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Vegetation Analysis of Beach Forest in Kamarian Village, Kairatu District, Western Seram Regency, Maluku

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ABSTRACT

This study analyzed the vegetation structure, composition, and dynamics of the beach forest in Kamarian Village, Western Seram Regency, Maluku Province. The research employed a systematic sampling method with continuous measurement plots across three distinct forest blocks, measuring vegetation parameters at four growth stages: trees, poles, saplings, and seedlings. Results revealed a well-developed four-strata forest structure (Strata A:20-29m, Strata B:4-20m, Strata C:1-4m, Strata D:0-1m) with dominant species including *Pterocarpus indicus*, *Terminalia catappa*, *Cerbera manghas*, and *Hibiscus tiliaceus*. A total of 31 plant species from multiple families were identified, with Anacardiaceae, Moraceae, Myrtaceae, and Fabaceae being well-represented. Importance Value Index analysis indicated varying ecological significance of species across growth stages and blocks. Block III demonstrated characteristics of a more mature forest segment with higher tree density (920 ind/ha) and diversity (H' = 1.06) compared to Blocks I and II. The forest exhibited active natural regeneration processes, particularly evident in Block III with 80,750 seedlings/ha, though significant regeneration bottlenecks were observed between growth stages. Shannon-Wiener diversity indices were predominantly low (H' < 1), except at the tree stage in Blocks I and III (1.02 & 1.06), indicating moderate ecological stress

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INTRODUCTION

Beach forests represent one of the most valuable yet vulnerable ecosystems in Indonesia's vast archipelago. These transitional zones between marine and terrestrial environments play crucial ecological roles, including shoreline stabilization, erosion control, habitat provision for diverse flora and fauna, and protection of inland areas from natural disasters such as tsunamis and storm surges (Cooke *et al.*, 2022). Despite their ecological significance, beach forests across Indonesia face mounting threats from anthropogenic activities, including land conversion, unsustainable resource extraction, and climate change impacts (Maja & Ayano, 2021).

Maluku Province, with its extensive coastline and numerous islands, harbors significant beach forest ecosystems that remain understudied compared to other regions in Indonesia. Among these areas, Seram Island, particularly its western region including Kamarian Village in Kairatu District, contains beach forest ecosystems that are vital to local communities and regional biodiversity. These forests provide essential ecosystem services including protection from coastal erosion, timber and non-timber forest products, medicinal plants, and cultural values for indigenous communities (Amusa *et al.*, 2024).

Vegetation analysis is a fundamental approach to understanding forest ecosystems, providing insights into species composition, diversity, structural characteristics, and ecological relationships (Ellenberg & Mueller-Dombois, 1974). For beach forests, which experience unique environmental conditions including salt spray, sand substrate, and periodic flooding, vegetation analysis reveals adaptations and ecological processes specific to these challenging environments (Hobohm *et al.*, 2021).

The beach forest of Kamarian Village represents a significant ecological resource for Western Seram Regency. Understanding its vegetation characteristics is essential for developing appropriate conservation strategies and sustainable management practices. Local communities in Kamarian have traditionally depended on these forests for various resources, establishing a complex socio-ecological relationship that spans generations (Eversberg *et al.*, 2022). However, changing land use patterns, demographic shifts, and economic development pressures may be altering this relationship, potentially threatening the integrity of these beach forest ecosystems (Sahavacharin *et al.*, 2022).

This study aims to address this knowledge gap by conducting a systematic vegetation analysis of the beach forest in Kamarian Village. By documenting species composition, structural characteristics, and ecological patterns, this research will contribute to the scientific understanding of beach forest ecosystems in Eastern Indonesia and provide valuable information for conservation planning, sustainable resource management, and climate change adaptation strategies for coastal communities in Western Seram Regency.

LITERATURE REVIEW

Beach Forest Ecosystem

Beach forests constitute a vital component of coastal and marine ecosystems, providing productive natural resources that serve as sources of food, mineral deposits, energy resources, communication and educational media, as well as recreational or tourism areas. This review explores the concept of beach forests, their ecological characteristics in Indonesia, and their functions, highlighting the importance of these ecosystems in the Indonesian archipelago.

Indonesia features several types of coastal areas based on their conditions, locations, and positions. The types of Beach areas commonly found throughout various regions in Indonesia include (Tuheteru & Mahfudz, 2012):

1. Rocky shores are coastal environments dominated by coral rocks that have undergone weathering or erosion.
2. Sandy beaches represent coastal areas with sandy environmental conditions that continue to experience surface elevation processes. The accumulation of sand originates from ocean wave action that carries sediment to the land surface.
3. Muddy coasts are characterized by areas submerged by seawater. These Beach types harbor relatively few organisms, primarily supporting certain marine animals such as sea snails and crabs.

Functions and Benefits of Beach Vegetation

Beach plants found in beach forests play essential roles in coastal ecological systems. These beach forests also serve as habitats for various fauna. The dominant animals in coastal areas are shorebirds, which are groups of waterbirds that ecologically depend on coastal areas as their habitat. Beach forests function as feeding grounds and/or breeding sites for these birds (Tuheteru & Mahfudz, 2012).

According to São Miguel *et al.* (2022), beach forest zones are also crucial sites for sea turtle nesting. One factor that makes beach forests preferred nesting grounds is the quartz sand texture, often vegetated with Beach plants such as screw pine (*Pandanus tectorius*). Beach vegetation forms beach forests that offer numerous benefits, including: mitigating tsunami wave impacts, preventing coastal abrasion, protecting terrestrial ecosystems from wind and storms, controlling erosion, providing habitat for flora and fauna, serving as breeding grounds, regulating global warming, producing raw materials for cosmetic industries, biodiesel, medicines, and generating bioenergy (Tuheteru & Mahfudz, 2012).

Beach vegetation also serves to protect buildings and agricultural crop cultivation in coastal areas. It provides protection from damage caused by storms or salt-laden winds by impeding speed and breaking wind pressure directed toward human settlements. This mechanism occurs because Beach tree species typically exhibit large or tall growth forms (Goltenboth *et al.*, 2006).

Beach vegetation functions critically in safeguarding against seawater intrusion processes. Seawater intrusion involves the contamination of mainland freshwater by seawater. This protective mechanism operates through two pathways: maintaining freshwater (groundwater) levels and preventing tidal water from entering rivers. Vegetation in Beach areas preserves surface water reserves, thereby inhibiting seawater intrusion toward land areas (Kindeberg *et al.*, 2023).

Vegetation Analysis

Vegetation analysis is a method for studying the composition and structure of vegetation and plant communities, with the primary focus on species composition (Soerianegara & Indrawan, 1998). Vegetation analysis encompasses two components: composition and structure. These can be presented quantitatively using parameters such as density, frequency, and canopy coverage or basal area. Studying vegetation analysis requires various supporting techniques, including sampling plots (e.g., single plots), multiple plots, transects, or plotless methods such as the quadrant approach. Vegetation analysis conducted over specific area extents typically employs rectangular, square, or circular plots. To analyze vegetation at tree, pole, sapling, and seedling stages, quadrat methods—using circular, square, or rectangular plots—are typically utilized (Kusmana, 1997).

Fundamentally, data obtained from vegetation analysis can be classified into two categories: qualitative and quantitative data. Qualitative data indicates how plant species are distributed—whether randomly, uniformly, or in clusters—as well as stratification, periodicity, and other characteristics. Conversely, quantitative data represents the number, size, wet and dry weight of a species, and the area it occupies. Quantitative data is derived from field sample plot observations, while qualitative data is obtained from field observations based on extensive experience or autecology research findings (Ellenberg & Mueller-Dombois, 1974).

METHODOLOGY

Research Location and Duration

This research was conducted in the beach forest of Kamarian Village, Kairatu District, Western Seram Regency, Maluku Province, Indonesia. The study was conducted from January 24 to February 7, 2025. The research location is in 3 blocks and can be seen in Figure 1.

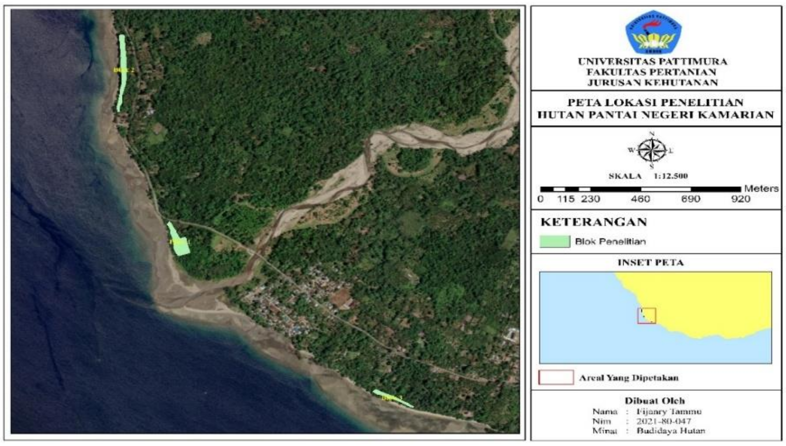

Figure 1. Map of Research Location

Research Equipment and Objects

The following equipment was used during the research: Roll meter , Hagameter, Diameter tape, Thermometer, Hygrometer, Luxmeter, Stationery, Camera.

The research objects were vegetation species growing in the beach forest of Kamarian Village, comprising different growth stages: trees, poles, saplings, and seedlings.

Data Collection Techniques

Data collection in this research was conducted according to the following procedure:

The researcher performed initial observations to determine the study area. Based on these observations, three observation blocks were established.

In each observation block, to determine the structure and composition of the beach forest, the researcher employed a combination method integrating the line transect method with nested plots.

Within each transect, continuous measurement plots were positioned, with dimensions of 20 × 20 meters for tree observation, and appropriate nested subplots for poles, saplings, and seedlings (Kusmana, 1997). For sapling and seedling observations, the number of individuals per species and species frequency were counted, followed by determination of the Importance Value Index (Ellenberg & Mueller-Dombois, 1974).

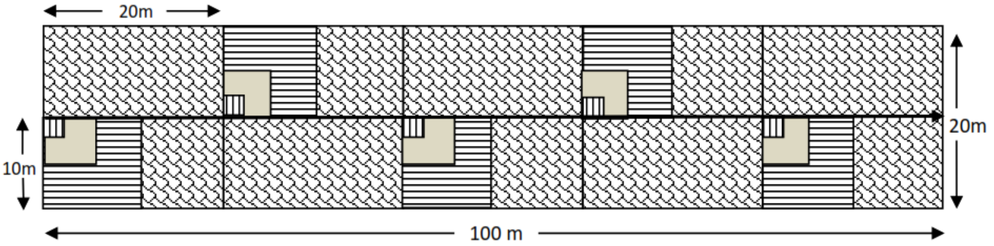

Figure 2. Transect Line and Observation Plots)

Note:

- Seedling stage (2m × 2m) : Diameter < 2 cm with height < 1.5 m
- Sapling stage (5m × 5m) : Diameter 5-9 cm
- Pole stage (10m × 10m) : Diameter 10 cm to < 20 cm
- Tree stage (20m × 20m) : Diameter ≥ 20 cm

Data Analysis

Vegetation parameters measured included Density, Relative Density, Frequency, Relative Frequency, Dominance, and Relative Dominance. Density was measured by counting the number of individuals per species occupying a specific area, while frequency parameters were determined by counting the number of species found in each observation plot. For dominance measurements, tree trunk diameter breast height above the ground surface. From the data on Density, Relative Density, Frequency, Relative Frequency, Dominance, and Relative Dominance, the Importance Value Index was then determined.

The collected data were analyzed using plot analysis to obtain the importance value index. This value was used to determine the vegetation structure using formulas according to Ellenberg and Mueller-Dombois (1974) as follows:

- Density (D) = Number of individuals of a species / Unit area (1)
- Relative Density (DR) = (Density of a species / Total density of all species) × 100 (2)
- Species Frequency (F) = Number of plots where a species is found / Total number of observed plots (3)
- Relative Frequency (FR) = (Frequency of a species / Total frequency of all species) × 100 (4)
- Dominance (Do) = Total basal area of a species / Unit area (5)
- Relative Dominance (RDo) = (Dominance of a species / Total dominance of all species) × 100 (6)
- Importance Value Index (IVI) = RD + RF + RDo (7)
- Biodiversity Richness (H) = Species Diversity Index The species diversity index was used to determine the level of species diversity. The calculation of the diversity index was performed using the Shannon-Wiener formula (Omayio *et al.*, 2019) as follows:

$$H' = -\Sigma \, pi \ln pi \qquad (8)$$

Where:

pi = ni/N
H' = Shannon-Wiener species diversity index
ni = Number of individuals of species i
N = Total number of individuals of all species

The diversity index criteria are categorized into three levels:

$H' < 1$ = Low diversity
$1 < H' < 3$ = Moderate diversity
$H' > 3$ = High diversity

The profile diagram data was collected within the same area as the data plot size, which was 20 m × 100 m. The profile diagram drawing focused only on tree and pole stages. The profile diagram technique used in this research was a simple profile in the form of a stand sketch, while still considering the proportional drawing technique according to real field conditions.

The Community Similarity Index (IS) represents the magnitude of similarity between two communities, ranging from 0% (completely different species composition) to 100% (identical species composition). According to (Ellenberg & Mueller-Dombois, 1974), IS is considered completely different if the value is 0%, and generally, two communities are considered similar if they have an IS ≥ 75%. The Community Similarity Index was used to determine the relative similarity of species composition between two stands being compared at each growth stage, using the formula (Irwanto, 2007; Kusmana, 1997):

$$IS = (2W/(A+B)) \times 100\% \qquad (9)$$

Where:
IS = Species Similarity Index
W = Sum of the smallest importance values of species found in both blocks being compared
A = Sum of all species values in one block
B = Sum of all species values in the other block

RESEARCH RESULT

Forest Structure of Kamarian Beach Region

Research results indicate that the Beach forest of Kamarian village consists of four strata: A, B, C, and D. The dominant species found in each stratum are presented in Table 1.

Table 1. Dominant Species Composing Each Stratum in the Beach Forest of Kamarian Village

Stratum	Dominant Species
A 20 m to 29 m	*Insia bijuga* (Kayu besi) *Terminalia catappa* (Ketapang) *Pterocarpus indicus* (Linggua) *Cerbera manghas* (Mangga brabu) *Hibiscus tiliaceus* (Waru)
B 4 m to 20 m	*Hibiscus tiliaceus* (Waru) *Cerbera manghas* (Mangga brabu) *Pterocarpus indicus* (Linggua) *Myristica fragrans (*Pala*)* *Calophyllum inophyllum* (Bintanggur).
C 1 m to 4 m	*Scaevola taccada* (Papaceda) *Pandanus bidur* (Pandan)
D Ground cover plants	*Pteridophyta* (Paku-pakuan) *Pandanus bidur* (Pandan) *Calotropis gigantea* (Widuri) *Ipomea pescaprae* (katang-katang)

As shown in Table 1, the Kamarian Beach forest is composed of four distinct strata. Each stratum contains three primary species with relatively uniform distribution patterns. The most dominant species include *Cerbera manghas* (Mangga brabu), *Hibiscus tiliaceus* (Waru), and *Pterocarpus indicus* (Linggua).

Stratum A is the most dominant, with tree heights ranging from 20-30 m. Species found in this stratum primarily belong to the tree category with relatively uniform stand structures. For clearer visualization, refer to the forest profile diagram of the Beach forest in Kamarian Village, West Seram District, Maluku Province (Figure 3).

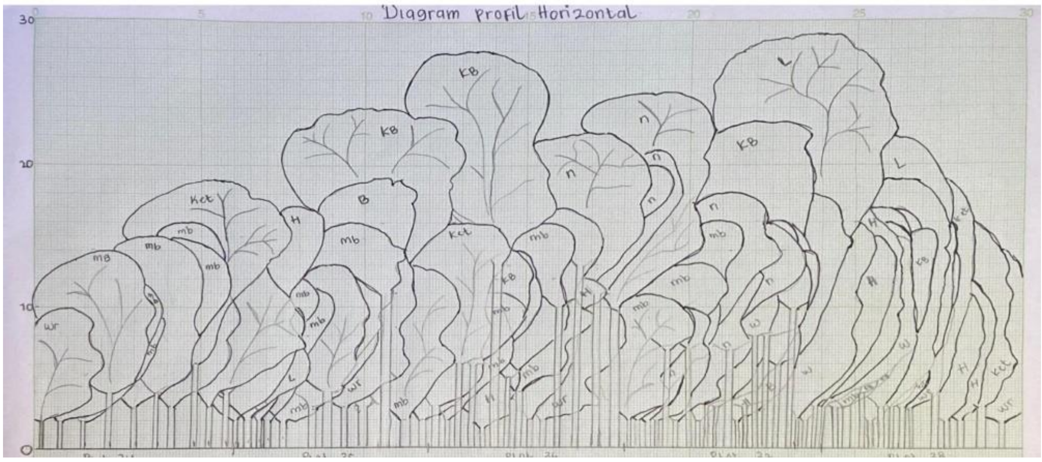

Figure 3. Profile Diagram of Kamarian Village Beach Forest

Note:

- Wr : *Hibiscus tiliaceus* (Waru)
- Mb : *Cerbera manghas* (Mangga Brabu)
- Ket : *Terminalia catappa* (Ketapang)
- H : *Barringtonia asiatica* (Hutung)
- L : *Pterocarpus indicus* (Linggua)
- N : *Canarium sylvestre* (Nanari)
- Kb : *Intsia bijuga* (Kayu Besi)
- B : *Calophyllum inophyllum* (Bintanggur)

The profile diagram represents the vertical structure, based on sampling. Measurements and observations were conducted on trees and poles within the plots. The observations and measurements included species identification, tree height, and tree diameter (Pentury *et al.*, 2025; Sapardi *et al.*, 2024; Sawitri, 2023). The plot selected to represent the profile diagram was chosen based on density, with a total of 67 dominant plant species identified across 5 plots. The high density indicates that certain species are more dominant and provides a clear representation of the Beach forest structure in Kamarian Village, West Seram District, Maluku Province.

Generally, the Beach forest profile shows vegetation layers from the tallest trees to smaller vegetation. Species such as *Terminalia catappa* (Ket), *Intsia bijuga* (Kb), *Pterocarpus indicus* (L), and *Canarium sylvestre* (N) are typically found in the canopy stratum as they are common in Beach ecosystems. *Hibiscus tiliaceus* (Wr), *Calophyllum inophyllum* (B), *Barringtonia asiatica* (H), and *Cerbera manghas* (Mb) are more widely distributed in the middle and lower layers.

Composition of Kamarian Village Beach Forest

Research conducted in the Beach forest of Kamarian Village, West Seram District, Maluku Province, was performed across three distinct blocks: Block I (plots 1-18), Block II (plots 19-40), and Block III (plots 41-50).

Based on research conducted in the Kamarian Village Beach forest across three observation blocks, the number of species found is presented in Table 2.

Table 2. Number of Species Found at Different Growth Stages

Growth Stage	Block 1	Block 2	Block 3
Tree	16	12	16
Pole	8	15	11
Sapling	9	12	10
Seedling	7	10	11

Overall, these data illustrate that each block has unique species composition at each growth stage and demonstrates ongoing natural regeneration potential, particularly at the seedling and sapling stages. The comprehensive plant species inventory is presented in Table 3 below:

Table 3. Plant Species in the Kamarian Village Beach Forest

No.	Scientific Name	Local Name	Family
1	*Ficus benjamina*	Beringin	Moraceae
2	*Calophyllum inophyllum*	Bintanggur	Calophyllaceae
3	*Meliosma* spp.	Bulatung	Sabiaceae
4	*Eugenia* spp.	Canara	Myrtaceae
5	*Syzygium aromaticum*	Cengkih	Myrtaceae
6	*Euphorbia tirucalli*	Daun patah tulang	Euphorbiaceae
7	*Gnetum gnemon*	Ganemo	Gnetaceae
8	*Ficus variegata*	Gondal	Moraceae
9	*Vitex cofassus*	Gufasa	Lamiaceae
10	*Premna corymbosa*	Gumira pantai	Lamiaceae
11	*Barringtonia asiatica*	Hutung	Lecythidaceae
12	*Syzygium malaccense*	Jambu	Myrtaceae
13	*Anacardium occidentale*	Jambu mete	Anacardiaceae
14	*Intsia bijuga*	Kayu besi	Fabaceae
15	*Spondias pinnata*	Kedondong hutan	Anacardiaceae
16	*Parmentiera cereifera*	Kelor pantai	Bignoniaceae
17	*Kleinhovia hospita*	Kinar	Malvaceae
18	*Canarium commune*	Kenari	Burseraceae
19	*Terminalia catappa*	Ketapang	Combretaceae
20	*Xylocarpus granatum*	Kira-kira	Meliaceae
21	*Mangifera odorata*	Kuini	Anacardiaceae
22	*Pterocarpus indicus*	Linggua	Fabaceae
23	*Mangifera indica*	Mangga	Anacardiaceae
24	*Cerbera manghas*	Mangga brabu	Apocynaceae
25	*Hernandia peltata*	Mata ikan	Hernandiaceae
26	*Canarium sylvestre*	Nanari	Burseraceae
27	*Myristica fragrans*	Pala	Myristicaceae
28	*Scaevola taccada*	Papaceda	Goodeniaceae
29	*Alstonia scholaris*	Pule	Apocynaceae
30	*Alangium javanicum*	Samar	Cornaceae
31	*Hibiscus tiliaceus*	Waru	Malvaceae

Table 3 shows nine Familyes containing multiple plant species. Anacardiaceae has four species: *Anacardium occidentale* (Jambu mete), *Spondias pinnata* (Kedondong hutan), *Mangifera odorata* (Kuini), and *Mangifera indica* (Mangga). Eight other Familyes contain two species each: Moraceae with *Ficus benjamina* (Beringin) and *Ficus variegata* (Gondal); Meliaceae with *Dysoxylum* spp. (Canara) and *Xylocarpus granatum* (Kira-kira); and Myrtaceae with *Syzygium aromaticum* (Cengkih) and *Syzygium malaccense* (Jambu).

The IVI must be determined from the total values of density, frequency, and dominance in relation to vegetation structure growth. Generally, plant species exhibit relatively high density values across all growth stages, from seedling to tree stage (Table 4, 5, 6, 7).

Table 4. The IVI Tree Stage of Beach Forest of Kamarian Village

No	**Scientific Name**	**Local Name**	**Family**	**IVI**		
				Block 1	**Block 2**	**Block 3**
1	*Pterocarpus indicus*	Linggua (Angsana)	Fabaceae	69.39	27.24	68.29
2	*Terminalia catappa*	Ketapang	Combretaceae	37.97	61.34	49.31
3	*Cerbera manghas*	Mangga Brabu	Apocynaceae	37.65	71.91	15.98
4	*Hibiscus tiliaceus*	Waru	Malvaceae	20.66	40.24	23.19
5	*Calophyllum inophyllum*	Bintanggur	Calophyllaceae	9.82	8.70	13.88
6	*Intsia bijuga*	Kayu Besi (Merbau)	Fabaceae	7.90	43.37	31.49
7	*Alstonia scholaris*	Pulai	Apocynaceae	3.70		22.05
8	*Ficus benjamina*	Beringgin	Moraceae	21.97		10.13
9	*Spondias pinnata*	Kedondong Hutan	Anacardiaceae	44.55		4.35
10	*Ficus variegata*	Gondal (Ara Benying)	Moraceae	11.64		
11	*Parmentiera cereifera*	Kelor Pantai	Bignoniaceae	9.87		
12	*Myristica fragrans*	Lenat (Renghas)	Myristicaceae	6.57		
13	*Mangifera odorata*	Kuini	Anacardiaceae	5.59		
14	*Kleinhovia hospita*	Kinar	Malvaceae	5.33		
15	*Eugenia spp*	Canara	Myrtaceae	3.83		
16	*Vitex cofassus*	Gofasa	Lamiaceae	3.58		
17	*Barringtonia asiatica*	Hutung (Putat Laut)	Lecythidaceae		20.06	16.36
18	*Syzygium aromaticum*	Cengkih	Myrtaceae		6.24	14.76
19	*Anacardium occidentale*	Jambu Mete	Anacardiaceae		4.75	4.54
20	*Canarium sylvestre*	Nanari	Burseraceae		11.43	
21	*Mangifera indica*	Mangga	Anacardiaceae		2.40	
22	*Premna corymbosa*	Gumira Pantai	Lamiaceae		2.33	
23	*Canarium commune*	Kenari	Burseraceae			8.98
24	*Hernandia peltata*	Mata Ikan (Kempis Cina)	Hernandiaceae			6.48
25	*Myristica fragrans*	Pala	Myristicaceae			6.09
26	*Gnetum gnemon*	Ganemo	Gnetaceae			4.10
27	*Syzygium malaccense*	Jambu	Myrtaceae			
28	*Alangium javanicum*	Samar	Cornaceae			
			Total	**300.00**	**300.00**	**300.00**

Table 5. The IVI Pole Stage of Beach Forest of Kamarian Village

No	**Scientific Name**	**Local Name**	**IVI**			
			Family	**Block 1**	**Block 2**	**Block 3**
1	*Pterocarpus indicus*	Linggua	Fabaceae	69.65	4.68	68.05
2	*Cerbera manghas*	Mangga Brabu	Apocynaceae	68.32	148.11	27.66
3	*Hibiscus tiliaceus*	Waru	Malvaceae	61.75	40.05	37.67
4	*Terminalia catappa*	Ketapang	Combretaceae	51.77	21.24	26.58
5	*Calophyllum inophyllum*	Bintanggur	Calophyllaceae	9.6	14.16	9.59
6	*Intsia bijuga*	Kayu Besi	Fabaceae	9.03	10.06	21.94
7	*Ficus variegate*	Gondal	Moraceae		6.72	7.31
8	*Hernandia peltata*	Mata Ikan	Hernandiaceae		5.21	7.07
9	*Canarium sylvestre*	Nanari	Burseraceae		12.8	
10	*Parmentiera cereifera*	Kelor Pantai	Bignoniaceae		10.96	
11	*Eugenia spp*	Canara	Myrtaceae		5.9	
12	*Alangium javanicum*	Samar	Cornaceae		5.25	
13	*Syzygium aromaticum*	Cengkih	Myrtaceae		5.19	
14	*Premna corymbosa*	Gumira Pantai	Lamiaceae		4.96	
15	*Barringtonia asiatica*	Hutung	Lecythidaceae	8.75	4.7	
16	*Spondias pinnata*	Kedondong Hutan	Anacardiaceae	21.12		
17	*Syzygium malaccense*	Jambu	Myrtaceae			35.18
18	*Myristica fragrans*	Pala	Myristicaceae			34.95
19	*Ficus benjamina*	Beringgin	Moraceae			23.99
			Total	**300.00**	**300.00**	**300.00**

Table 6. The IVI Sapling Stage of Beach Forest of Kamarian Village

No	**Scientific Name**	**Local Name**	**Family**	**IVI**		
				Block 1	**Block 2**	**Block 3**
1	*Terminalia catappa*	Ketapang	Combretaceae	39.69	49.69	14.66
2	*Hibiscus tiliaceus*	Waru	Malvaceae	38.52	23.04	17.63
3	*Cerbera manghas*	Mangga Brabu	Apocynaceae	36.17	54.45	29.54
4	*Calophyllum inophyllum*	Bintanggur	Calophyllaceae	21.7	13.81	11.68
5	*Barringtonia asiatica*	Hutung	Lecythidaceae	8.41	18.78	27.2
6	*Pterocarpus indicus*	Linggua	Fabaceae		13.71	35.59
7	*Intsia bijuga*	Kayu Besi	Fabaceae		4.07	13.47
8	*Scaevola taccada*	Papaceda	Goodeniaceae		9.14	
9	*Alangium javanicum*	Samar	Cornaceae		4.07	
10	*Euphorbia tirucalli*	Daun Patah Tulang	Euphorbiaceae		3.08	
11	*Premna corymbosa*	Gumira Pantai	Lamiaceae		3.08	
12	*Canarium sylvestre*	Nanari	Burseraceae		3.08	
13	*Hernandia peltata*	Mata Ikan	Hernandiaceae	32.64		27.48
14	*Spondias pinnata*	Kedondong Hutan	Anacardiaceae	10.76		
15	*Xylocarpus granatum*	Kira-Kira	Meliaceae	7.23		
16	*Ficus variegate*	Gondal	Moraceae	4.88		6.6
17	*Syzygium malaccense*	Jambu	Myrtaceae			16.17
			Total	**200.00**	**200.00**	**200.00**

Table 7. The IVI Seedling Stage of Beach Forest of Kamarian Village

No	**Scientific Name**	**Local Name**	**Family**	**IVI**		
				Block 1	**Block 2**	**Block 3**
1	*Terminalia catappa*	Ketapang	Combretaceae	18.04	66.99	32.62
2	*Cerbera manghas*	Mangga Brabu	Apocynaceae	13.73	31.4	25.59
3	*Pterocarpus indicus*	Linggua	Fabaceae	95.25	17.63	39.44
4	*Barringtonia asiatica*	Hutung	Lecythidaceae	3.45	14.54	4.56
5	*Calophyllum inophyllum*	Bintanggur	Calophyllaceae	14.59	10.5	41.21
6	*Hibiscus tiliaceus*	Waru	Malvaceae	36.04	7.7	16.47
7	*Spondias pinnata*	Kedondong Hutan	Anacardiaceae	18.89		
8	*Intsia bijuga*	Kayu Besi	Fabaceae		39.44	13.06
9	*Scaevola taccada*	Papaceda	Goodeniaceae		6.02	
10	*Premna corymbosa*	Gumira Pantai	Lamiaceae		3.85	
11	*Canarium sylvestre*	Nanari	Burseraceae		1.93	
12	*Hernandia peltata*	Mata Ikan	Hernandiaceae			15.54
13	*Syzygium malaccense*	Jambu	Myrtaceae			4.25
14	*Meliosma spp*	Bulatung	Sabiaceae			3.63
15	*Xylocarpus granatum*	Kira-Kira	Meliaceae			3.63
			Total	200.00	200.00	200.00

Similarity and Dissimilarity of Research Blocks

The similarity and dissimilarity indices presented in Table 1 illustrate the ecological relationships between three research blocks across different forest regeneration stages. These indices provide critical insights into species composition variation and community structure dynamics. The similarity index (IS) measures the degree of resemblance between vegetation blocks, while the dissimilarity index (ID) quantifies their differences. Higher similarity values indicate greater overlap in species composition between blocks, suggesting similar environmental conditions or successional stages. Conversely, higher dissimilarity values reflect more distinct vegetation communities, potentially resulting from differences in microhabitat characteristics, disturbance history, or other ecological factors influencing species distribution.

Tabel 8. Similarity and Dissimilarity Index of Research Blocks (%)

Stage	IS/ID	Blok 1	Blok 2	Blok 3
Tree	Blok 1	X	65,95	59,12
	Blok 2	34,05	x	64,47
	Blok 3	40,88	35,53	X
Pole	IS/ID	Blok 1	Blok 2	Blok 3
	Blok 1	X	49,02	40,47
	Blok 2	50,98	x	88,65
	Blok 3	59,53	11,35	x
Sapling	IS/ID	Blok 1	Blok 2	Blok 3
	Blok 1	X	48,54	38,23
	Blok 2	51,46	x	44,96
	Blok 3	61,77	55,04	x

Stage	IS/ID	Blok 1	Blok 2	Blok 3
Seedling	IS/ID	Blok 1	Blok 2	Blok 3
	Blok 1	x	64,48	47,14
	Blok 2	35,52	x	50,70
	Blok 3	52,86	49,30	x

The analysis of similarity and dissimilarity indices reveals distinctive patterns across different forest regeneration stages. In the tree stage, blocks 1 and 2 demonstrate the highest similarity (65.95%), while the pole stage shows remarkable similarity between blocks 2 and 3 (88.65%), indicating a notably homogeneous composition in these areas. The sapling stage exhibits more balanced dissimilarity values, suggesting a transitional phase in community development. Interestingly, the seedling stage reveals moderate to high similarity between all blocks, with values ranging from 47.14% to 64.48%, which may indicate a more uniform distribution of newly establishing species across the research area. These findings emphasize the dynamic nature of forest community assembly processes and highlight the importance of considering multiple vegetation strata when assessing ecological similarity patterns, as different regeneration stages can exhibit distinct spatial organization and species association trends.

Species Diversity and Ecological Characteristics

Based on data analysis, the species diversity index in the Beach forest of Kamarian Village from tree to seedling levels is predominantly categorized as low, with values less than 1. However, at the tree stage in Blocks I and III, the diversity falls within the moderate category.

Table 9. Shannon-Wiener Diversity Index (H') by Growth Stage

Growth Stage	**Block 1**	**Block 2**	**Block 3**
Tree	1.02	0.90	1.06
Pole	0.79	0.82	0.96
Sapling	0.86	0.88	0.96
Seedling	0.67	0.82	0.91

The low species diversity index in the Kamarian Beach forest can be attributed to several factors affecting species composition, distribution, and ecosystem health. Anthropogenic pressures (human activities) such as land clearing, logging, and agriculture contribute to forest degradation and species loss. Land conversion for settlements or commercial use reduces natural habitats for many plant species, resulting in the survival of only more tolerant or adaptive species, thereby reducing overall diversity.

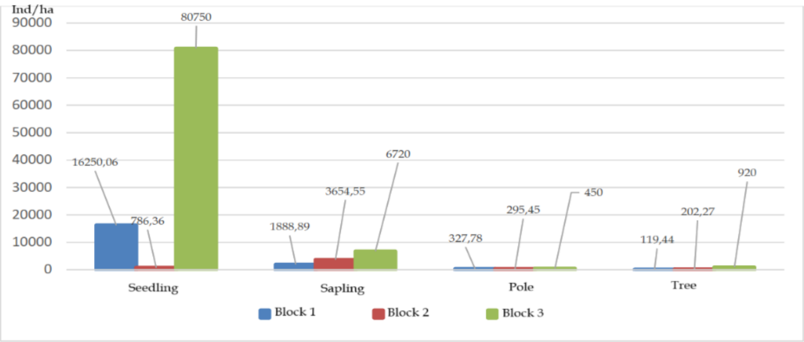

Figure 4. Density (N/ha) Graph Across Research Blocks

At the seedling stage, numbers are very high across all blocks, particularly in Block III with 80,750 ind/ha, followed by Block I with 16,250 ind/ha, and the lowest in Block II with 786 ind/ha. This indicates that early regeneration processes are highly active in Blocks I and III.

At the sapling stage, Block II has the highest number with 3,654 ind/ha, indicating active and stable growth of young vegetation in this area, followed by Block III with 6,720 ind/ha and Block I with 1,889 ind/ha, representing the advanced phase of regeneration. For the pole stage, numbers are relatively low across all blocks, with Block III having the highest at 450 individuals/ha, indicating that some plants are developing stronger structures; Blocks I and II follow with 328 ind/ha and 295 ind/ha respectively.

At the tree stage, the highest number is found in Block III with 920 ind/ha, followed by Block II with 202 ind/ha, and the lowest in Block I with 119 ind/ha, demonstrating that Block III has successful regeneration through to the adult plant stage. Overall, vegetation numbers tend to decrease with increasing growth stages, which is a common pattern in natural ecosystems where only a small proportion of plants successfully grow to become mature trees.

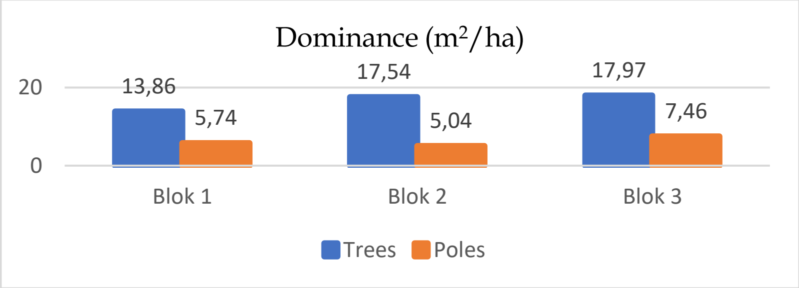

Figure 5. Dominance Graph Across Research Blocks (m^2/ha)

Dominance in vegetation analysis refers to the extent of influence or contribution of certain plant species to the overall plant community in an area. Dominance is typically related to size, density, or surface area occupied by a species. Species with high values in parameters such as canopy cover, basal area, density, and IVI can be considered dominant species that play important roles in forest ecosystem structure and function (Sapardi *et al.*, 2024).

At the tree stage, Block III shows the highest value at 17.97 m^2/ha, followed by Block II with 17.54 m^2/ha, and Block I with the lowest at 13.86

m^2/ha. These values indicate that Block III has the most mature vegetation structure with dominance of adult trees, likely reflecting a more stable ecosystem that has developed over time without major disturbances (Figure. 5).

The Beach forest vegetation is also influenced by abiotic factors, which significantly affect the plant species growing in a particular area. Plant diversity and abundance are heavily influenced by environmental conditions (Irwanto *et al.*, 2024). Several environmental factors observed in this study are presented in Table 10.

Table 10. Light Intensity, Temperature and Humidity in Kamarian Village Beach Forest

Block	Light Intensity (LUX)	Temperature (°C)	Humidity (%)
Block 1	752-766	26-30	87-93.20
Block 2	157-164	26-30	87-92.70
Block 3	752-766	26-30	87-93.20

Environmental conditions significantly influence the distribution of species and individuals at each growth stage. Factors such as light availability, temperature, and humidity play crucial roles in determining plant survival and growth (Kindeberg *et al.*, 2023). Supportive habitats can help certain species achieve higher growth stages, while unfavorable conditions may hinder development.

Table 10 presents data on microenvironmental conditions across the three observation blocks, including light intensity (LUX), temperature (°C), and humidity (%). Blocks I and III have similarly high light intensities ranging from 752-766 lux, whereas Block II has significantly lower values at 157-164 lux, indicating that Block II has greater density, diameter, and dominance, resulting in more shaded or covered conditions. Temperature across all three blocks is relatively uniform, ranging from 26-30°C, showing no significant differences in this parameter. Humidity is also relatively high and consistent, with Blocks I and III ranging from 87-93.20%, and Block II slightly lower at 87-92.70%. Overall, these data indicate that the primary difference between blocks lies in light intensity, which can influence vegetation growth and regeneration in each block.

DISCUSSION

The vegetation analysis of Kamarian Village beach forest reveals a complex ecosystem with distinct stratification, species composition, and ecological dynamics across the three study blocks. This discussion integrates our findings with established ecological principles and relevant research to provide a comprehensive understanding of this beach forest ecosystem.

Forest Structure and Stratification

The beach forest of Kamarian Village exhibits a structure of four strata. The presence of emergent tall trees (stratum A) reaching heights of 20-29 meters indicates a coastal forest ecosystem that has developed over a significant period. This vertical stratification creates diverse microhabitats that support various plant communities adapted to specific light conditions, humidity levels, and soil characteristics (Jiang *et al.*, 2025).

Notably, the dominance of *Intsia bijuga* (Kayu besi), *Terminalia catappa* (Ketapang), and *Pterocarpus indicus* (Linggua) in stratum A aligns with findings from similar coastal forests in the Maluku archipelago (O'Connor *et al.*, 2023). These species possess adaptations that enable them to withstand coastal environmental stressors such as salt spray, strong winds, and sandy substrates (Hobohm *et al.*, 2021). The multi-layered canopy structure, particularly evident in Block III, serves as an effective buffer against coastal erosion and provides vital wildlife habitat, supporting the ecological resilience of this coastal region (Aburto-Oropeza *et al.*, 2025).

Species Composition and Ecological Significance

The beach forest harbors 31 plant species belonging to diverse families, with Anacardiaceae, Moraceae, Myrtaceae, Lamiaceae, Fabaceae, Apocynaceae, Burseraceae, and Malvaceae being particularly well-represented. This taxonomic diversity, though moderate compared to inland tropical forests, is characteristic of coastal forest ecosystems in Eastern Indonesia (Monk *et al.*, 2000). The dominance of salt-tolerant species such as *Terminalia catappa*, *Hibiscus tiliaceus*, and *Barringtonia asiatica* across all three blocks underscores their ecological importance in this coastal environment.

The Importance Value Index (IVI) analysis reveals that *Pterocarpus indicus*, *Terminalia catappa*, and *Cerbera manghas* consistently demonstrate high ecological significance across all growth stages. These species exhibit superior adaptation strategies to coastal conditions, including salt tolerance, efficient water use, and wind resistance (Breckle, 2002). Their prominence suggests they play keystone roles in maintaining ecosystem stability and function, including shoreline protection, nutrient cycling, and habitat provision (Dahdouh-Guebas *et al.*, 2005).

Interestingly, the variable distribution of IVI values across blocks indicates localized environmental heterogeneity, potentially influenced by factors such as distance from shoreline, topography, human disturbance, and soil characteristics (Hogarth, 2015). For instance, Block III's higher species diversity at the tree stage (H' = 1.06) suggests it may represent a more mature, less disturbed segment of the forest compared to the other blocks (Álvarez-Molina *et al.*, 2012).

Regeneration Patterns and Forest Dynamics

The density analysis across growth stages presents a classic reverse J-shaped distribution curve, with seedling numbers far exceeding those of mature trees. This pattern indicates active natural regeneration processes (Whitmore, 1989), particularly evident in Block III with 80,750 seedlings/ha. However, the sharp reduction in numbers from seedling to sapling stages (approximately 12-fold decrease in Block III) indicates significant mortality during early development stages, a common phenomenon in tropical forests due to competition for resources and various environmental stressors (Li & Wei, 2024).

The regeneration bottleneck observed between pole and tree stages, especially in Blocks I and II, suggests potential anthropogenic disturbances or natural selection pressures affecting the transition to mature forest (Chazdon *et al.*, 2016). Block III's higher tree density (920 ind/ha) and dominance (17.97

m²/ha) indicate a more successful regeneration trajectory and potentially less disturbed conditions compared to the other blocks.

The similarity and dissimilarity indices further illuminate the forest's spatial heterogeneity, with the high similarity (88.65%) between Blocks II and III at the pole stage suggesting similar environmental conditions or successional stages in these areas. Conversely, the moderate dissimilarity between blocks at the tree stage indicates that mature vegetation communities have developed distinct characteristics, potentially due to microhabitat variations or differing disturbance histories (Larrieu *et al.*, 2022).

Environmental Factors and Forest Health

The relatively low Shannon-Wiener diversity indices ($H' < 1$ for most growth stages) suggest moderate ecological stress in this ecosystem. While some level of stress is expected in coastal environments due to salt exposure, wind, and sandy substrates (Ellison, 2000), the particularly low diversity in Block II's seedling stage ($H' = 0.82$) compared to Block III ($H' = 0.91$) may indicate additional anthropogenic pressures affecting regeneration processes.

The microenvironmental analysis reveals that light intensity varies significantly between blocks (157-164 lux in Block II versus 752-766 lux in Blocks I and III), while temperature and humidity remain relatively consistent. The lower light intensity in Block II corresponds with its higher tree dominance (17.54 m²/ha), creating a more closed canopy that affects understory regeneration dynamics (Montgomery & Chazdon, 2001). This relationship between canopy structure and light availability likely influences species composition across growth stages, favoring shade-tolerant species in areas with denser canopy cover.

These environmental variations, combined with potential anthropogenic disturbances, contribute to the observed patterns of species distribution and regeneration success across the three blocks. The moderate to low diversity indices suggest that this beach forest ecosystem, while functional, may benefit from conservation efforts to enhance resilience against increasing coastal development pressures and climate change impacts (Raza *et al.*, 2019).

Conservation Implications

The Kamarian Village beach forest represents an important ecological resource with significant ecosystem services, including coastal protection, carbon sequestration, and biodiversity support. The presence of commercially valuable timber species such as *Intsia bijuga* (Kayu besi) and *Pterocarpus indicus* (Linggua) alongside medicinal plants like *Cerbera manghas* and *Calotropis gigantea* highlights the socioeconomic importance of this ecosystem to local communities (Shasha *et al.*, 2023; Subramanian *et al.*, 2023).

Conservation strategies should focus on maintaining the structural integrity of this beach forest, particularly by protecting mature trees that serve as seed sources and create favorable microenvironments for regeneration. Community-based forest management approaches that integrate traditional ecological knowledge with scientific understanding could enhance sustainable utilization while preserving ecological function (Sinthumule, 2023).

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions can be drawn:

1. The beach forest exhibits a well-developed four-strata structure with emergent trees reaching 20-29 meters, creating diverse microhabitats that support various plant communities.
2. The forest harbors 31 plant species across multiple families, with keystone species including *Pterocarpus indicus*, *Terminalia catappa*, and *Cerbera manghas* demonstrating consistently high ecological significance across all growth stages.
3. Block III demonstrates characteristics of a more mature, less disturbed forest segment with higher tree density (920 ind/ha) and dominance (17.97 m^2/ha).
4. The forest displays active natural regeneration processes, as evidenced by the classic reverse J-shaped distribution curve of plant densities across growth stages.
5. The relatively low Shannon-Wiener diversity indices ($H' < 1$ for most growth stages) indicate moderate ecological stress, which is partially attributable to the inherently challenging coastal environment but may also reflect anthropogenic pressures.

Recommendations

Based on these findings, we recommend the following conservation and management strategies: Establish formal community-based forest management systems that integrate traditional ecological knowledge with scientific understanding. This approach should emphasize sustainable harvest practices for non-timber forest products while strictly regulating timber extraction.

ADVANCED RESEARCH

Future research should focus on detailed assessment of soil characteristics and their influence on vegetation patterns

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