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Mangrove Ecosystem Modeling To Support Fisheries Resource Conservation

Rian Fermantoro [1*]

[1] Institut Pertanian Bogor

* Correspondence: islam.wahid1993@gmail.com

ABSTRACT

The state of the mangrove ecosystem in Padang City, West Sumatra's South Coast, which has seen a reduction in both quantity and quality as a result of human activity, is the main subject of this study. The goal of this research is to create a modeling model of the mangrove ecosystem that will help conserve fishery resources and enhance the well-being of coastal populations. Local community interviews, field survey techniques, and primary and secondary data analysis are all used in this study. Three distinct stations—near settlements, transition regions, and far from settlements—were used to measure the height and density of mangrove vegetation. The important value index (IVI) of mangrove species and litter generation was also calculated by analyzing the data. The findings demonstrated that the distance from populated areas affected the mangrove vegetation's height and density. The species Rhizophora apiculata had the greatest INP, suggesting that it plays a significant role in stabilizing ecosystems. Significant contributions to aquatic productivity and nitrogen cycling were shown by higher litter generation in less disturbed regions. According to local community interviews, there is a high level of understanding of the significance of mangroves for fishery resources and coastal protection. The necessity of ecosystem-based management in mangrove forest conservation programs is supported by this study. The study's findings can serve as a foundation for creating more sensible regulations that will preserve the sustainability of fishery resources and enhance the well-being of coastal communities.

Keywords: Mangrove Ecosystem Modeling, Fishery Resources Conservation, Coastal Community Welfare.

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1. Introduction

Agricultural Power Journal, Month **2025**, Vol *2*, No *1*

One of the coastal ecosystems that is crucial to the survival of the many biota that inhabit these places is the mangrove ecosystem. In coastal regions, mangrove habitats are crucial to preserving ecological equilibrium. Indonesia has the biggest mangrove environment in the world, covering an area of around 3.5 million hectares and accounting for about 23% of the worldwide mangrove ecosystem.

According to Bengen (2002), mangrove ecosystems serve a variety of intricate ecological, economic, and social purposes. Because of their biological function as a buffer between land and sea ecosystems and their interactions with other coastal ecosystems, including coral reefs, seagrass beds, and estuaries, mangrove ecosystems are susceptible to both positive and negative changes [1].

According to estimates, mangrove forests may generate up to 7-8 tons of organic material per hectare annually from leaf litter. A further factor contributing to high productivity is that only around 7% of the leaves produced are actually eaten by the animals; the remainder are broken down by microbes and other decomposing creatures before entering the energy system [2].

In Kalimantan, mangroves are thought to generate between 21.10 and 29.35 tons of dry weight per hectare year, or between 21100 and 29350 kg per hectare annually. Coastal fisheries with a relatively high economic value can be directly exploited as catch fisheries thanks to this mangrove litter [3]. In the Wulan River Estuary, Demak, founded that mangrove litter output was 16508.95 kg/ha/year, and that the litter's contribution to fisheries potential was 1405.25 kg/ha/year, with an economic value of Rp 616 857 350/ha/year [4].

In West Sumatra, the mangrove ecosystem—particularly along Padang City's South Coast—is essential to preserving the natural equilibrium and sustaining the way of life for coastal inhabitants. In addition to providing home for a variety of species, mangrove forests also act as important carbon sinks and a buffer against natural calamities. But as of right now, the region's mangrove forest acreage has significantly shrunk; according to the most recent data, there are only around 16,900 hectares of mangroves left [7]. Numerous reasons contribute to this reduction, such

Agricultural Power Journal, Month **2025**, Vol *2*, No *1*

as the conversion of land for infrastructure and agriculture and the effects of climate change, which are posing a growing danger to the ecosystem's sustainability [6][9].

Effort to create a model of the mangrove ecosystem that would aid in the preservation of fisheries resources. This study is important since it aims to comprehend the ecological and economic worth of mangrove forests and how they affect the well-being of nearby populations. According to earlier research, Padang City's south coast mangrove forests provide IDR 459,573,912 in direct economic advantages and IDR 6,700,650,000 in indirect benefits.1 Therefore, it is anticipated that this study will offer solid empirical evidence in favor of conservation and sustainable management practices.

One of the contentious theories in this subject is that, with the right management, ecosystem recovery and restoration are still possible even when mangrove acreage is declining. Those who doubt the capacity of severely damaged ecosystems to recover frequently disagree with this viewpoint [10]. By examining data on the ecosystem's physical-chemical conditions and the traits of mangrove plants, this study will investigate this claim.

This study's primary goal is to create a useful model for simulating mangrove ecosystems in order to aid in the protection of fishery resources and further knowledge of the connection between mangrove ecosystems and the well-being of coastal communities. The study's primary finding is that sustainable mangrove forest management may boost biodiversity while also offering substantial financial advantages to nearby populations, which in turn motivates them to support conservation initiatives [8][9].

2. Materials and Method

a. Location of Research

This study was carried out at Padang City, West Sumatra, in the Pesisir Selatan mangrove forest region. This site was selected because it supports local fishing resources and is one of the regions with a key mangrove environment. This project is to investigate the relationship between mangrove ecosystems and the welfare of coastal populations in light of the notable decline in mangrove forest

Agricultural Power Journal, Month **2025**, Vol *2*, No *1*

areas in recent years. Additionally, it seeks to create a novel ecosystem modeling model to aid in conservation.

b. Research Materials

In this investigation, the following resources were used:

1) Primary Data:

Field Survey: Measuring the physical condition of mangrove forests, interviewing locals, and keeping an eye on biodiversity. GPS (Global Positioning System) device for location determination. To determine the plants' height, use a tape measure. Use a digital camera for visual documentation. Map mangrove areas precisely and efficiently with a drone.

2) Secondary Data:

Statistics on fisheries and the area covered by mangrove forests are provided by the West Sumatra Marine and Fisheries Service. NDVI (Normalized Difference Vegetation Index) technology is used to analyze land change utilizing satellite images from environmental monitoring organizations.

c. Techniques for Gathering Data

In order to offer thorough information on the state of the mangrove ecosystem, the data gathering approach is implemented in many stages:

1) Survey of the Field:

Observations were made at three distinct stations depending on environmental characteristics: close to settlements, transition zones, and remote from settlements. The investigation was carried out 2024. Direct measurements of the mangrove forest's physical characteristics and vegetation were used to gather data.

2) Respondent selection: Eighty respondents with expertise of the use of mangrove forests were chosen from coastal villages using the purposive selection approach. To learn more about how the community perceives the mangrove environment and how it affects their life, in-depth interviews were done.

Agricultural Power Journal, Month **2025**, Vol *2*, No *1*

3) Vegetation Analysis: At each site, 10 m × 10 m sample plots were used to measure the height and density of the vegetation. To ascertain the species composition and the condition of the mangrove ecosystem, data were evaluated.
4) Drone Mapping: By precisely mapping mangrove forest regions using drones, a more thorough spatial study of plant distribution and land use change over time was made possible. GIS (Geographic Information System) software will be used to process drone data and create themed maps that show the state of the mangrove ecosystem today.
5) Dynamic Modeling Model: Using the data gathered, a dynamic model of managing mangrove ecosystems is created by incorporating pertinent factors such capture fisheries, silvofishery pond aquaculture potential, and litter generation. Diagrams of causal loops will be used in this model to illustrate the cause-and-effect connections between these variables.

d. Table of Data Analysis

The table that will be utilized in the data analysis is as follows:

No	Parameter	Unit	Measurement Method
1	Mangrove Species Density	Individual/m^2	Using a 10m x 10m plot
2	Average Vegetation Height	Meter	Using a height measuring tool
3	Mangrove Area	Hectare	Mapping using drones and GIS
4	Important Value Index (INP)	Percentage (%)	Calculating based on the number of individual species

Agricultural Power Journal, Month **2025**, Vol *2*, No *1*

No	Parameter	Unit	Measurement Method
5	Litter Production	Ton/ha/year	Direct measurement in the field

Some formulas that will be used in data analysis are as follows:

1) Density of Species (Di):

$$Di = \frac{Ni}{A}$$

Description:

Di = Density of species-i (individuals/m^2)

Ni = Total number of individuals of species-i

A = Total area of sampling area (m^2)

2) Important Value Index (INP):

$$INP = \frac{(\text{Frequency} + \text{Density} = \text{Dominance})}{total\ frequency + todal\ dencity + total\ dominance} \times 100$$

Frequency$i$ = Frequency of occurrence of species-i

Densityi = Density of species-i

Dominancei = Dominance of species-i

3) Litter production

$$P = \frac{M_{\text{litter}}}{A}$$

Description:

P = Litter production (ton/ha/year)

M_{litter} = Total litter biomass collected

A = Sampling area (ha)

Researcher is aware that the study's findings may not be as broadly applicable if there are restrictions on the quantity of respondents. It is anticipated that the study's novel methodology would significantly advance knowledge of the connection between mangrove ecosystems and the welfare of coastal populations and aid in the creation of more sensible conservation laws in West Sumatra. To facilitate the replication of this work in different settings, readers will have access to all relevant materials, data, and methods.

3. Result

a. Mangrove Vegetation Density and Elevation

There were notable differences between the three study sites' mangrove vegetation height and density assessments.

Table 1. Density and Height of Mangrive Vegetation at Three Research Stations

Station	Density (individuals/m²)	Average Height (m)
Near Settlement	4,5	3,2
Transition Area	6,8	4,5
Far from Settlement	8,2	5,1

It is evident from the above table that, in comparison to stations close to populations, those farther away have greater average vegetation densities and heights. This suggests that the development of mangrove vegetation may be impacted by human activity.

b. Important Value Index (INP):

was calculated for each mangrove species found in the study location.

Table 2. shows the INP results for the dominant species identified

Mangrove Species	Frequency (%)	Density (%)	Dominance (%)	INP (%)
Rhizophora apiculata	45	50	40	45

Mangrove Species	Frequency (%)	Density (%)	Dominance (%)	INP (%)
Avicennia marina	30	25	30	28
Sonneratia alba	25	25	30	27

Rhizophora apiculata is the dominating species with the greatest INP value, according to the INP data, suggesting that it plays a significant role in the mangrove ecosystem in the study region.

c. Litter Production

To find out how much mangrove ecosystems contribute to nutrient cycle, litter generation was assessed. Location-based differences in litter output were shown by the measurement findings.

Table 3. Litter Production at Three Research Stations

Station	Litter Production (ton/ha/year)
Near Settlement	3,5
Transition Area	5,2
Far from Settlement	7,8

The best serasah products are found in regions that are far from settlement, and they can help increase tanah kesuburan and decrease hayati keanekaragaman.

4. Discussion

The study's findings shed light on the state of the mangrove environment along Padang City's south shore and how it affects the well-being of nearby populations. Results demonstrating differences in plant height and density between areas close to and distant from populated areas support the working premise that human activity negatively impacts the mangrove ecosystem's health. In keeping with earlier research

Agricultural Power Journal, Month **2025**, Vol *2*, No *1*

demonstrating that urbanization and irresponsible land use may harm mangrove ecosystems, land conversion for construction and other economic activities is responsible for the loss in mangrove forest quality in more densely populated places.

Data on vegetation height and density indicate that stations located further from populated areas had greater average height and density. According to research by Alongi (2008), mangroves that are not impacted by human activity typically develop better and have a wider variety of biological life. One key indicator of the health of the mangrove ecosystem is the density of dominating species, such Rhizophora apiculata. The existence of this species is crucial for maintaining local fisheries resources since it is recognized to offer crucial habitat for a variety of fisheries species [12].

Rhizophora apiculata was the dominating species in the research region, according to the INP analysis results. This result is consistent with earlier research that demonstrated the species' critical role in maintaining the integrity of the mangrove ecosystem. The high INP suggests that this species contributes significantly to ecological services, such as protecting the shoreline and providing habitat for marine life, in addition to its quantitative dominance.

Stations located distant from populated areas produce more trash, a sign of a healthier environment that can sustain improved nutrient cycling. Maintaining soil fertility and boosting mangrove ecosystem productivity both of which benefit fishery ecosystems require optimal litter formation.

According to local community interviews, people are aware of the value of mangrove forests as a fishery resource and for protecting the shoreline. Up to 75% of respondents acknowledged the advantages mangroves have for the environment and the economy. According to Sutherland et al. (2015), this raises the possibility of boosting community participation in conservation initiatives, which can increase the efficacy of conservation initiatives [13].

These discoveries have wide-ranging ramifications, especially when it comes to conservation and natural resource management. The study's findings highlight the necessity of managing mangrove forests using an ecosystem-based strategy, which

Agricultural Power Journal, Month **2025**, Vol *2*, No *1*

includes preserving important regions from infrastructure development and land conversion. Both human welfare and environmental sustainability can be enhanced by policies that engage local communities in the management of mangrove forests.

Given the rising reported frequency of natural catastrophes like tidal flooding, future studies are anticipated to examine the effects of climate change on mangrove ecosystems in this region. Furthermore, it would be beneficial to conduct longitudinal studies to track long-term shifts in the health of mangrove ecosystems and their effects on fishery resources. In order to comprehend the intricate relationships between social, economic, and environmental aspects in the context of mangrove forest conservation, research should also use an interdisciplinary approach. Therefore, the study's findings offer a solid foundation for the creation of conservation plans for mangrove forests in West Sumatra and increase awareness of how crucial it is to preserve this ecosystem for the sustainability of fisheries resources and coastal protection.

5. Conclusions

The state of the mangrove ecosystem on Padang City's south coast was effectively recognized and examined in this study, along with its consequences for fisheries resources and the well-being of coastal inhabitants. The findings demonstrated that the height and density of mangrove vegetation differed according to the distance from populated areas, with better conditions seen in places farther away. According to the Importance Value Index (IVI), Rhizophora apiculata is the dominant species and is crucial to the stability of the ecosystem. Significant contributions to aquatic productivity and nitrogen cycling were shown by higher litter generation in less disturbed regions.

Furthermore, local residents' knowledge of the value of mangroves as a fishery resource and for protecting the coast was high, according to conversations with them. These results lend credence to the idea that the sustainability of fishery resources is enhanced by the existence of robust mangrove forests. The small sample size and possible bias in the interviews are two of the study's drawbacks, though.

Agricultural Power Journal, Month **2025**, Vol *2*, No *1*

In addition to underscoring the necessity of ecosystem-based management in conservation programs, this study has improved scientific knowledge of the relationships between mangrove ecosystems and community well-being. To track long-term shifts in the health of mangrove ecosystems and their effects on fishery resources, more longitudinal research is required.

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