastal habitats, forming a vital bridge between terrestrial and marine environments, and delivering an array of invaluable ecosystem services, including robust coastal defense against storms and erosion, efficient carbon sequestration, essential breeding grounds for various fish and invertebrate species, and critical habitat for diverse wildlife [1]. Their ecological significance underscores their pivotal role in maintaining coastline health and sustaining human livelihoods, especially for communities directly dependent on marine and coastal resources. Indonesian mangroves, in particular, boast exceptional biodiversity, play a vital role in local livelihoods, and necessitate dedicated conservation efforts.

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Despite their significant ecological and socioeconomic value, global mangrove ecosystems face unprecedented threats, leading to widespread degradation and area loss. Pressures from human activities, such as unsustainable aquaculture, deforestation for timber or agriculture, and uncontrolled urban development, combined with the escalating impacts of climate change like sea-level rise and more intense storms, collectively jeopardize these fragile environments. This persistent degradation weakens mangrove resilience, making them more vulnerable to further ecological disturbances [2, 3]. Anthropogenic factors, including land cover changes and environmental degradation, are key drivers of mangrove loss and associated carbon emissions in regions such as South Sumatra, where the depletion of carbon stocks due to human activities in protected forests represents an especially pressing concern [4].

One of the most detrimental threats to degraded mangrove ecosystems is the proliferation of Invasive Alien Species (IAS). IAS are non-native organisms whose introduction and expansion beyond their natural historical or current distribution threaten biodiversity, with the capacity to outcompete native vegetation for essential resources, alter habitat structures, disrupt natural ecological processes, and even lead to the decline of native flora and fauna populations [5]. The financial implications associated with IAS are also substantial, impacting livelihoods and demanding significant resources for effective management and control [6].

Air Telang Protected Forest (ATPF) in South Sumatra, Indonesia, exemplifies a mangrove ecosystem severely threatened by degradation and subsequent IAS invasion. These species are progressively colonizing areas previously occupied by native mangroves, forming dense, often monospecific stands that fundamentally alter ecosystem characteristics [7, 8]. The unchecked proliferation of these IAS, particularly the aggressive invasion by *N. fruticans*, poses a serious and evolving threat to the remaining native mangrove biodiversity, compromising ATPF's ecological integrity, and diminishing the vital ecosystem services it provides to local communities [9]. The phenomenon of rapid *N. fruticans* invasion and mangrove forest loss has also been documented in other regions like the Niger Delta [10]. For effective and community-inclusive management and conservation strategies for ATPF's valuable mangrove resources, it is crucial to comprehend the specific mechanisms of their invasiveness, their comprehensive negative environmental impacts, and, critically, any benefits they might offer to local populations.

2 Methods

This research was conducted in the ATPF, South Sumatra Province, Indonesia (Fig.1). This location was specifically chosen as it contains mangrove ecosystems identified as degraded and significantly impacted by IAS plants, with *N. fruticans* being particularly prominent [8]. The presence of *N. fruticans* here aligns with observed invasion patterns in various other disturbed coastal areas, often exacerbated by already degraded environmental conditions [9]. Previous studies have also highlighted land cover changes and a decline in mangrove vegetation quality in ATPF over several decades [4].

2.1 Research design

This study employed a qualitative descriptive survey method. A qualitative approach was chosen to gain an in-depth understanding of the presence, distribution patterns, and various impacts of dominant invasive plants within the ATPF region. The primary objective was to

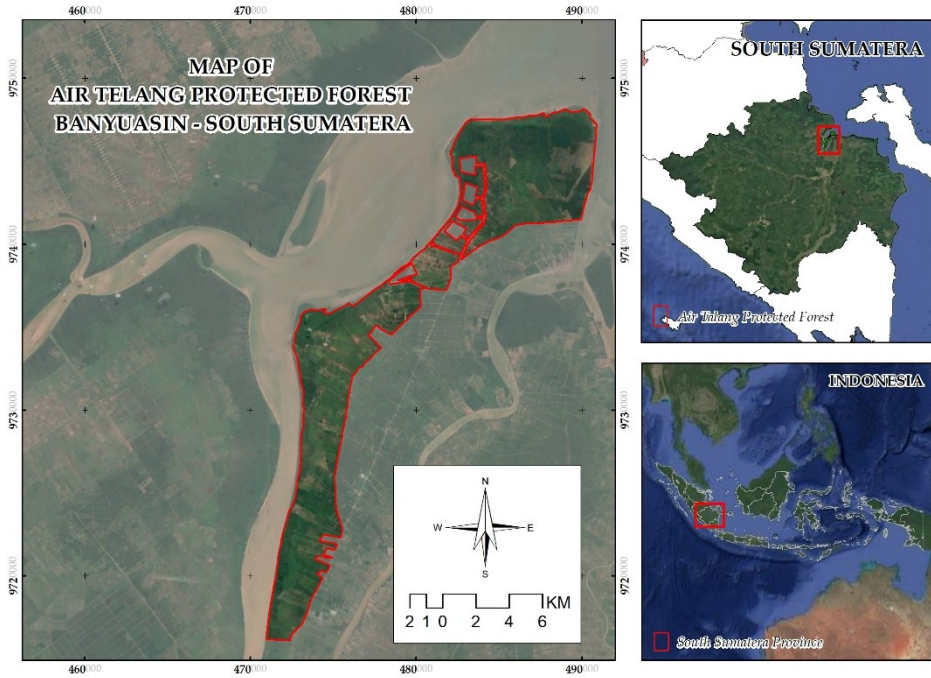


Fig. 1. Map of the study area in ATPF.

comprehensively describe the invasion phenomenon and the characteristics of affected areas, considering the complex nature of ecological and social interactions [5].

2.2 Site and sample determination

Site determination for the survey was specifically carried out in ATPF areas showing signs of degradation or confirmed presence of IAS. Sampling areas were determined using purposive sampling method. This approach allowed researchers to deliberately select the most relevant and informative areas or key informants for the study's objectives, based on predefined specific criteria [4].

The research team conducted systematic transects through the selected sampling areas. These transects extended along an ecological gradient, moving from terrestrial areas (secondary forests or degraded areas on the landward side) to the coastal zone (intertidal zone). Along these transects, researchers carefully observed and documented the presence and characteristics of dominant invasive plants, as well as their observable impacts on the surrounding environment.

2.3 Data collection and analysis

Data collection focused on direct observation, detailed field documentation, and structured interviews. The data collected included:

1. Identification and characterization of invasive plants: This involved determining the types of invasive plants dominating the surveyed areas [11]. Crucial to understanding invasion dynamics was the recording of their growth characteristics, distribution patterns, and estimation of the area dominated by these invasive species [12].

2. Observation of invasive dominance: Documenting how invasive plants intensely compete for space, light, and other vital resources, as well as their interactions with native mangrove vegetation. This is crucial for identifying shifts in community structure and overall ecosystem function [13].
3. Environmental conditions and habitat degradation: Conducting visual observations and qualitative descriptions of general environmental conditions (e.g., soil composition, presence of fresh or brackish water) and indicators of habitat degradation (e.g., erosion levels, sedimentation, presence of waste, or other signs of human disturbance). This information is essential for understanding invasion drivers and ecosystem vulnerability [14].
4. Visual documentation: Taking photographs and videos as supporting data to illustrate field conditions, the presence of invasive plants, and observed impacts. Visual documentation is vital in qualitative research to provide context and tangible evidence.
5. Interviews with local communities: Conducting semi-structured or unstructured interviews with residents living near ATPF. These interviews were critical for obtaining local perspectives, traditional ecological knowledge, and socioeconomic impacts of IAS that might not be evident solely through field observations. These interviews aimed to gather information on: 1) Community perceptions regarding the presence and spread of invasive plants in their area; 2) Utilization of invasive plants by the community (e.g., as building materials, animal feed, or potential energy sources); 3) Negative impacts of IAS directly experienced by the community (e.g., on livelihoods, access to resources, or overall environmental health); 4) Local wisdom or traditional knowledge related to the management or adaptation strategies in response to IAS presence, including insights from ethnobotanical studies.

The collected data comprised detailed field notes, narrative descriptions, comprehensive visual documentation, and interview transcripts. This rich dataset was then qualitatively analyzed to build a holistic understanding of the impacts of IAS on the degraded mangrove ecosystem in ATPF, as well as the intricate role of local communities in this context.

3 Results and discussion

3.1 Description of identified IAS

Research conducted in the ATPF led to the identification of three primary IAS: *N. fruticans* (nipah), *A. aureum* (paku laut), and *D. trifoliata* (tuba laut) (Fig. 2). All three species were observed to have widespread distribution across both terrestrial and coastal (intertidal) zones, a pattern consistent with reports of similar invasions in other disturbed coastal ecosystems [9, 10].

N. fruticans grows erect with a submerged stem and large pinnate leaves, often forming extensive, dense stands. It is known for its wide salinity tolerance and rapid regeneration capabilities [2]. *A. aureum* thrives in brackish environments. Its stiff, erect fronds can grow very densely, creating large clumps that dominate mangrove forest floors or open areas [1]. *D. trifoliata* is a woody climber or liana capable of physically strangling and shading out other vegetation. Its leaves are compound, typically with three leaflets (trifoliate), and its roots are known to contain toxic compounds [15].

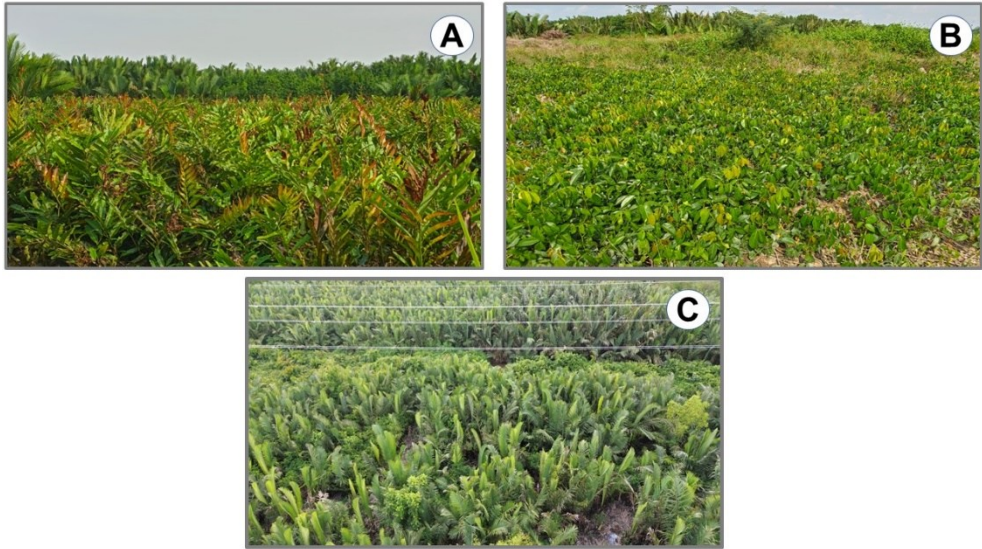


Fig. 2. Populations of three IAS species in the ATPF : (A) *A. aureum*, (B) *D. trifoliata*, (C) *N. fruticans*.

3.2 Distribution and spread patterns of IAS

All three identified IAS were found to be extensively distributed throughout ATPF, ranging from the terrestrial to the coastal (intertidal) zones. This widespread dispersal pattern highlights their strong adaptation to different environmental gradients within the degraded mangrove ecosystem (Fig. 3). Their pervasive presence across various ecological zonations indicates a severe level of invasion and widespread ecological disruption.

N. fruticans is often dominates areas with a consistent supply of fresh or brackish water, but also shows the ability to spread into more saline zones, especially in disturbed locations [8]. Studies specifically focusing on ATPF have documented the *N. fruticans* invasion phenomenon and its specific distribution patterns [12]. *A. aureum* is commonly found in disturbed areas, such as deforested sites, open grounds, or under sparse mangrove canopies; its ability to tolerate salinity fluctuations allows it to spread across the entire gradient [1]. *D. trifoliata* is frequently observed climbing along forest edges or in more open areas, utilizing existing mangrove stands as structural support. Its presence in various zones underscores its flexible adaptation to substrate conditions and light exposure.

The invasion of these IAS often begins in areas disturbed by human activities such as logging, land conversion, or hydrological changes, which further create empty ecological niches and reduce the competitive advantage of native species.



Fig. 3. Aerial photo of the distribution of three IAS species (*N. fruticans*, *A. aureum*, and *D. trifoliata*) in ATPF. All three are associated with each other and with other plants.

3.3 Invasiveness of IAS and their ability to dominate areas

The ability of these three IAS to dominate areas in ATPF is primarily driven by a set of highly effective invasive characteristics. Both *N. fruticans* with its dense stands and *A. aureum* forming thick clumps fiercely compete with native mangrove seedlings and trees for essential resources such as light, space, and nutrients [13]. *D. trifoliata* physically strangles and shades out host vegetation, thereby inhibiting photosynthesis and overall growth [7]. *N. fruticans* exhibits rapid regeneration from rhizomes and seeds, while *A. aureum* produces a large number of easily dispersed spores [2]. *D. trifoliata* reproduces both sexually through seeds and asexually via stolons and rhizomes, enabling swift proliferation in its habitat and effective long-distance dispersal [15].

N. fruticans and *A. aureum* typically form dense, monospecific stands, fundamentally altering the existing vegetation structure. *D. trifoliata* creates a thick layer that shades the mangrove canopy, effectively blocking light and suppressing the growth of native species underneath [7]. All three species demonstrate high tolerance to a wide range of varying environmental conditions, including salinity fluctuations and disturbed soil conditions. This remarkable adaptability allows them to survive and thrive in habitats that may no longer be ideal for true mangrove species.

3.4 Negative environmental impacts of IAS presence

The dominance of *N. fruticans*, *A. aureum*, and *D. trifoliata* in ATPF poses significant negative ecological impacts. IAS monocultures inhibit the reproduction of native species and hinder natural regeneration and ecological succession of mangrove forests [13]. This leads to a drastic decline in plant species diversity and negatively impacts associated fauna. Studies on species composition in degraded ATPF areas indicate substantial changes in mangrove vegetation.

The unique root structures and dense growth patterns of these IAS modify local ecosystem structure and hydrology. This affects tidal water flow patterns, sedimentation rates, and

oxygen availability in the soil. These changes create conditions unsuitable for the growth of true mangroves and other aquatic organisms. The shift from the complex structure of native mangrove forests to areas dominated by IAS stands substantially disrupts food chains and results in the loss of vital wildlife habitats for species dependent on the healthy, characteristic structure of mangroves.

Habitat degradation and widespread ecosystem changes due to this invasion can directly lead to a decline in local fisheries productivity, as vital mangrove functions as nursery grounds and primary food sources are severely compromised. This invasion diminishes various essential ecosystem services provided by mangroves, such as coastal protection from erosion and storms. While these IAS do possess root systems or biomass, their effectiveness in dissipating wave energy and stabilizing sediments may not be as optimal as true mangroves. Anthropogenic activities in protected mangrove forests, including in Air Telang, have caused significant carbon stock loss, further compromising these vital ecosystem services [4].

The accumulation of dry biomass from *N. fruticans*, *A. aureum*, and dry foliage from *D. trifoliata* can build up into highly flammable material. This significantly increases the risk of forest fires during dry seasons, posing a serious threat to mangrove ecosystems, which are typically fire-resistant due to their consistently wet conditions.

3.5 Benefits of IAS to coastal communities in ATPF

Despite being categorized as invasive species with detrimental ecological impacts, this research also identified various benefits perceived by local communities living around ATPF. These utilizations often reflect local wisdom and adaptive strategies in interacting with their environment. Building Materials and Handicrafts: *N. fruticans* leaves have traditionally been used as durable roofing material and for weaving various handicrafts [12]. The fruit of *N. fruticans* is edible, and its sap can be processed into sugar, vinegar, or even alcoholic beverages, demonstrating its potential as an alternative food and energy source [6]. Although requiring careful handling, some parts of *D. trifoliata* species are known to contain rotenone, which can be used as a natural pesticide or in various traditional medicinal applications [15]. *A. aureum* also has a record of ethnobotanical use [5].

Overall, the invasion of *N. fruticans*, *A. aureum*, and *D. trifoliata* in ATPF is a clear indicator of mangrove ecosystem degradation and poses a serious threat to biodiversity and the provision of essential ecosystem services. While recognized local utilization potential exists, the negative ecological impacts are far more dominant. Therefore, future management strategies for ATPF must strive to balance invasion mitigation efforts for ecosystem restoration with sustainable utilization practices that genuinely benefit community well-being without exacerbating environmental degradation.

4 Conclusions

Our research in ATPF identified *N. fruticans*, *A. aureum*, and *D. trifoliata* as dominant invasive alien plant species, widely distributed and aggressively degrading the mangrove ecosystem. These species severely reduce biodiversity, alter habitat structure, disrupt food chains, diminish fisheries productivity, reduced other ecosystem services and increase fire risk. While local communities find some uses for them, these minor benefits are far outweighed by the extensive ecological damage. Therefore, effective management in HLAT must balance invasion mitigation efforts with sustainable local utilization to restore the ecosystem and support community well-being.

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