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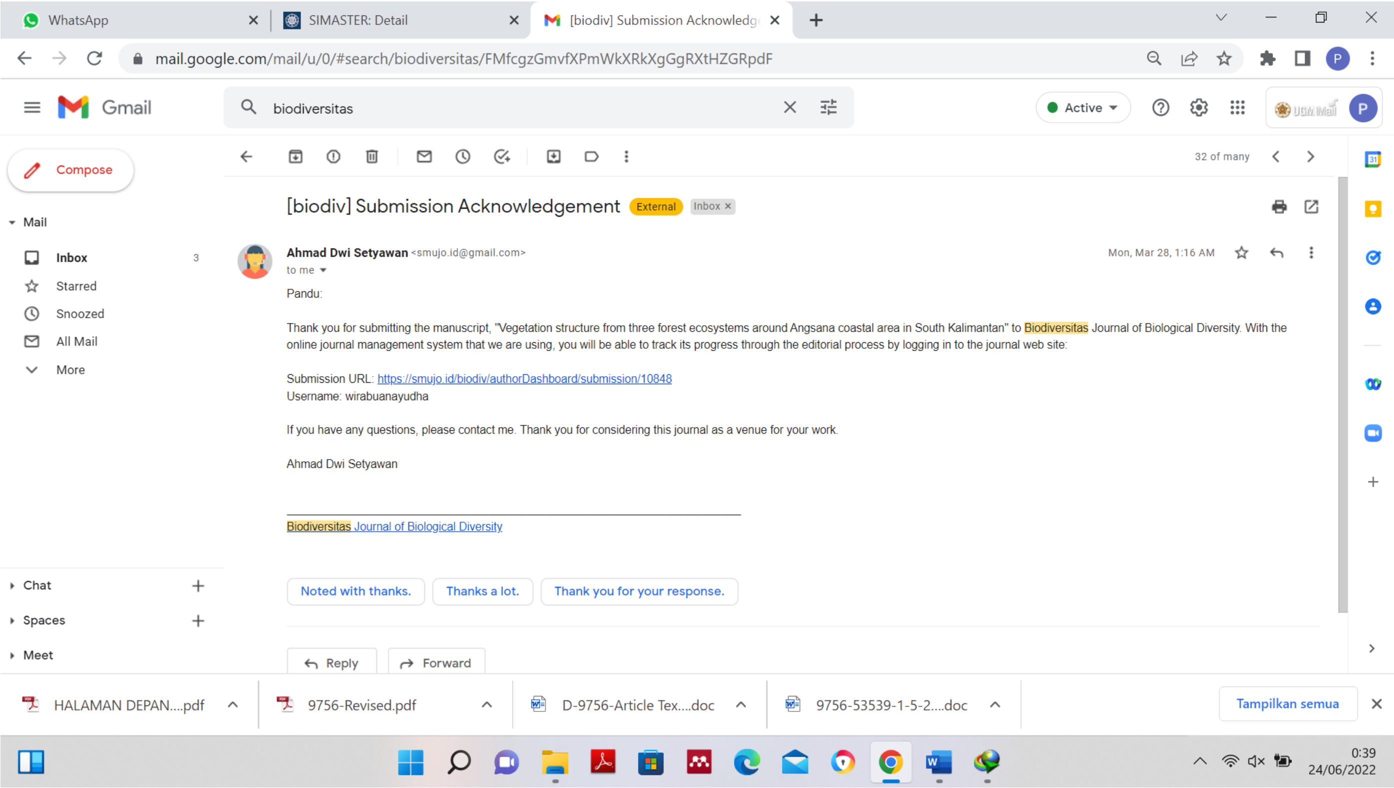

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Vegetation structure from three forest ecosystems around Angsana coastal area in South Kalimantan

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Yusanto Nugroho, Suyanto, Dindin Makinudin, Silvyna Aditia, Dinda Dewi Yulimasita, Ahmad Yusuf Afandi, Moehar Maraghiy Harahap, Syamsu Alam, Jeriels Matatula, Pandu Yudha Adi Putra Wirabuana

Address

(Fill in your institution's name and address, your personal cellular phone and email)

Faculty of Forestry, Universitas Gadjah Mada
Jln. Agro No. 1 Kampus Bulaksumur, Yogyakarta
+6281226887738

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This study found the number of species in three forest ecosystems was relatively different. The highest species presence was recorded in Heath Forest (22 species), followed by Beach Forest (18 species) and Mangrove Forest (7 species). These results were also followed by the degree of richness, heterogeneity, and evenness wherein Heath Forest indicated a better condition than other types of forests around coastal ecosytems. Interestingly, the species abundance gradually declined from seedling to tree, except in Mangorove Forest. Our study also recorded the greatest importance value index in every forest was possessed by different species at each life stage. The vegetation composition in Mangrove Forest was relatively more similar to Beach Forest than Heath Forest with a similarity index of 47.1%. Overall, this study concluded there are high variation of species from three forest ecosystems around Angsana coastal area.

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Vegetation structure from three forest ecosystems around Angsana coastal area in South Kalimantan

YUSANTO NUGROHO[1], SUYANTO[1], DINDIN MAKINUDIN[2], SILVYNA ADITIA[2], DINDA DEWI YULIMASITA[2], AHMAD YUSUF AFANDI[3], MOEHAR MARAGHIY HARAHAP[4], JERIELS MATATULA[5], PANDU YUDHA ADI PUTRA WIRABUANA[6,♥]

[1]Faculty of Forestry, Universitas Lambung Mangkurat, Jln. Ahmad Yani km 36 Banjarbaru, South Kalimantan, Indonesia.
[2]CSR Division, PT Borneo Indobara, Jln. Propinsi km 180 Angsana, Tanah Tumbu, South Kalimantan, Indonesia.
[3]Reserach Center for Limnology and Water Resources, National Research and Innovation Agency, Indonesia.
[4]Department of Forest Conservation, Faculty of Forestry, Universitas Sumatera Utara, Medan Baru, Medan 20155, North Sumatra, Indonesia.
[5]Forestry Field Program, Politeknik Pertanian Negeri Kupang, Jl. Prof. Herman Johanes, Lasiana, Kupang 85011, East Nusa Tenggara, Indonesia.
[6] Department of Forest Management, Faculty of Forestry, Universitas Gadjah Mada, Jln. Agro No. 1 Bulaksumur, Sleman 55281, Yogyakarta, Indonesia.
Tel./Fax.: +62-274-548815, ♥email: pandu.yudha.a.p@ugm.ac.id

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Abstract. Vegetation communities around the coastal ecosystem play essential contributions in supporting disaster management and climate change mitigation. However, the available information about vegetation structure from coastal areas is still limited even though it is highly required as a fundamental consideration to determine the alternative strategies for environmental preservation. This study investigated the vegetation characteristics from three forest ecosystems around Angsana coastal area in South Kalimantan, i.e., heath forests (HF), beach forests (BF), and mangrove forests (MF). A field survey was conducted using transect-line methods with every sampling plot size of 10×10 m and an interval from 20 m. The vegetation structure from three forest ecosystems was assessed using species abundance, plant diversity, importance value index (IVI), and similarity level. Results demonstrated the number of species from three types of forests was relatively different, wherein the highest species abundance was observed in HF (22 species), followed by BF (18 species) and MF (7 species). This finding was also followed by the trend of vegetation diversity in which HF had the most outstanding richness (*Dmg* = 4.52), heterogeneity (*H'* = 2.86), and evenness (*J'* = 0.94). The highest IVI in BF for every vegetation stage was noted in Hibiscus tiliaceus, while Rhizophora mucronata consistently had the greatest IVI in MF for every life form. Interestingly, the highest IVI in HF from seedlings to trees were possessed by the different species, i.e., seedling (*Adina minutiflora*), sapling (*Rhodedomia tomentosa* and *Premna serratifolia*), poles (*Tristania maingayi*), and trees (*Vitex ovata*). Moreover, our study also observed that species abundance in forest ecosystems gradually declined from seedlings to trees, except in MF. The vegetation composition in MF was more similar to BF than HF, with a similarity level of 47.1%. Based on these results, this study concluded the vegetation structure from three forest ecosystems in the Angsana coastal area is highly diverse, wherein every type of forest had specific characteristics as its entity.

Key words: coastal ecosystems, environmental preservation, plant diversity, species abundance, vegetation characteristics

Abbreviations: HF (Heath Forests), BF (Beach Forests), MF (Mangrove Forests), IVI (Importance Value Index), *Dmg* (Margalef Index), *H'* (Shannon-Wiener Index), *J'* (Pielou Evenness Index).

Running title: Vegetation structure in coastal ecosystems

INTRODUCTION

The vegetation around coastal ecosystems currently becomes an interesting issue in the tropics since it has a strategic position in disaster management, climate change mitigation, and rural development. Besides preventing abrasion (Matatula et al. 2021), the vegetation communities in the coastal area also play an essential role as a windbreak to protect the local settlement around it (Sadono et al. 2020a). Several studies also report that the presence of vegetation in coastal ecosystems contributes to reducing carbon emissions in the atmosphere (Purwanto et al. 2022) and minimizing the rate of sea-water intrusion into the land (Sadono et al. 2020b). Meanwhile, other references record that the canopy of coastal vegetation is suitable as a habitat for some bird species (Purwanto et al. 2021). Moreover, their root system, particularly for mangroves, provides an excellent environmental condition to facilitate the breeding process of sea organisms like shrimps, fish, and crab (Matatula et al. 2019). On another side, the vegetation landscape in the coastal zone is also prospective to develop as an area for ecotourism wherein it can provide additional benefits for the local community welfare (Sánchez-Prieto et al. 2021). These explanations indicate that the sustainability of vegetation in the coastal ecosystem is required to maintain the area's stability in the future. Therefore, it is essential to implement the effort of sustainable coastal management (SCM) for supporting biodiversity conservation in coastal ecosystems. To achieve this goal, understanding the vegetation structure becomes a fundamental requirement to determine the alternatives strategies for SCM.

The vegetation structure in the coastal zone is naturally unique since it consists of different types of forest ecosystems. There are two types of forests located in coastal areas, namely beach and mangrove forests (Kusmana et al. 2017). Beach forests (BF) are a type of forest-grown in the sand area, while mangrove forests (MF) are commonly found in the tidal zone (Lillo et al. 2019). The plant dimensions between BF and MF are considerably different, wherein most species in MF have unique root systems such as *Bruguiera sp.*, *Rhizophora sp.*, and *Avicennia sp.* (Srikanth et al. 2015). On another side, the vegetation formation in BF is predominantly by *Ipomoea pescaprae* and *Baringtonia sp.* (Wardhani and Poedjirahajoe 2020). However, in a specific circumstance, the coastal ecosystems may also have the third type of forest, generally known as heath forests (HF). This forest exists in the coastal area due to the quartz sand deposits carried by rivers (Syuharni et al. 2014). In Indonesia, HF is only found in certain locations such as Borneo and Bangka Belitung Islands (Maimunah et al. 2019). Thus, the presence of HF in the coastal ecosystem will provide more challenges for coastal managers to maintain the sustainability of coastal vegetation.

This study aimed to identify the vegetation characteristics from three forest ecosystems around Angsana coastal area in South Kalimantan. The study site is one of the coastal zones with HF as part of forest ecosystems besides BF and MF. Unfortunately, the information about vegetation structure in this location is not available even though this site has a high potential to manage as the center of biodiversity conservation for coastal ecosystems. Nevertheless, the results will provide adequate information for managers regarding potential biodiversity in Angsana coastal areas as primary considerations to determine the alternative strategies for environmental preservation.

MATERIALS AND METHODS

Study area

This investigation was undertaken around Angsana coastal area located in South Kalimantan. The geographic position of this site is situated in S3°45'−3°46' and E115°35'− E115°36' (Figure 1). It has 94.81 hectares and consists of several land cover types: shrubs, forests, roads, settlements, oil palm plantation, and bare land. Nevertheless, more than 70% landscape in the study area is dominated by forest ecosystems with a coverage of 69.11 ha. There are three types of forests in this area, namely mangrove forests (MF), beach forests (BF), and heath forests (HF). Among them, the most extensive forest cover was found in HF (32.79 ha), followed by MF (30.34 ha) and BF (5.98 ha). The circumstance indicates high potential biodiversity in Angsana coastal ecosystems, particularly from the forest vegetation.

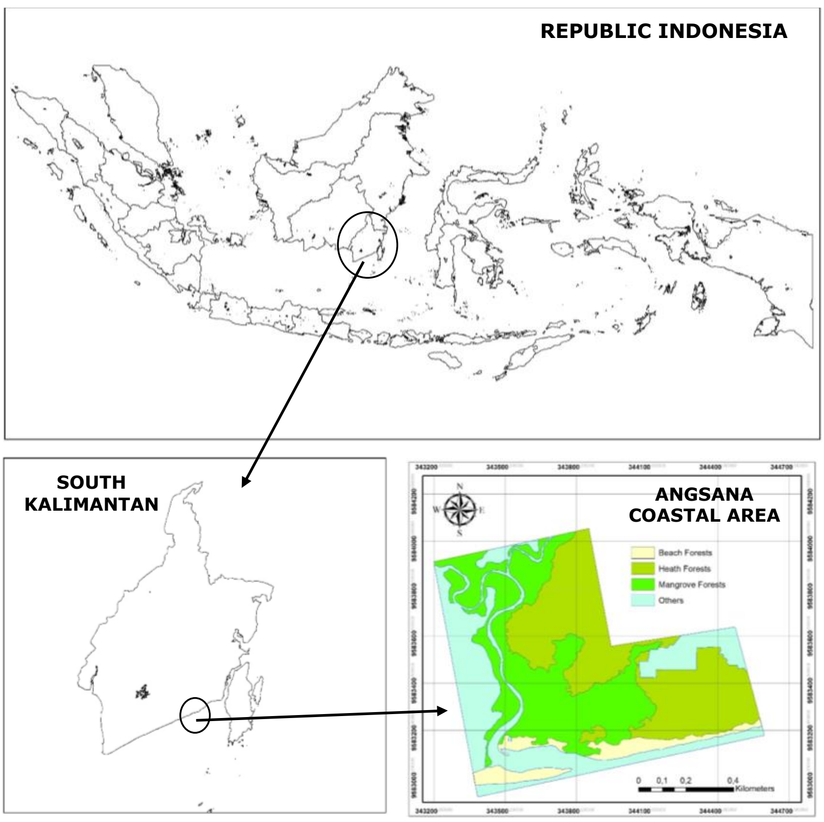

Figure 1. Location of Angsana coastal ecosystems in South Kalimantan. The different color in the map indicates land cover variations.

The Angsana coastal area is a unique ecosystem near the coal mining concession site. In the early beginning, this area was not well-managed and almost became a degraded coastal ecosystem due to the high rate of vegetation loss. However, stakeholders have made many efforts to accelerate the recovery of the ecosystem, particularly from PT Borneo Indobara as a primary company that had legal permission for mining exploration around this site. By collaborating with the local community living around the area, The Division of Corporate Social Responsibility from PT Borneo Indobara (CSR-BIB) has conducted reforestation programs intensively in this location since 2017. The activity of reforestation was not only worked for MF but also to rehabilitate the ecosystem condition in BF and MF.

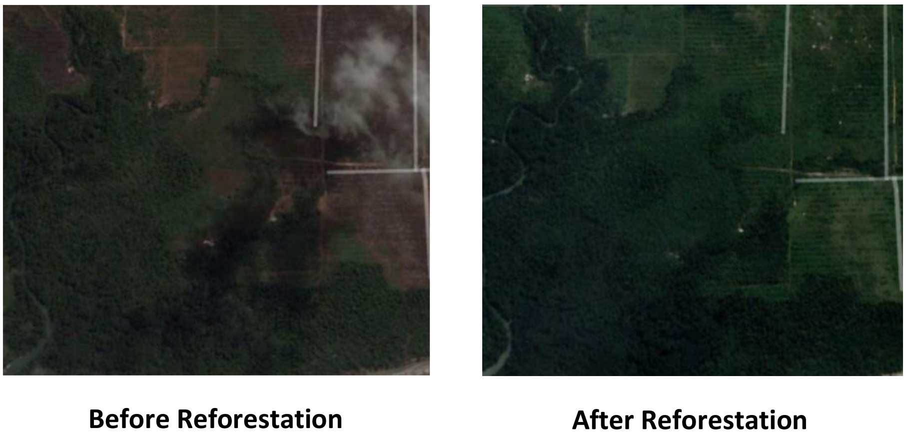

Figure 2. Comparison of landscape conditions in Angsana coastal ecosystems before and after reforestation program managed by collaboration between the local community and CSR-BIB based on Google Earth satellite imagery. The brown color indicated degraded land without vegetation cover.

Furthermore, to increase the community awareness for conserving coastal biodiversity, CSR-BIB also held training and supervising to develop ecotourism in Angsana coastal area. It aimed to improve the knowledge of local community wherein the effort of environmental preservation in the coastal zone had the potential to improve community welfare. In a short period from 2017 to 2021, these initiatives have demonstrated an excellent contribution to increasing the forest covers in Angsana coastal area (Figure 2).

Procedures

Data were collected from August to December 2021. Vegetation survey was conducted using a transect-line method with every sampling plot size of 10×10 m and interval from each 20 m. The transect length had 500 m with 20 m wide (Figure 3). The number of transects in this study was nine units and evenly distributed in every forest ecosystem. The distance between transects ranged from 1 to 2 km depending on the coverage area of forest ecosystems. To support the observation process, the sampling plot was divided into several sub-plots for facilitating the vegetation measurement based on their life stage, i.e., 2×2 m (seedlings), 5×5 m (saplings), and 10×10m (poles and trees) (Matatula et al. 2021). Several parameters were observed from this survey, like the type of species, number of species, and their growth performance. In this context, the growth performance of every species was only measured in poles and trees and just focused on diameter. As one of the essential variables in forest mensuration, the diameter had a strong correlation with other parameters like height (Barbosa et al. 2019), volume (Wirabuana et al. 2021a), and biomass (Setiahadi 2021). The size of diameter could also describe the competitive position of individual trees at a stand-level (Maleki et al. 2015).

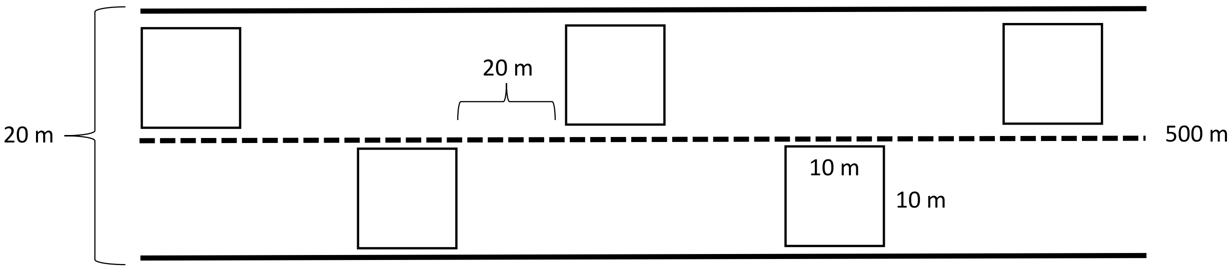

Figure 3. Visual illustration of a transect-line method for vegetation survey in this study

Data analysis

Descriptive analysis was conducted to understand the vegetation structure from three forest ecosystems in the Angsana coastal area. First, data from vegetation surveys were analyzed to calculate species density, species dominance, and frequency distribution (Eddy et al. 2019). Then, that information was used to quantify the relative abundance, relative dominance, and relative frequency from every species (Kasim et al. 2019). Finally, to identify the strategic position of species in each forest ecosystem, the importance value index (IVI) was determined by summing these three indicators (Yuliana et al. 2019). However, the IVI for seedlings and saplings was only counted using relative abundance and frequency.

Meanwhile, the diversity of vegetation from three forest ecosystems was assessed using three fundamental parameters: richness, heterogeneity, and evenness (Singh 2020). First, species richness was assessed by Margalef Index (*Dmg*), while species heterogeneity was estimated by Shannon-Winner Index (*H'*) (Li et al. 2018). Afterward, species evenness was reviewed by Pielou-Evenness Index (*J'*) (Wirabuana et al. 2021c). This study also quantified the Sorensen similarity index to determine a similarity degree of vegetation composition among three forest ecosystems in the Angsana coastal area (Lv et al. 2021). Furthermore, we also evaluated the existence of species in every life form of vegetation, from seedlings to trees, in assessing the regeneration capacity of species in the study area.

RESULTS AND DISCUSSION

Species distribution and importance value index

Results found that the number of species in MF is substantially lower than other forest ecosystems for each vegetation life form (Figure 4). In contrast, the highest species abundance in every life stage was recorded in HF. Interestingly, total species in BF and HF gradually declined along with the increasing life form. However, a similar trend did not find in MF wherein the number of species from seedlings to trees looked almost equal. The occurrence of species declining and vegetation growth was naturally discovered in most forest ecosystems since there was high competition among plants to obtain adequate resources like water, nutrients, light, and space (Looney et al. 2016). This process caused natural mortality for weaker plants because they could not get resources optimally (Wirabuana et al. 2021b). Meanwhile, the more robust species would survive and still grow well.

In a forest ecosystem, the plant competition was classified into two groups, namely intraspecific and interspecific. The intraspecific competition was a competition between individuals from the same species, while interspecific competition was a competition between individuals from different species (Barabás et al. 2016). Every plant in forest ecosystems would face both types of competition if it did not grow in a monoculture stand. In addition, the occurrence of plant competition in the forest was also a part of the nutrient cycle since when the dead trees decompose, they will release many nutrients into the soil layer.

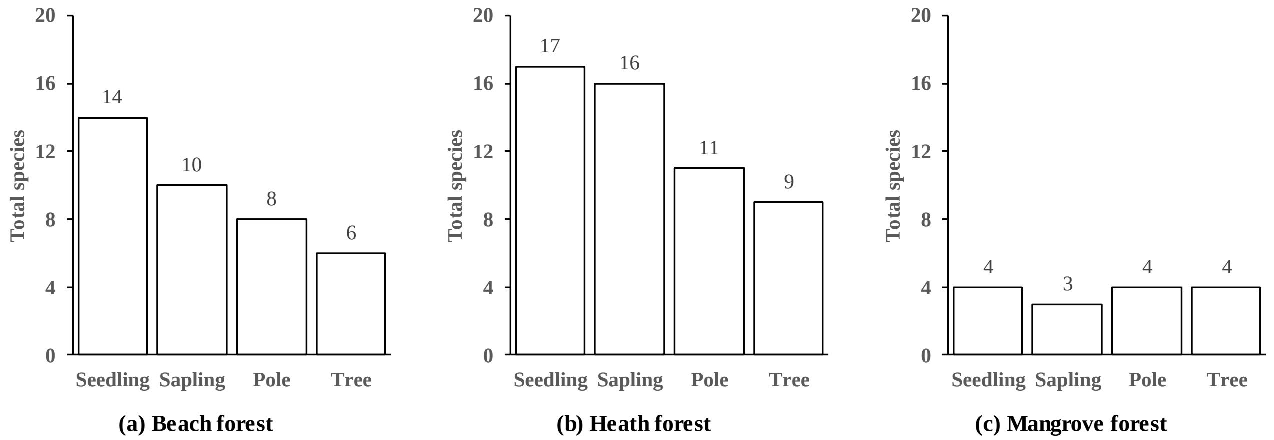

Figure 4. The number of species in every life form at three different forest ecosystems in the Angsana coastal area

MF had a lower number of species since the environmental condition of this forest had a lot of limiting factors, and only certain species could survive this situation. This ecosystem is situated in a tidal area with high salinity (Matatula et al. 2019). The substrate of mangroves was also dominated by mud; thus, only a few species having unique root systems can survive in mangroves (Srikanth et al. 2015). Results demonstrated seven species found in MF, including *Acrosticum aereum, Brugueiera cylindrica, Brugueiera gymnoriza, Lumnitzera littorea, Nypa fruticans, Rhizophora mucronata,* and *Rhizophora apiculata* (Table 1). Unlike BF and HF, the reforestation activity in MF was conducted more intensively from 2017 to 2021. More than 3,000 seedlings have been planted every year. Therefore, the number of species from seedlings to MF trees was almost balanced and equal. Our study also found no species that were evenly distributed in three forest ecosystems (Table 1). It indicated that each species had specific habitat requirements to support its growth and development. However, some species were also observed in different types of forests, such as Chrysobalanus icaco in BF and HF, as well as Rhizophora apiculata in MF and BF. Moreover, the highest IVI of species from every forest ecosystem was relatively different. For example, hibiscus tiliaceus became the most important species in BF for every life form based on its IVI, while Rhizophora mucronata was the essential species in MF. Attractively, the highest IVI of species in HF was noted in some different species, i.e., *Adina minutiflora* (seedlings), *Premna serratifolia*, *Rhodedomia tomentosa* (saplings), *Tristania maingayi* (poles), and *Vitex ovata* (trees). Results also noted that from 37 species distributed in Angsana coastal area, only a few species had good regeneration. These were indicated by their distribution from seedlings to trees (Khan et al. 2018), like *Adina minutiflora, Artocarpus rafscens, Casuarina equisetifolia, Garcinia sp., Litsea firma, Podocarpus letifolius, Rhizophora mucronata, Rhizophora apiculata,* and *Tristania maingayi*.

Table 1. Importance value index of species in every life form vegetation at three forest ecosystems in Angsana coastal area

No.	Species	Beach forests				Heath forest				Mangrove forest			
		Seedling	Sapling	Pole	Tree	Seedling	Sapling	Pole	Tree	Seedling	Sapling	Pole	Tree
1	*Acrosticum aereum*	8.55								22.02			
2	*Adina minutiflora*					**29.18**	17.09	36.00	18.69				
3	*Artocarpus rafscens*					5.70	8.55	20.87	26.95				
4	*Avicennia marina*	26.18	26.53	18.54									
5	*Brugueiera cylindrica*				24.24							42.38	33.22
6	*Brugueiera gymnoriza*		9.26	20.17							22.23		
7	*Calamus erinaceus*						8.55	19.15	17.12				
8	*Calophyllum inophylum*			23.06	34.12								
9	*Casuarina equisetifolia*	12.55	18.53	20.17	30.23								
10	*Chrysobalanus icaco*	18.82	18.53				8.55						
11	*Diospyrus buxifolio*						8.55	21.81					
12	*Evodia aromatica*					5.70		19.15	20.04				
13	*Excoecaria agallocha*	10.82											
14	*Flagellaria indica*					5.70							
15	*Garcinia sp*					21.35	8.55	20.87	23.77				
16	*Hibiscus tiliaceus*	**42.73**	**58.32**	**142.83**	**87.82**								
17	*Ixora coccinea*					17.78							
18	*Litsea firma*					17.10	12.55	39.63	40.22				
19	*Lumnitzera littorea*											25.35	16.01
20	*Macaranga triloba*					5.70							
21	*Mangifer sp*						8.55						
22	*Melastoma malabatricum*	8.55				14.21	8.55						
23	*Morinda citrifolia*	12.55	18.53										
24	*Nypa Fruticans*									12.93			
25	*Podocarpus letifolius*					13.53	8.55	38.20	29.41				
26	*Pandanus Tectorius*	6.27											
27	*Peltophorum pterocarpum*						8.55	19.15					
28	*Peronema canescens*					5.70							
29	*Premna serratifolia*	17.09	18.53			5.70	**21.09**						
30	*Rhizophora mucronata*	6.27	13.26		46.06					**88.08**	**105.56**	**171.60**	**142.02**
31	*Rhodedomia tomentosa*	8.55				5.70	**21.09**						
32	*Rizophora apiculata*	6.27	9.26	23.06	77.53					76.98	72.22	60.67	108.75
33	*Schima noronhoe*					16.34	17.09						
34	*Terminalia catappa*			17.12									
35	*Tristania maingayi*					5.70	17.09	**46.03**	41.05				
36	*Vismia cayennensis*					19.22	17.09						
37	*Vitex ovata*	14.82	9.26	35.05		5.70		19.15	**82.76**				
	Importance value index	200	200	300	300	200	200	300	300	200	200	300	300

Note: The bold value indicated the highest importance value index of species in every life form

Vegetation diversity and similarity level among forest ecosystems

Results showed the highest richness, heterogeneity, and evenness of vegetation were discovered in HF, while the lowest diversity index was recorded in MF (Figure 5). Interestingly, the vegetation communities in MF were more similar to BF than HF, with a similarity level of 47.1%. It was also supported by the results wherein most species in MF were also found in BF. From seven species that existed in MF, approximately five species were also observed in BF. These findings signified that some schemes of biodiversity strategies in MF also had the potential to conduct in BF. The reverse was also applied wherein the alternative plan for vegetation preservation in BF could be adopted in MF.

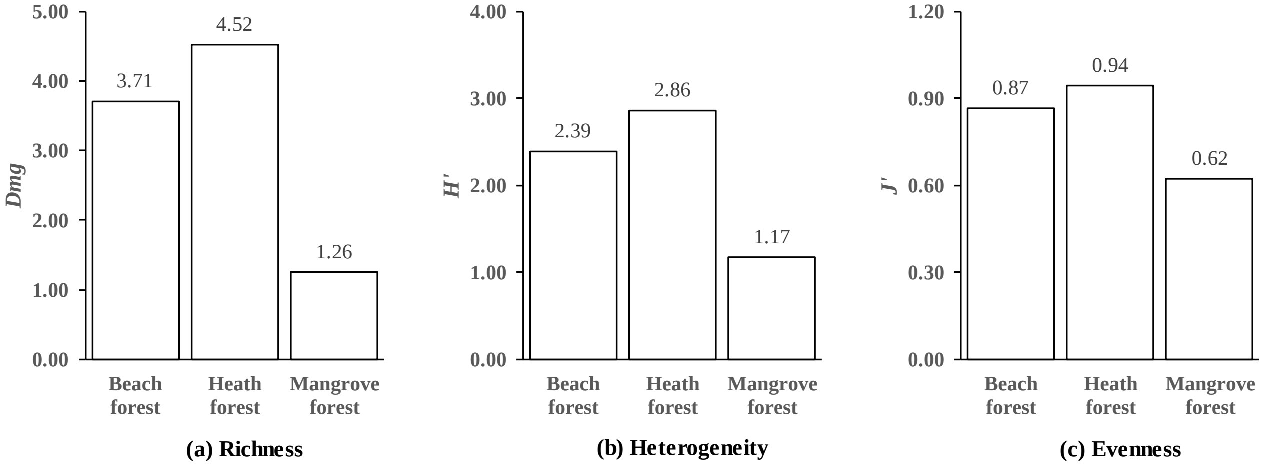

Figure 5. The trend of richness, heterogeneity, and evenness from three types of forest ecosystems in the Angsana coastal area

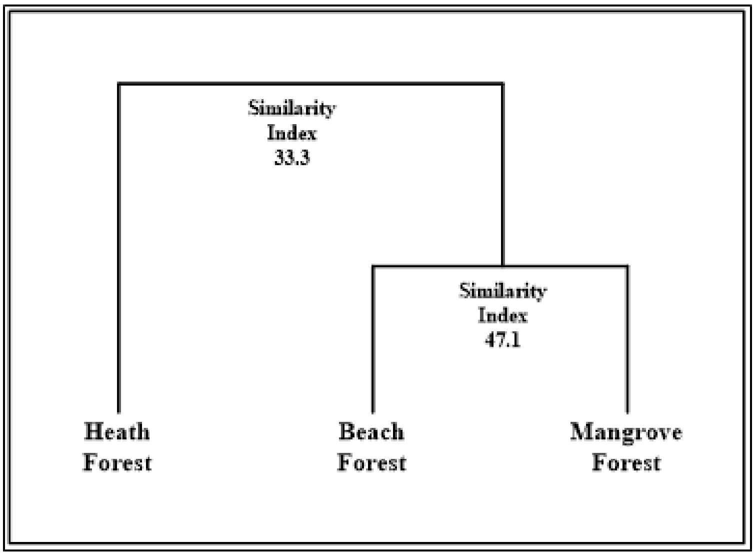

Figure 6. Similarity index of vegetation communities among three forest ecosystems in Angsana coastal area

In ecosystems management, vegetation diversity becomes one of the most important parameters to assess environmental stability (De Boeck et al. 2018). Higher diversity indicates better environmental health (Zhang et al. 2018), even though it is not generally applied in every type of forest, especially in mangroves. Unlike other ecosystems, mangroves have many limitations for supporting plant growth like substrate condition, flooding, and wind speed (Froilan et al. 2020). Therefore, there are only few species that can grow well in mangroves that can grow well in mangroves. This explanation confirms why the richness, heterogeneity, and evenness in MF was considerably lower than BF and MF. It also indicated that the resistance of mangroves to the disturbance was relatively weaker than other forests in Angsana coastal area.

Referring to the results, the vegetation communities in MF were almost similar to BF, but it was considerably different from the plant communities in HF. On another side, a part of the vegetation community in BF was also discovered in HF. This finding indicated that the environmental condition in BF was situated in the transition phase between HF and MF. In addition, the similarity of vegetation between forests can also occur due to the tolerance level of species into site conditions. For example, most mangrove species could also survive in beach areas even though the soil condition was dominated by sand. It is caused by sea waves that stimulate salinity conditions in the soil.

Implication Results

This study concluded that the vegetation structure among three forest ecosystems was highly varied, wherein the highest diversity was observed in HF. Every type of forest had specific characteristics that became its unique entity. This fact indicated a high potential to develop the Angsana coastal area as the center of biodiversity conservation for coastal ecosystems. However, our study also realized that only nine species had good regeneration capacity from 37 species observed in Angsana coastal area. This circumstance should be anticipated as soon as possible to minimize the risk of species extinction. In this case, we recommend that managers conduct enrichment planting to accelerate the effort of landscape conservation in the study area. This activity can focus on the other species that still no have good regeneration.

Furthermore, it is essential to develop more efficient monitoring systems for measuring the dynamics of land cover in Angsana coastal area since the challenge of reforestation in coastal ecosystems is substantially more complex than terrestrial ecosystems. Therefore, the monitoring method should provide accurate information rapidly to minimize the risk of vegetation losses. In this context, using an unmanned aerial vehicle can become a better solution than satellite imagery since it can accelerate the data acquisition process (Hsu et al. 2020). Furthermore, this instrument can also estimate the potential of blue carbon storage in Angsana coastal ecosystems (Peciña et al. 2021). These efforts will provide more comprehensive information regarding the essential contribution of Angsana coastal ecosystems for supporting biodiversity conservation and climate change mitigation.

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SUBMISSION CHECKLIST

Ensure that the following items are present:

The first corresponding author must be accompanied with contact details:	**Give mark (X)**
• E-mail address	x
• Full postal address (incl street name and number (location), city, postal code, state/province, country)	x
• Phone and facsimile numbers (incl country phone code)	x

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All necessary files have been uploaded, and contain:	x
• Keywords	x
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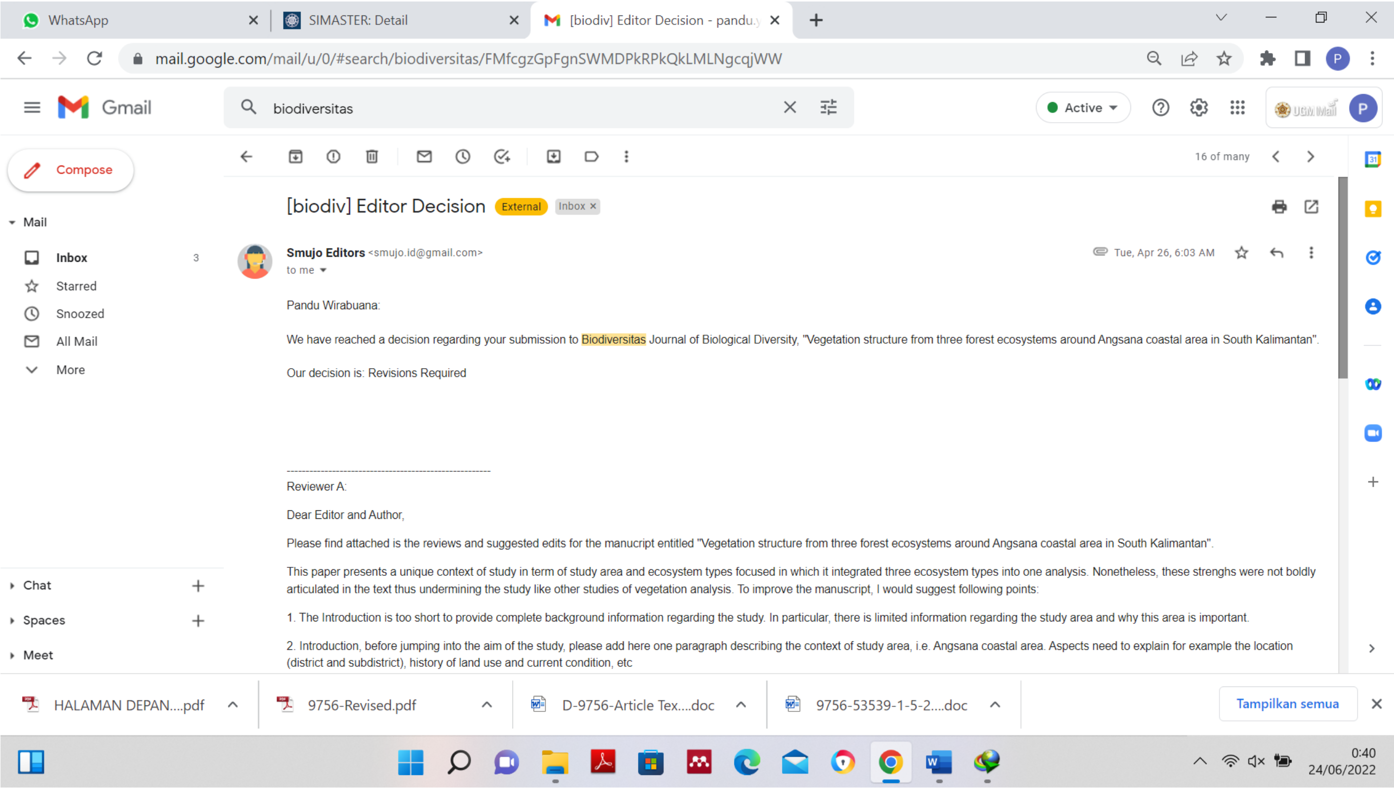
x

Further considerations	x
• Manuscript has been “spell & grammar-checked” Better, if it is revised by a professional science editor or a native English speaker	x
• References are in the correct format for this journal	x
• All references mentioned in the Reference list are cited in the text, and vice versa	x
• Colored figures are only used if the information in the text may be losing without those images	x
• Charts (graphs and diagrams) are drawn in black and white images; use shading to differentiate	x

BUKTI EDITOR DECISION 26 APRIL 2022 – REVISION



[biodiv] Editor Decision External Inbox

Smujo Editors <smujo.id@gmail.com>
to me

Tue, Apr 26, 6:03 AM

Pandu Wirabuana:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Vegetation structure from three forest ecosystems around Angsana coastal area in South Kalimantan".

Our decision is: Revisions Required

Reviewer A:

Dear Editor and Author,

Please find attached is the reviews and suggested edits for the manucript entitled "Vegetation structure from three forest ecosystems around Angsana coastal area in South Kalimantan".

This paper presents a unique context of study in term of study area and ecosystem types focused in which it integrated three ecosystem types into one analysis. Nonetheless, these strenghs were not boldly articulated in the text thus undermining the study like other studies of vegetation analysis. To improve the manuscript, I would suggest following points:

1. The Introduction is too short to provide complete background information regarding the study. In particular, there is limited information regarding the study area and why this area is important.

2. Introduction, before jumping into the aim of the study, please add here one paragraph describing the context of study area, i.e. Angsana coastal area. Aspects need to explain for example the location (district and subdistrict), history of land use and current condition, etc

Vegetation diversity, structure and composition of three forest ecosystems inaround Angsana coastal area, in South Kalimantan, Indonesia

Abstract. Vegetation communities around coastal ecosystems play important roles in mitigating natural disaster and support disaster management and climate change mitigation. However, available information about vegetation structurecommunities in coastal areas is still limited despite being a requirement in developing alternative strategies for environmental preservation. Angsana coastal area in South Kalimantan, Indonesia has unique characteristics in which it has three different forest ecosystems, namely heath forest (HF), beach forest (BF), and mangrove forest (MF). This study aimed to identify the vegetation diversity, structure and composition of the three forest ecosystems in Angsana coastal area. In this study, vegetation characteristics were determined for three forest ecosystems around Angsana coastal area in South Kalimantan, i.e., heath forest (HF), beach forest (BF), and mangrove forest (MF). A field survey was conducted using transect line methods with a sampling plot size of 10 × 10 m and an interval of 20 m. Vegetation structure communities wereas assessed using species abundance, plant diversity, importance value index (IVI), and similarity level. Results showed thatapproximately 37 species from 25 families have been discoveredwere recorded in the study site. The highest species abundance observed in HF (22 species), followed by BF (18 species) and MF (7 species). The same trend was found for vegetation diversity, in which HF had the most outstandinghighest richness (*Dmg* = 4.52), heterogeneity (*H'* = 2.86), and evenness (*J'* = 0.94). *Hibiscus tiliaceus* had the highest IVI in BF infor allevery vegetation stages, and *Rhizophora mucronata* consistently had the greatest IVI in MF for every life formin all stages. The following sSpecies from seedlings to trees exhibited the highest IVI in HF were *Adina minutiflora* (: seedlings) (*Adina minutiflora*), *Rhodedomia tomentosa* and *Premna serratifolia* (saplings) (*Rhodedomia tomentosa* and *Premna serratifolia*), *Tristania maingayi* (poles) (*Tristania maingayi*), and *Vitex ovata* (trees) (*Vitex ovata*). Our study also observed that species abundance in forest ecosystems gradually declined from seedlings to trees, except in MF. Among the three forest types, vegetation composition was highly similar between MF and BF with a similarity level of 47.1%. On the basis of these results, this study concluded that the three forest ecosystems in Angsana coastal area exhibit a highly diverse vegetation structure, and each type of forest has specific characteristics as its entity.

Key words: coastal ecosystems, environmental preservation, plant diversity, species abundance, vegetation characteristics

Abbreviations: HF (Heath Forests), BF (Beach Forests), MF (Mangrove Forests), IVI (Importance Value Index), *Dmg* (Margalef Index), *H'* (Shannon-Wiener Index), *J'* (Pielou–Evenness Index)

Running title: Vegetation structure in coastal ecosystems

INTRODUCTION

Commented [AR1]: The Introduction is too short to provide complete background information regarding the study. In particular, there is limited information regarding the study area and why this area is important.

The Vvegetation of around coastal ecosystems is an emerging research topic currently an interesting issue in tropic research because of its strategic positionroles in disaster andmanagement, climate change mitigation, and rural development. In addition to preventing abrasion (Matatula et al. 2021), vegetation communities in coastal areas play an essential functionrole as a windbreak to protect the surrounding local settlement (Sadono et al. 2020a). The presence of vegetation in coastal ecosystems also contributes to reducing carbon emissions in the atmosphere (Purwanto et al. 2022) and minimizing the rate of sea water intrusion into the land (Sadono et al. 2020b). The canopy of coastal vegetation is a suitable habitat for some bird species (Purwanto et al. 2021), and their root system, particularly those of mangroves, provides an excellent environmental condition to facilitate the breeding of sea organisms such as shrimps, fish, and crab

(Matatula et al. 2019). The vegetation landscape in coastal zones also ~~shows prospects~~has the potentials to be developed as an area for ecotourism~~, and thus provide additional benefits for~~ to improve ~~the welfare of~~ the local community welfare (Sánchez-Prieto et al. 2021). Therefore, the ~~sustainability of~~ vegetation in coastal ecosystems must be conserved and sustainably managed to ensure its long-term benefits~~d to maintain the area's stability in the future~~.

In term of biodiversity conservation, understanding the vegetation structure becomes a fundamental requirement to develop alternatives strategies for ~~S~~sustainable coastal management (SCM). ~~must be implemented to support biodiversity conservation in coastal ecosystems. For this goal, understanding the vegetation structure becomes a fundamental requirement to develop alternatives strategies for SCM.~~

The vegetation structure in coastal zones is naturally unique because it consists of different types of forest ecosystems. There are two common types of forests located in coastal areas, namely ~~are~~ beach forest (BF) and mangrove forest (MF) (Kusmana et al. 2017) in which ~~;~~ the former grows in the sandy area, and the latter is commonly found in the tidal zone (Lillo et al. 2019). Plant habitus and characteristics~~dimensions~~ considerably differ between BF and MF. ~~On the one hand~~For example, most species in MF have unique root systems such as *Bruguiera sp.*, *Rhizophora sp.*, and *Avicennia sp.* (Srikanth et al. 2015). On the other hand, the vegetation formation in BF is ~~pre~~dominated by plants such as *Ipomoea pescaprae* and *Barringtonia* spp. (Wardhani and Poedjirahajoe 2020). Under specific circumstances, coastal ecosystems may also exhibit a third type of vegetation generally known as heath forest (HF). This forest exists in the coastal area due to the quartz sand deposits carried by rivers (Syuharni et al. 2014). In Indonesia, HF is only found in certain regions~~locations~~ such as Kalimantan (Indonesian Borneo) and Bangka Belitung Islands (Maimunah et al. 2019). The presence of this forest type in coastal ecosystems brought challenges for ~~coastal managers~~stakeholders to maintain the sustainability of coastal vegetation.

BEFORE JUMPING INTO THE AIM OF THE STUDY, PLEASE ADD HERE ONE PARAGRAPGH DESCRIBING THE CONTEXT OF STUDY AREA, I.E. ANGSANA COASTAL AREA. ASPECTS NEED TO EXPLAIN FOR EXAMPLE THE LOCATION (DISTRICT AND SUBDISTRICT), HISTORY OF LAND USE AND CURRENT CONDITION, ETC.

This study aimed to identify the vegetation diversity, structure and composition ~~characteristics~~ of ~~the~~ three forest ecosystems (i.e., mangrove forest, beach forest and heath forest) around Angsana coastal area in South Kalimantan. ~~The study site is one of the coastal zones comprising HF, BF, and MF as parts of the forest ecosystem.~~ Despite the high ~~potential~~importance of this area ~~to become~~as ~~the~~a center of biodiversity conservation for coastal ecosystems in Kalimantan region, information about its vegetation structure is not available. ~~Nevertheless~~We expected, the results will provide ~~adequate~~ information for stakeholders~~managers~~ regarding the ~~potential~~ biodiversity in Angsana coastal areas as primary consideration to develop alternative strategies for environmental preservation.

MATERIALS AND METHODS

Study area

This ~~investigation~~study was conducted in~~around~~ Angsana coastal area located in South Kalimantan with geographic position of S3°45'−3°46' and E115°35'− E115°36' (Figure 1). The study site has an area of 94.81 ha and consists of several land cover types: shrubs, forests, roads, settlements, oil palm plantation, and bare land. Annual rainfall ranges 3,000 mm year^{-1} with a mean daily temperature of 29°C. More than 70% of the landscape in the study area wa~~i~~s dominated by forest ecosystems with ~~a~~extent ~~coverage~~ of 69.11 ha. Three types of forests exist in this area, namely~~,~~ mangrove forest (MF), beach forest (BF), and heath forest (HF). Among them, the most extensive forest coverage was attributed to HF (32.79 ha), followed by MF (30.34 ha) and BF (5.98 ha). This circumstance indicated the high importance of~~potential~~ biodiversity in Angsana coastal ecosystems, particularly ~~from~~ in term of forest vegetation.

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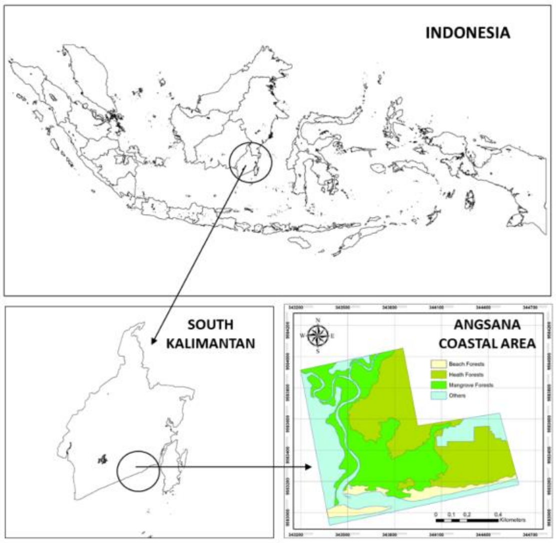

Figure 1. Location of Angsana coastal ecosystems in South Kalimantan. Different colors in the map indicate land cover variations.

The Angsana coastal area is a unique ecosystem located near ~~athe~~ coal mining concession site. Initially, this area was not well managed and almost became a degraded ~~coastal ecosystem~~area due to the high rate of vegetation loss. However, stakeholders including a coal mining company have put~~directed~~ efforts to accelerate the recovery of this ecosystem through corporate social responsibility (CSR) program. ~~, particularly PT Borneo Indobara as a primary company that obtained legal permission for mining exploration around this site.~~ By collaborating with the local community living around the area, the ~~Corporate Social Responsibility Division of PT Borneo Indobara (CSR-BIB)~~mining company has intensively conducted reforestation programs in this location since 2017. Such~~This~~ activities~~y~~ were~~as~~ not only ~~directed~~conducted in ~~to~~ the mangrove forest~~MF~~ but also ~~aimed to rehabilitate the ecosystem condition~~ in the beach forest ~~BF~~ and ~~MF~~heath forest.

Figure 2. Comparison of landscape conditions in Angsana coastal ecosystems, South Kalimantan before and after reforestation program ~~managed by the collaboration between the local community and CSR-BIB~~ based on Google Earth satellite imagery. The brown color indicates degraded land without vegetation cover.

The CSR program ~~BIB~~ also held training and supervising activities to develop ecotourism in Angsana coastal area, increase community awareness for conserving coastal biodiversity, and inform the local community that efforts for environmental preservation in coastal zones can also improve their welfare. In a short period from 2017 to 2021, these initiatives have contributed to the increase in forest covers in Angsana coastal area (Figure 2).

Commented [AR2]: This might be better to be put in the Introduction to highlight the importance of the studied area as per comment above.

Also, it is uncommon to mention explicitly a private entity in a scientific journal to avoid conflict of interest and to broaden readership. Thus, I would suggest to remove the name of the company, instead it can be put in the Acknowledgement.

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Procedures

Data were collected from August to December 2021. Vegetation survey was conducted using a transect line method with a sampling plot size of 10 × 10 m and an interval from each 20 m. The transect line was 500 m long and 20 m wide (Figure 3). Nine transects were evenly distributed in each~~every~~ forest ecosystem, and the distance between transects ranged from 1 km to 2 km depending on the coverage area of the forest ecosystem. Vegetation ~~measurement~~inventory was conducted by establishing nested plots (sub-plots) within the sampling plot based on life stage, i.e., 2 × 2 m (seedlings), 5 × 5 m (saplings), and 10 × 10 m (poles and trees) ~~was also conducted by dividing the sampling plot into several sub-plots to support the observation results~~ (Matatula et al. 2021). The following parameters were recorded and measured: name of ~~type of~~ species, number of species, and ~~growth performance~~diameter (for poles and trees only). ~~For every species, growth performance was only measured in poles and trees by focusing on the diameter.~~ As one of the essential variables in forest ~~mensuration~~inventory, diameter has a strong correlation with other parameters such as height (Barbosa et al. 2019), volume (Wirabuana et al. 2021a), and biomass (Setiahadi 2021) and could also describe the competitive position of individual trees at a stand level (Maleki et al. 2015).

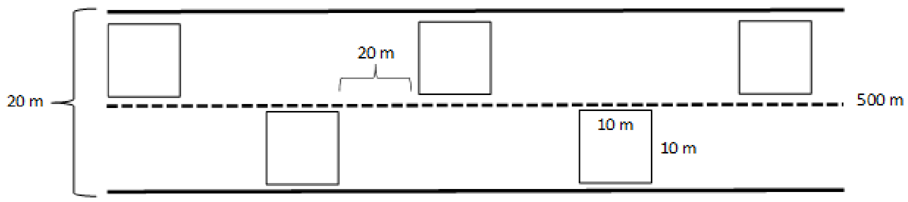

Figure 3. Visual illustration of a transect line method for vegetation survey

Data analysis

Descriptive analysis was conducted to understand the vegetation structure of the three forest ecosystems in Angsana coastal area. First, data from vegetation surveys were analyzed to calculate species density, species dominance, and frequency distribution (Eddy et al. 2019). The obtained valued were then used to quantify the relative abundance, relative dominance, and relative frequency for every species (Kasim et al. 2019). Finally, importance value index (IVI) was determined by summing up these three indicators to identify the strategic position of species in each forest ecosystem (Yuliana et al. 2019). However, the IVI for seedlings and saplings was only counted using relative abundance and frequency. The equations for calculating those parameters were presented below:

$$Species\ density = \frac{Numbe\ of\ individual}{Size\ of\ sampling\ plot} \quad [1]$$

$$Species\ dominance = \frac{Total\ basal\ area\ of\ species}{Size\ of\ sampling\ plot} \quad [2]$$

$$Species\ frequency = \frac{Number\ of\ plot\ wherein\ species\ existing}{Total\ sampling\ plot} \quad [3]$$

$$Relative\ density = \frac{Species\ density}{Total\ species\ density}\ x\ 100 \quad [4]$$

$$Relative\ dominance = \frac{Species\ dominance}{Total\ species\ dominance}\ x\ 100 \quad [5]$$

$$Relative\ frequency = \frac{Species\ frequency}{Total\ species\ frequency}\ x\ 100 \quad [6]$$

$$Important\ value\ index = Relative\ density + Relative\ dominance + Relative\ frequency \quad [7]$$

Vegetation diversity in the three forest ecosystems was assessed using three fundamental parameters: i.e., species richness calculated using~~by~~ Margalef Index (*Dmg*) (Singh 2020), species heterogeneity estimated using~~by~~ Shannon–Winner Index (*H'*) (Li et al. 2018), and species evenness evaluated using~~by~~ Pielou–Evenness Index (*J'*) (Wirabuana et al. 2021c). Sorensen similarity index (SC) was also calculated to determine the similarity degree of vegetation composition among the three forest ecosystems in Angsana coastal area (Lv et al. 2021). The ~~existence~~ structure of species in ~~every~~each ~~vegetation~~ life ~~form~~stage from seedlings to trees was also examined to assess the regeneration capacity of species in the study area (Nagel et al. 2010). The equations for computing richness, evenness, heterogeneity, and similarity index were expressed below:

$$Dmg = \frac{S-1}{ln(N)} \quad [8]$$

$$H' = -\sum\left(\frac{n_i}{N} x \ln\frac{n_i}{N}\right) \quad [9]$$

$$J' = \frac{H'}{\ln(S)} \quad [10]$$

$$SC = \frac{2W}{(A+B)} \quad [11]$$

wherein S was the number of species, N represented total tree population, n_i described the sum of trees for each species, W was the number of common species between two forest types, A indicated the number of species only found in first forest, and B represented the number of species only discovered in second forest.

RESULTS AND DISCUSSION

Species distribution and IVI

The results showed that~~ around~~ 37 species from 25 families were found in the studied area~~around Angsana coastal area~~. The number of species in MF was substantially lower than that in other forest ecosystems for each vegetation life form (Figure 4). Meanwhile, the highest species abundance in each~~every~~ life stage was recorded in HF. The number of total species in BF and HF gradually declined ~~with the progression~~as~~ of~~ the life form grew to adult stages. However, this trend was not observed in MF, in which the number of species from seedlings to trees was almost equal. Decline in ~~S~~species number ~~decline ~~and abundance~~ vegetation growth~~ were naturally discovered in most forest ecosystems due to the high competition among plants to obtain adequate resources, such as water, nutrients, light, and space (Looney et al. 2016). This process caused natural mortality for weak plants because they could not optimally acquire resources (Wirabuana et al. 2021b). Meanwhile, the robust species would survive and grow well.

Plant competition in a forest ecosystem is classified into two groups, namely~~,~~ intraspecific and interspecific. Intraspecific competition occurs among~~between~~ individuals within~~from~~ the same species, and interspecific competition occurs among~~between~~ individuals across~~from~~ different species (Barabás et al. 2016). Every plant in forest ecosystems would face both types of competition if it does~~id~~ not grow in a monoculture stand. Plant competition in the forest is also a part of the nutrient cycle because when the dead trees decomposed, they will release ~~many ~~nutrients into the soil layer.

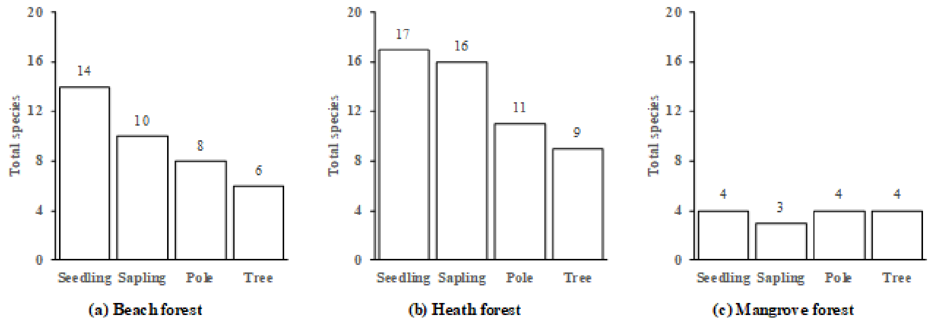

Figure 4. Number of species in every life form at three different forest ecosystems in Angsana coastal area

Among the forest types, MF had a lower number of species because its environmental conditions, had many limiting factors in which only certain species ~~that ~~can ~~only be ~~survive~~d by certain species~~. This ecosystem is situated in~~ a~~ tidal area with high salinity (Matatula et al. 2019). The substrate of mangrove ecosystem~~s~~ is~~was~~ also dominated by mud; thus, only a few species with unique root systems can survive in these forests (Srikanth et al. 2015). In the studied area~~is work~~, seven species were found in MF, namely~~,~~ *Acrostichum aureum, Brugueiera cylindrica, Brugueiera gymnorriza, Lumnitzera littorea, Nypa fruticans, Rhizophora mucronata,* and *Rhizophora apiculata* (Table 1). Differ~~ent~~ from that in BF and HF, the reforestation activity in MF was conducted more intensively from 2017 to 2021. More than 3,000 seedlings were planted every year. Therefore, the number of species from seedlings to~~ MF~~ trees in MF was almost balanced and equal.

Our study also found that none of the species was evenly distributed in the three forest ecosystems (Table 1), indicating that each species had specific habitat requirements to support its growth and development. However, some species were ~~also ~~observed in different types of forests, such as *Chrysobalanus icaco* in BF and HF and *R. apiculata* in MF and BF. Moreover, the highest IVI of species relatively differed ~~for every~~across the three forest ecosystems. For example, *Hibiscus tiliaceus* was the most important species in BF ~~for every~~at all life forms based on the~~its~~ IVI, and *R. mucronata* was the essential species in MF. In HF, the highest IVI was noted in ~~some different~~several species, i.e., *Adina minutiflora* (seedlings), *Premna serratifolia*, *Rhodedomia tomentosa* (saplings), *Tristania maingayi* (poles), and *Vitex ovata* (trees).

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Commented [AR5]: Throughout the text, please check the accuracy of the latin name of each species. You can check in taxonomical databases such as POWO or IPNI.

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Among the 37 species ~~distributed~~ recorded in Angsana coastal area, only the following species showed good regeneration as indicated by their distribution from seedlings to trees (Khan et al. 2018): *A. minutiflora, Artocarpus rafscens, Casuarina equisetifolia, Garcinia sp., Litsea firma, Podocarpus laetifolius, R. mucronata, R. apiculata*, and *T. maingayi*.

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Table 1. Importance value index of species in each ~~every~~ growth stage in the three forest ecosystems in Angsana coastal area, South Kalimantan

No.	Species	Family	Beach forests				Heath forest				Mangrove forest			
			Seedling	Sapling	Pole	Tree	Seedling	Sapling	Pole	Tree	Seedling	Sapling	Pole	Tree
1	*Acrostichum au~~e~~reum*	Pteridaceae	8.55								22.02			
2	*Adina minutiflora*	Rubiaceae					**29.18**	17.09	36.00	18.69				
3	*Artocarpus rafscens*	Moraceae					5.70	8.55	20.87	26.95				
4	*Avicennia marina*	Acanthaceae	26.18	26.53	18.54									
5	*Brugu~~e~~iera cylindrica*	Rhizophoraceae				24.24							42.38	33.22
6	*Brugu~~e~~iera gymnorhiza*	Rhizophoraceae		9.26	20.17							22.23		
7	*Calamus erinaceus*	Arecaceae						8.55	19.15	17.12				
8	*Calophyllum inophyllum*	Clusiaceae			23.06	34.12								
9	*Casuarina equisetifolia*	Casuarinaceae	12.55	18.53	20.17	30.23								
10	*Chrysobalanus icaco*	Chrysobalanaceae	18.82	18.53				8.55						
11	*Diospyros buxifoliae~~o~~*	Ebenaceae						8.55	21.81					
12	*Evodia aromatica*	Lauraceae					5.70		19.15	20.04				
13	*Excoecaria agallocha*	Euphorbiaceae	10.82											
14	*Flagellaria indica*	Flagellariaceae					5.70							
15	*Garcinia sp*	Clusiaceae					21.35	8.55	20.87	23.77				
16	*Hibiscus tiliaceus*	Malvaceae	**42.73**	**58.32**	**142.83**	**87.82**								
17	*Ixora coccinea*	Rubiaceae					17.78							
18	*Litsea firma*	Lauraceae					17.10	12.55	39.63	40.22				
19	*Lumnitzera littorea*	Combretaceae											25.35	16.01
20	*Macaranga triloba*	Euphorbiaceae					5.70							
21	*Mangifera sp.*	Anacardiaceae						8.55						
22	*Melastoma malabatricum*	Melastomataceae	8.55				14.21	8.55						
23	*Morinda citrifolia*	Cicadellidae	12.55	18.53										
24	*Nypa Fruticans*	Arecaceae									12.93			
25	*Podocarpus latifolius*	Podocarpaceae					13.53	8.55	38.20	29.41				
26	*Pandanus tectorius*	Pandanaceae	6.27											
27	*Peltophorum pterocarpum*	Fabaceae						8.55	19.15					
28	*Peronema canescens*	Lamiaceae					5.70							
29	*Premna serratifolia*	Lamiaceae	17.09	18.53			5.70	**21.09**						
30	*Rhizophora mucronata*	Rhizophoraceae	6.27	13.26		46.06					**88.08**	**105.56**	**171.60**	**142.02**
31	*Rhodedomia tomentosa*	Myrtaceae	8.55				5.70	**21.09**						
32	*Rizophora apiculata*	Rhizophoraceae	6.27	9.26	23.06	77.53					76.98	72.22	60.67	108.75
33	*Schima noronhoe*	Theaceae					16.34	17.09						
34	*Terminalia catappa*	Combretaceae			17.12									
35	*Tristania maingayi*	Myrtaceae					5.70	17.09	**46.03**	41.05				
36	*Vismia cayennensis*	Hypericaceae					19.22	17.09						
37	*Vitex ovata*	Lamiaceae	14.82	9.26	35.05		5.70		19.15	**82.76**				
	Importance value index		200	200	300	300	200	200	300	300	200	200	300	300

Note: The bold value indicates the highest importance value index of species in every life form

Commented [AR9]: Please check the accuracy of the latin names.

Vegetation diversity and similarity level among forest ecosystems

The highest richness, heterogeneity, and evenness of vegetation were discovered in HF, and the lowest diversity index was recorded in MF (Figure 5). Compared with that between MF and HF, the similarity in vegetation communities between MF and BF was higher with a similarity level of 47.1%. This result was supported by the observation that most species in MF were also found in BF. Five out of the seven species in MF were also found in BF. These findings signified that some biodiversity strategies in MF can also be applied in BF and vice versa.

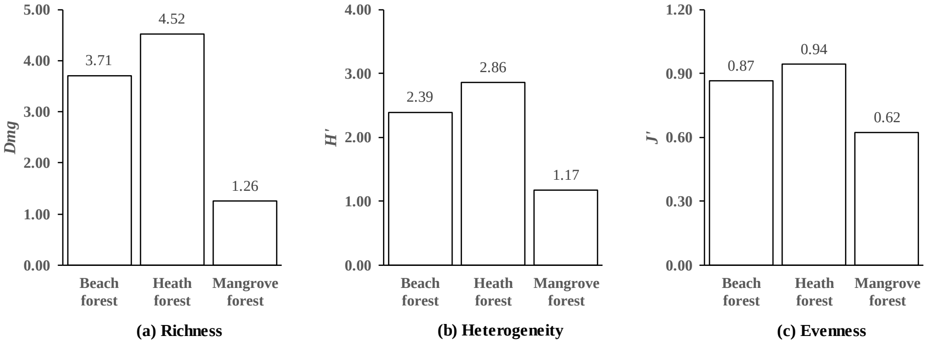

Figure 5. Biodiversity indices in term of Trend of richness, heterogeneity, and evenness in the three types of forest ecosystems in Angsana coastal area

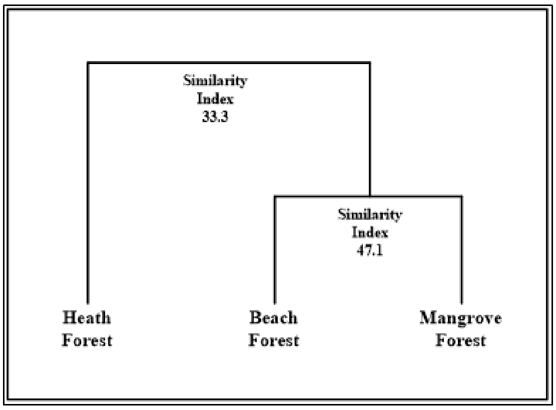

Figure 6. Similarity index of vegetation communities in the three forest ecosystems in Angsana coastal area

In ecosystem management, vegetation diversity is one of the most important parameters to assess environmental stability (De Boeck et al. 2018). High diversity indicates good environmental health (Zhang et al. 2018), even though this relationship does is not generally applyied in every type of forest, especially in mangroves. Different from other ecosystems, mangroves have many limitations for supporting plant growth, such as substrate condition, flooding, and wind speed (Froilan et al. 2020). Therefore, only a few species can grow well in mangroves. This finding explained why the richness, heterogeneity, and evenness in MF were considerably lower than those in BF and MF and why the resistance of mangroves to disturbance was relatively weaker compared with that of other forest types in Angsana coastal area.

According to the results, the vegetation communities in MF were almost similar to those in BF but were considerably different from those in HF. Meanwhile, a part of the vegetation community in BF was also discovered in HF. This finding indicated that the environmental condition in BF was situated in the transition phase between HF and MF. Similarities in vegetation between forests can also occur due to the tolerance level of species to site conditions. For example, most mangrove species could survive in beach areas, even though the soil was predominantly sand and its salinity was simulated by sea waves.

Implication results

This study concluded that vegetation structure highly varied among the three forest ecosystems, with the highest diversity observed in HF. Each~~Every~~ type of forest had specific characteristics that became its unique entity. Therefore, Angsana coastal area shows high potential to be established as a site ~~developed as the center of~~for biodiversity conservation especially representing~~for~~ coastal ecosystems of Borneo. However, only nine out of the 37 species observed in Angsana coastal area exhibited good regeneration capacity. This circumstance should be anticipated as soon as possible to minimize the risk of species extinction. We recommend that managers conduct enrichment planting to accelerate the effort of landscape conservation in the study area. This activity must be focused on other species that lack good regeneration. This program can be only implemented by collaborating with the local community around site.

Furthermore, additional efficient monitoring systems must be developed for measuring the dynamics of land cover in Angsana coastal area because the challenge of reforestation in coastal ecosystems is substantially more complex than in terrestrial ecosystems. Therefore, the monitoring method should provide rapid and accurate information to minimize the risk of vegetation losses. In this context, using an unmanned aerial vehicle ~~can~~ is a better solution than satellite imagery because the former can accelerate the data acquisition process (Hsu et al. 2020). Furthermore, this instrument can also estimate the potential of blue carbon storage in Angsana coastal ecosystems (Peciña et al. 2021). With these efforts, comprehensive information regarding the essential contribution of Angsana coastal ecosystems can be obtained and used to support biodiversity conservation and climate change mitigation.

ACKNOWLEDGMENTS

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April 29, 2022

Subject: Revision and re-submission manuscript ID 10848

Dear Editor Biodiversitas Journal of Biological Diversity,

Thank you for your decision e-mail and the opportunity to revise our article entitled "Vegetation structure from three forest ecosystems around Angsana Coastal Area in South Kalimantan". The suggestions provided by the reviewer have been immensely helpful to revise several aspects in our article. Our response to reviewer's comment have been enclosed below. We hope the revised article will be better suit to the Biodiversitas Journal of Biological Diversity.

Sincerely yours,
Pandu Yudha Adi Putra Wirabuana

Department of Forest Management
Faculty of Forestry
Universitas Gadjah Mada
Jln. Agro No.1 Kampus UGM, Bulaksumur, Yogyakarta 55281, Indonesia
e-mail: pandu.yudha.a.p@ugm.ac.id

Response to Reviewer's Comment

Part of Article	Reviewer's Comment	Author's Response
Introduction	- The Introduction is too short to provide complete background information regarding the study. In particular, there is limited information regarding the study area and why this area is important (Line 38) - Before jumping into the aim of the study, please add here one paragrapgh describing the context of study area, i.e. angsana coastal area. aspects need to explain for example the location (district and subdistrict), history of land use and current condition, etc. (Line 67-70)	- Several sentences have been added to strenghten the study background (Line 58-64)
Materials and Methods	- This might be better to be put in the Introduction to highlight the importance of the studied area as per comment above. - Also, it is uncommon to mention explicitly a private entity in a scientific journal to avoid conflict of interest and to broaden readership. Thus, I would suggest to remove the name of the company, instead it can be put in the Acknowledgement. - What year is the google image taken before the reforestation program? (Line 99-100) - What year is the google image taken after the reforestation program? (Line 99-100)	- We think it will be better to place here and not to move in introduction. We have added other sentences to improve the introduction - Author thinks the private entity is part of historical management in Angsana coastal area. Moreover, a letter of permittance have been also obtained for publish this research. The company also become a sponsor to conduct this study - The google image before reforestation is taken in 2015 (Line 85-86) - The google image after reforestation is obtained in 2021 (Line 85-86)
Results and Discussions	- Throughout the text, please check the accuracy of the latin name of each species. You can check in taxonomical databases such as POWO or IPNI. (Line 167-168) - Please check the latin name (Line 179) - Please check the accuracy of the latin names. (Line 181)	We have checked taxonomical database and revised the botanical name

Vegetation diversity, structure and composition of three forest ecosystems in Angsana coastal area, South Kalimantan, Indonesia

Abstract. Vegetation communities around coastal ecosystems play important roles in mitigating natural disaster and climate change. However, available information about vegetation communities in coastal areas is still limited despite being a requirement in developing strategies for environmental preservation. Angsana coastal area in South Kalimantan, Indonesia has unique characteristics in which it has three different forest ecosystems, namely heath forest (HF), beach forest (BF), and mangrove forest (MF). This study aimed to identify the vegetation diversity, structure and composition of the three forest ecosystems in Angsana coastal area. A field survey was conducted using transect line methods with a sampling plot size of 10 × 10 m and an interval of 20 m. Vegetation communities were assessed using species abundance, plant diversity, importance value index (IVI), and similarity level. Results showed that 37 species from 25 families were recorded in the study site. The highest species abundance observed in HF (22 species), followed by BF (18 species) and MF (7 species). The same trend was found for vegetation diversity, in which HF had the highest richness (*Dmg* = 4.52), heterogeneity (*H'* = 2.86), and evenness (*J'* = 0.94). *Hibiscus tiliaceus* had the highest IVI in BF in all vegetation stages, and *Rhizophora mucronata* consistently had the greatest IVI in MF in all stages. Species exhibited the highest IVI in HF were *Adina minutiflora* (seedlings), *Rhodedomia tomentosa* and *Premna serratifolia* (saplings), *Tristania maingayi* (poles), and *Vitex ovata* (trees). Our study also observed that species abundance in forest ecosystems gradually declined from seedlings to trees, except in MF. Among the three forest types, vegetation composition was highly similar between MF and BF with a similarity level of 47.1%. On the basis of these results, this study concluded that the three forest ecosystems in Angsana coastal area exhibit a highly diverse vegetation structure, and each type of forest has specific characteristics as its entity.

Key words: coastal ecosystems, environmental preservation, plant diversity, species abundance, vegetation characteristics

Abbreviations: HF (Heath Forests), BF (Beach Forests), MF (Mangrove Forests), IVI (Importance Value Index), *Dmg* (Margalef Index), *H'* (Shannon-Wiener Index), *J'* (Pielou–Evenness Index)

Running title: Vegetation structure in coastal ecosystems

INTRODUCTION

Vegetation of coastal ecosystems is an emerging research topic because of its strategic roles in disaster and climate change mitigation, and rural development. In addition to preventing abrasion (Matatula et al. 2021), vegetation communities in coastal areas play an essential function as a windbreak to protect the surrounding local settlement (Sadono et al. 2020a). The presence of vegetation in coastal ecosystems also contributes to reducing carbon emissions in the atmosphere (Purwanto et al. 2022) and minimizing the rate of sea water intrusion into the land (Sadono et al. 2020b). The canopy of coastal vegetation is a suitable habitat for some bird species (Purwanto et al. 2021), and their root system, particularly those of mangroves, provides an excellent environmental condition to facilitate the breeding of sea organisms such as shrimps, fish, and crab (Matatula et al. 2019). The vegetation landscape in coastal zones also has the potentials to be developed as an area for ecotourism to improve the local community welfare (Sánchez-Prieto et al. 2021). Therefore, the vegetation in coastal ecosystems must be conserved and sustainably managed to ensure its long-term benefits.

In term of biodiversity conservation, understanding the vegetation structure becomes a fundamental requirement to develop alternatives strategies for sustainable coastal management (SCM). The vegetation structure in coastal zones is naturally unique because it consists of different types of forest ecosystems. There are two common types of forests located in coastal areas, namely beach forest (BF) and mangrove forest (MF) (Kusmana et al. 2017) in which the former grows in the sandy area, and the latter is commonly found in the tidal zone (Lillo et al. 2019). Plant habitus and characteristics considerably differ between BF and MF. For example, most species in MF have unique root systems such as *Bruguiera sp.*, *Rhizophora sp.*, and *Avicennia sp.* (Srikanth et al. 2015). On the other hand, the vegetation formation in BF is dominated by plants such as *Ipomoea pescaprae* and *Barringtonia* spp. (Wardhani and Poedjirahajoe 2020). Under specific circumstances, coastal ecosystems may also exhibit a third type of vegetation generally known as heath forest (HF). This forest exists in the coastal area due to the quartz sand deposits carried by rivers (Syuharni et al. 2014). In Indonesia, HF is only found in certain regions such as Kalimantan (Indonesian Borneo) and Bangka Belitung Islands (Maimunah et al. 2019). The presence of this forest type in coastal ecosystems brought challenges for stakeholders to maintain the sustainability of coastal vegetation.

As one of the coastal area in South Kalimantan, Angsana beach is an unique coastal ecosystems with three different types of forests, including mangrove forest, beach forest and heath forest. However, the information about vegetation characteristics in this site is still not clearly documented eventhough it has a high potential to become the center of biodiversity conservation in coastal zone. Therefore, this study aimed to identify the vegetation diversity, structure and composition of three forest ecosystems (i.e., mangrove forest, beach forest and heath forest) around Angsana coastal area in South Kalimantan. We expected, the results will provide information for stakeholders regarding the biodiversity in Angsana coastal areas as primary consideration to develop alternative strategies for environmental preservation.

MATERIALS AND METHODS

Study area

This study was conducted in Angsana coastal area located in South Kalimantan with geographic position of S3°45'–3°46' and E115°35'– E115°36' (Figure 1). The study site has an area of 94.81 ha and consists of several land cover types: shrubs, forests, roads, settlements, oil palm plantation, and bare land. Annual rainfall ranges 3,000 mm year^{-1} with a mean daily temperature of 29°C. More than 70% of the landscape in the study area was dominated by forest ecosystems with extent of 69.11 ha. Three types of forests exist in this area, namely mangrove forest (MF), beach forest (BF), and heath forest (HF). Among them, the most extensive forest coverage was attributed to HF (32.79 ha), followed by MF (30.34 ha) and BF (5.98 ha). This circumstance indicated the high importance of biodiversity in Angsana coastal ecosystems, particularly in term of forest vegetation.

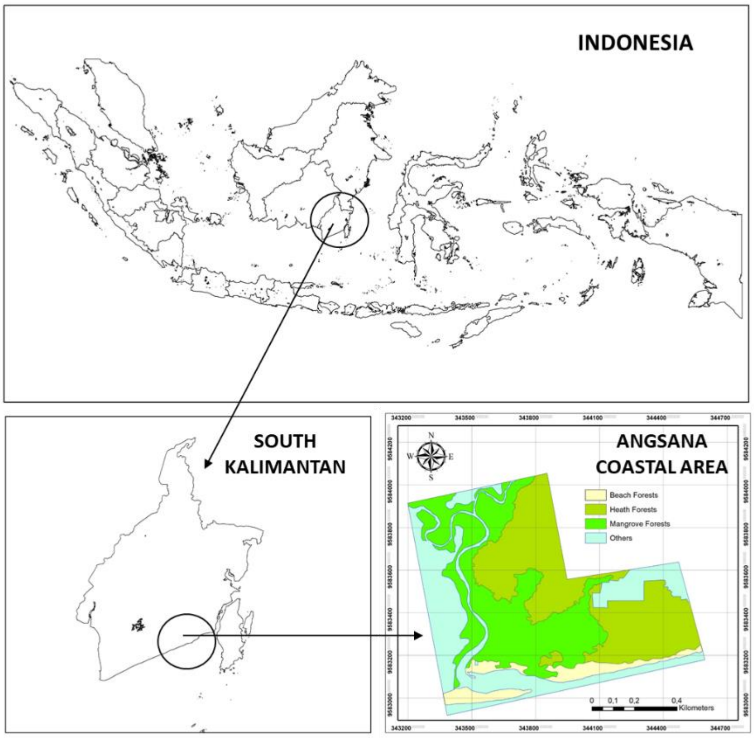

Figure 1. Location of Angsana coastal ecosystems in South Kalimantan. Different colors in the map indicate land cover variations.

The Angsana coastal area is a unique ecosystem located near a coal mining concession site. Initially, this area was not well managed and almost became a degraded area due to the high rate of vegetation loss. However, stakeholders including a coal mining company have put efforts to accelerate the recovery of this ecosystem through corporate social responsibility (CSR) program, particularly from PT Borneo Indobara as a primary company that obtained legal permission for mining exploration around this site. By collaborating with the local community living around the area, the Corporate Social Responsibility Division of PT Borneo Indobara (CSR-BIB) has intensively conducted reforestation programs in this location since 2017. Such activities were not only conducted in the mangrove forest but also in the beach forest and heath forest.

Figure 2. Comparison of landscape conditions in Angsana coastal ecosystems, South Kalimantan in 2015 (before reforestation) and in 2021 (after reforestation) based on Google Earth satellite imagery. The brown color indicates degraded land without vegetation cover.

The CSR program from BIB also held training and supervising activities to develop ecotourism in Angsana coastal area, increase community awareness for conserving coastal biodiversity, and inform the local community that efforts for environmental preservation in coastal zones can also improve their welfare. In a short period from 2017 to 2021, these initiatives have contributed to the increase in forest covers in Angsana coastal area (Figure 2).

Procedures

Data were collected from August to December 2021. Vegetation survey was conducted using a transect line method with a sampling plot size of 10 × 10 m and an interval from each 20 m. The transect line was 500 m long and 20 m wide (Figure 3). Nine transects were evenly distributed in each forest ecosystem, and the distance between transects ranged from 1 km to 2 km depending on the coverage area of the forest ecosystem. Vegetation inventory was conducted by establishing nested plots (sub-plots) within the sampling plot based on life stage, i.e., 2 × 2 m (seedlings), 5 × 5 m (saplings), and 10 × 10 m (poles and trees) (Matatula et al. 2021). The following parameters were recorded and measured: name of species, number of species, and diameter (for poles and trees only). As one of the essential variables in forest inventory, diameter has a strong correlation with other parameters such as height (Barbosa et al. 2019), volume (Wirabuana et al. 2021a), and biomass (Setiahadi 2021) and could also describe the competitive position of individual trees at a stand level (Maleki et al. 2015).

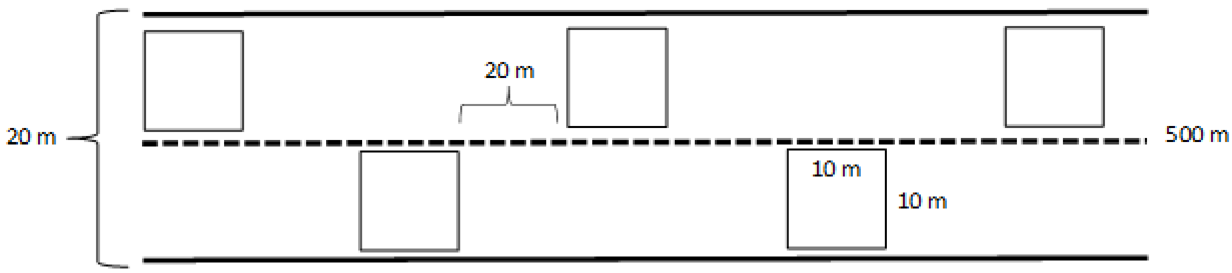

Figure 3. Visual illustration of a transect line method for vegetation survey

Data analysis

Descriptive analysis was conducted to understand the vegetation structure of the three forest ecosystems in Angsana coastal area. First, data from vegetation surveys were analyzed to calculate species density, species dominance, and frequency distribution (Eddy et al. 2019). The obtained valued were then used to quantify the relative abundance, relative dominance, and relative frequency for every species (Kasim et al. 2019). Finally, importance value index (IVI) was determined by summing up these three indicators to identify the strategic position of species in each forest ecosystem (Yuliana et al. 2019). However, the IVI for seedlings and saplings was only counted using relative abundance and frequency. The equations for calculating those parameters were presented below:

$$Species\ density = \frac{Numbe\ of\ individual}{Size\ of\ sampling\ plot} \qquad [1]$$

$$Species\ dominance = \frac{Total\ basal\ area\ of\ species}{Size\ of\ sampling\ plot} \qquad [2]$$

$$Species\ frequency = \frac{Number\ of\ plot\ wherein\ species\ existing}{Total\ sampling\ plot} \qquad [3]$$

$$Relative\ density = \frac{Species\ density}{Total\ species\ density}\ x\ 100 \qquad [4]$$

$$Relative\ dominance = \frac{Species\ dominance}{Total\ species\ dominance}\ x\ 100 \qquad [5]$$

$$Relative\ frequency = \frac{Species\ frequency}{Total\ species\ frequency}\ x\ 100 \qquad [6]$$

$$Important\ value\ index = Relative\ density + Relative\ dominance + Relative\ frequency \qquad [7]$$

Vegetation diversity in the three forest ecosystems was assessed using three fundamental parameters, i.e. species richness calculated using Margalef Index (*Dmg*) (Singh 2020), species heterogeneity estimated using Shannon–Winner Index (*H′*) (Li et al. 2018), and species evenness evaluated using Pielou–Evenness Index (*J′*) (Wirabuana et al. 2021c). Sorensen similarity index (SC) was also calculated to determine the similarity degree of vegetation composition among the three forest ecosystems in Angsana coastal area (Lv et al. 2021). The structure of species in each life stage from seedlings to trees was also examined to assess the regeneration capacity of species in the study area (Nagel et al. 2010). The equations for computing richness, evenness, heterogeneity, and similarity index were expressed below:

$$Dmg = \frac{S-1}{ln(N)} \qquad [8]$$

$$H' = -\sum\left(\frac{n_i}{N} x\ ln\frac{n_i}{N}\right) \qquad [9]$$

$$J' = \frac{H'}{ln(S)} \qquad [10]$$

$$SC = \frac{2W}{(A+B)} \qquad [11]$$

wherein *S* was the number of species, *N* represented total tree population, n_i described the sum of trees for each species, *W* was the number of common species between two forest types, *A* indicated the number of species only found in first forest, and *B* represented the number of species only discovered in second forest.

RESULTS AND DISCUSSION

Species distribution and IVI

The results showed that 37 species from 25 families were found in the studied area. The number of species in MF was substantially lower than that in other forest ecosystems for each vegetation life form (Figure 4). Meanwhile, the highest species abundance in each life stage was recorded in HF. The number of total species in BF and HF gradually declined as the life form grew to adult stages. However, this trend was not observed in MF, in which the number of species from seedlings to trees was almost equal. Decline in species number and abundance were naturally discovered in most forest ecosystems due to the high competition among plants to obtain adequate resources, such as water, nutrients, light, and space (Looney et al. 2016). This process caused natural mortality for weak plants because they could not optimally acquire resources (Wirabuana et al. 2021b). Meanwhile, the robust species would survive and grow well.

Plant competition in a forest ecosystem is classified into two groups, namely intraspecific and interspecific. Intraspecific competition occurs among individuals within the same species, and interspecific competition occurs among individuals across different species (Barabás et al. 2016). Every plant in forest ecosystems would face both types of competition if it does not grow in a monoculture stand. Plant competition in the forest is also a part of the nutrient cycle because when the dead trees decomposed, they will release nutrients into the soil layer.

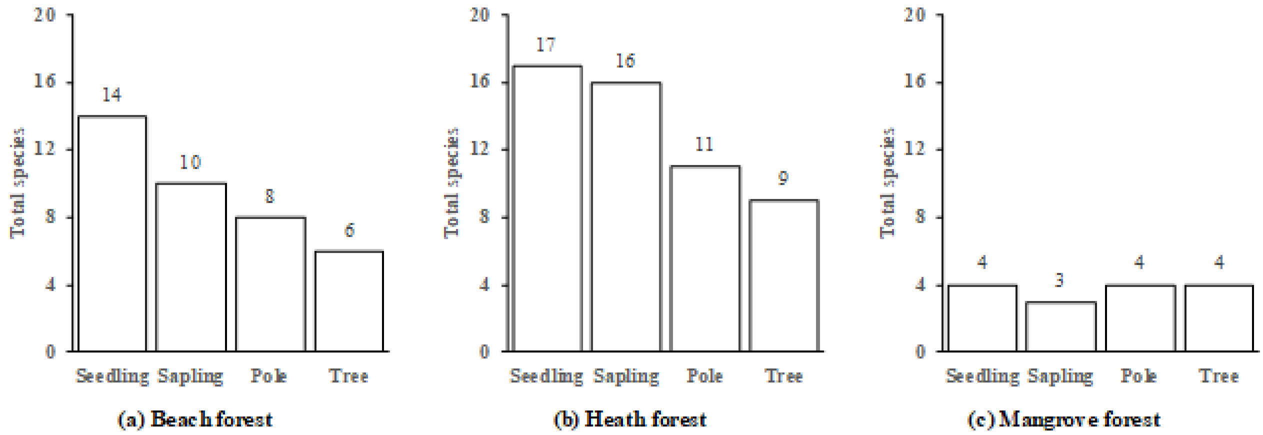

Figure 4. Number of species in every life form at three different forest ecosystems in Angsana coastal area

Among the forest types, MF had a lower number of species because its environmental conditions had many limiting factors in which only certain species can survive. This ecosystem is situated in tidal area with high salinity (Matatula et al. 2019). The substrate of mangrove ecosystem is also dominated by mud; thus, only a few species with unique root systems can survive in these forests (Srikanth et al. 2015). In the studied area, seven species were found in MF, namely *Acrostichum aureum*, *Bruguiera cylindrica*, *Bruguiera gymnorriza*, *Lumnitzera littorea*, *Nypa fruticans*, *Rhizophora mucronata*, and *Rhizophora apiculata* (Table 1). Differ from that in BF and HF, the reforestation activity in MF was conducted more intensively from 2017 to 2021. More than 3,000 seedlings were planted every year. Therefore, the number of species from seedlings to trees in MF was almost balanced and equal.

Our study also found that none of the species was evenly distributed in the three forest ecosystems (Table 1), indicating that each species had specific habitat requirements to support its growth and development. However, some species were observed in different types of forests, such as *Chrysobalanus icaco* in BF and HF and *R. apiculata* in MF and BF. Moreover, the highest IVI of species relatively differed across the three forest ecosystems. For example, *Hibiscus tiliaceus* was the most important species in BF at all life forms based on the IVI, and *R. mucronata* was the essential species in MF. In HF, the highest IVI was noted in several species, i.e., *Adina minutiflora* (seedlings), *Premna serratifolia*, *Rhodomyrtus tomentosa* (saplings), *Tristania maingayi* (poles), and *Vitex ovata* (trees). Among the 37 species recorded in Angsana coastal area, only the following species showed good regeneration as indicated by their distribution from seedlings to trees (Khan et al. 2018): *A. minutiflora*, *Artocarpus rafscens*, *Casuarina equisetifolia*, *Garcinia sp.*, *Litsea firma*, *Podocarpus latifolius*, *R. mucronata*, *R. apiculata*, and *T. maingayi*.

Table 1. Importance value index of species in each growth stage in the three forest ecosystems in Angsana coastal area, South Kalimantan

No.	Species	Family	Beach forests				Heath forest				Mangrove forest			
			Seedling	Sapling	Pole	Tree	Seedling	Sapling	Pole	Tree	Seedling	Sapling	Pole	Tree
1	*Acrostichum aureum*	Pteridaceae	8.55								22.02			
2	*Adina minutiflora*	Rubiaceae					**29.18**	17.09	36.00	18.69				
3	*Artocarpus rafscens*	Moraceae					5.70	8.55	20.87	26.95				
4	*Avicennia marina*	Acanthaceae	26.18	26.53	18.54									
5	*Bruguiera cylindrica*	Rhizophoraceae				24.24							42.38	33.22
6	*Bruguiera gymnorhiza*	Rhizophoraceae		9.26	20.17							22.23		
7	*Calamus erinaceus*	Arecaceae						8.55	19.15	17.12				
8	*Calophyllum inophyllum*	Clusiaceae			23.06	34.12								
9	*Casuarina equisetifolia*	Casuarinaceae	12.55	18.53	20.17	30.23								
10	*Chrysobalanus icaco*	Chrysobalanaceae	18.82	18.53				8.55						
11	*Diospyros buxifolia*	Ebenaceae						8.55	21.81					
12	*Evodia aromatica*	Lauraceae					5.70		19.15	20.04				
13	*Excoecaria agallocha*	Euphorbiaceae	10.82											
14	*Flagellaria indica*	Flagellariaceae					5.70							
15	*Garcinia sp*	Clusiaceae					21.35	8.55	20.87	23.77				
16	*Hibiscus tiliaceus*	Malvaceae	**42.73**	**58.32**	**142.83**	**87.82**								
17	*Ixora coccinea*	Rubiaceae					17.78							
18	*Litsea firma*	Lauraceae					17.10	12.55	39.63	40.22				
19	*Lumnitzera littorea*	Combretaceae											25.35	16.01
20	*Macaranga triloba*	Euphorbiaceae					5.70							
21	*Mangifera sp.*	Anacardiaceae						8.55						
22	*Melastoma malabatricum*	Melastomataceae	8.55				14.21	8.55						
23	*Morinda citrifolia*	Cicadellidae	12.55	18.53										
24	*Nypa Fruticans*	Arecaceae									12.93			
25	*Podocarpus latifolius*	Podocarpaceae					13.53	8.55	38.20	29.41				
26	*Pandanus tectorius*	Pandanaceae	6.27											
27	*Peltophorum pterocarpum*	Fabaceae						8.55	19.15					
28	*Peronema canescens*	Lamiaceae					5.70							
29	*Premna serratifolia*	Lamiaceae	17.09	18.53			5.70	**21.09**						
30	*Rhizophora mucronata*	Rhizophoraceae	6.27	13.26		46.06					**88.08**	**105.56**	**171.60**	**142.02**
31	*Rhodomyrtus tomentosa*	Myrtaceae	8.55				5.70	**21.09**						
32	*Rizophora apiculata*	Rhizophoraceae	6.27	9.26	23.06	77.53					76.98	72.22	60.67	108.75
33	*Schima noronhoe*	Theaceae					16.34	17.09						
34	*Terminalia catappa*	Combretaceae			17.12									
35	*Tristania maingayi*	Myrtaceae					5.70	17.09	**46.03**	41.05				
36	*Vismia cayennensis*	Hypericaceae					19.22	17.09						
37	*Vitex ovata*	Lamiaceae	14.82	9.26	35.05		5.70		19.15	**82.76**				
	Importance value index		200	200	300	300	200	200	300	300	200	200	300	300

Note: The bold value indicates the highest importance value index of species in every life form

Vegetation diversity and similarity level among forest ecosystems

The highest richness, heterogeneity, and evenness of vegetation were discovered in HF, and the lowest diversity index was recorded in MF (Figure 5). Compared with that between MF and HF, the similarity in vegetation communities between MF and BF was higher with a similarity level of 47.1%. This result was supported by the observation that most species in MF were also found in BF. Five out of the seven species in MF were also found in BF. These findings signified that some biodiversity strategies in MF can also be applied in BF and vice versa.

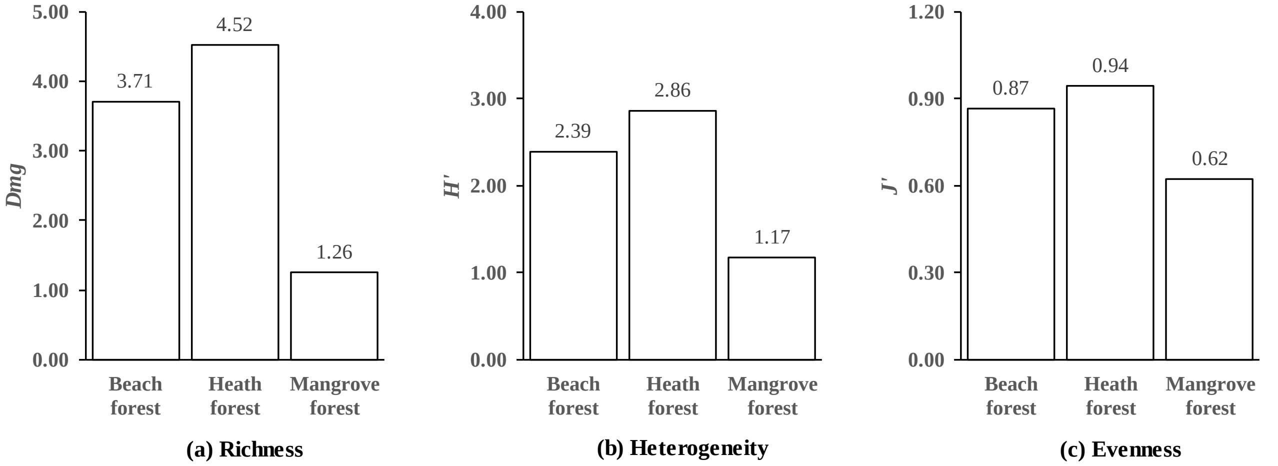

Figure 5. Biodiversity indices in term of richness, heterogeneity, and evenness in the three types of forest ecosystems in Angsana coastal area

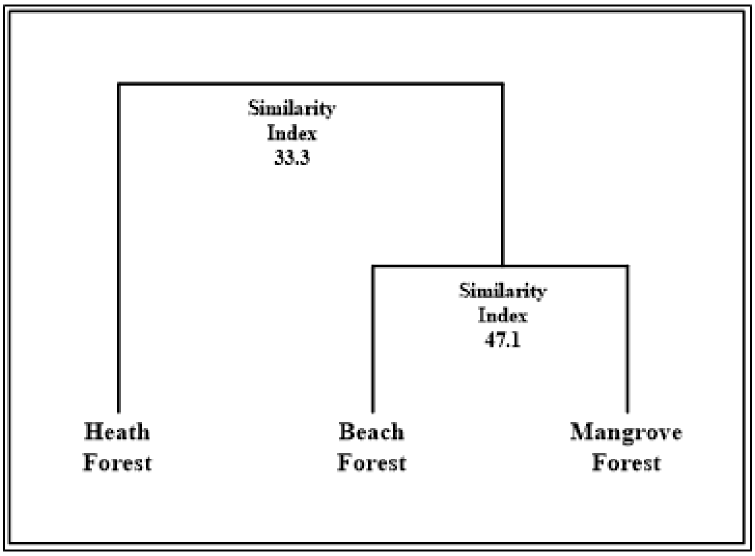

Figure 6. Similarity index of vegetation communities in the three forest ecosystems in Angsana coastal area

In ecosystem management, vegetation diversity is one of the most important parameters to assess environmental stability (De Boeck et al. 2018). High diversity indicates good environmental health (Zhang et al. 2018), even though this relationship does not generally apply in every type of forest, especially in mangroves. Different from other ecosystems, mangroves have many limitations for supporting plant growth, such as substrate condition, flooding, and wind speed (Froilan et al. 2020). Therefore, only a few species can grow well in mangroves. This finding explained why the richness, heterogeneity, and evenness in MF were considerably lower than those in BF and MF and why the resistance of mangroves to disturbance was relatively weaker compared with that of other forest types in Angsana coastal area.

According to the results, the vegetation communities in MF were almost similar to those in BF but were considerably different from those in HF. Meanwhile, a part of the vegetation community in BF was also discovered in HF. This finding indicated that the environmental condition in BF was situated in the transition phase between HF and MF. Similarities in vegetation between forests can also occur due to the tolerance level of species to site conditions. For example, most mangrove species could survive in beach areas, even though the soil was predominantly sand and its salinity was simulated by sea waves.

Implication results

This study concluded that vegetation structure highly varied among the three forest ecosystems, with the highest diversity observed in HF. Each type of forest had specific characteristics that became its unique entity. Therefore, Angsana coastal area shows high potential to be established as a site for biodiversity conservation especially representing coastal ecosystems of Borneo. However, only nine out of the 37 species observed in Angsana coastal area exhibited good regeneration capacity. This circumstance should be anticipated as soon as possible to minimize the risk of species extinction. We recommend that managers conduct enrichment planting to accelerate the effort of landscape conservation in the study area. This activity must be focused on other species that lack good regeneration. This program can be only implemented by collaborating with the local community around site.

Furthermore, additional efficient monitoring systems must be developed for measuring the dynamics of land cover in Angsana coastal area because the challenge of reforestation in coastal ecosystems is substantially more complex than in terrestrial ecosystems. Therefore, the monitoring method should provide rapid and accurate information to minimize the risk of vegetation losses. In this context, using an unmanned aerial vehicle is a better solution than satellite imagery because the former can accelerate the data acquisition process (Hsu et al. 2020). Furthermore, this instrument can also estimate the potential of blue carbon storage in Angsana coastal ecosystems (Peciña et al. 2021). With these efforts, comprehensive information regarding the essential contribution of Angsana coastal ecosystems can be obtained and used to support biodiversity conservation and climate change mitigation.

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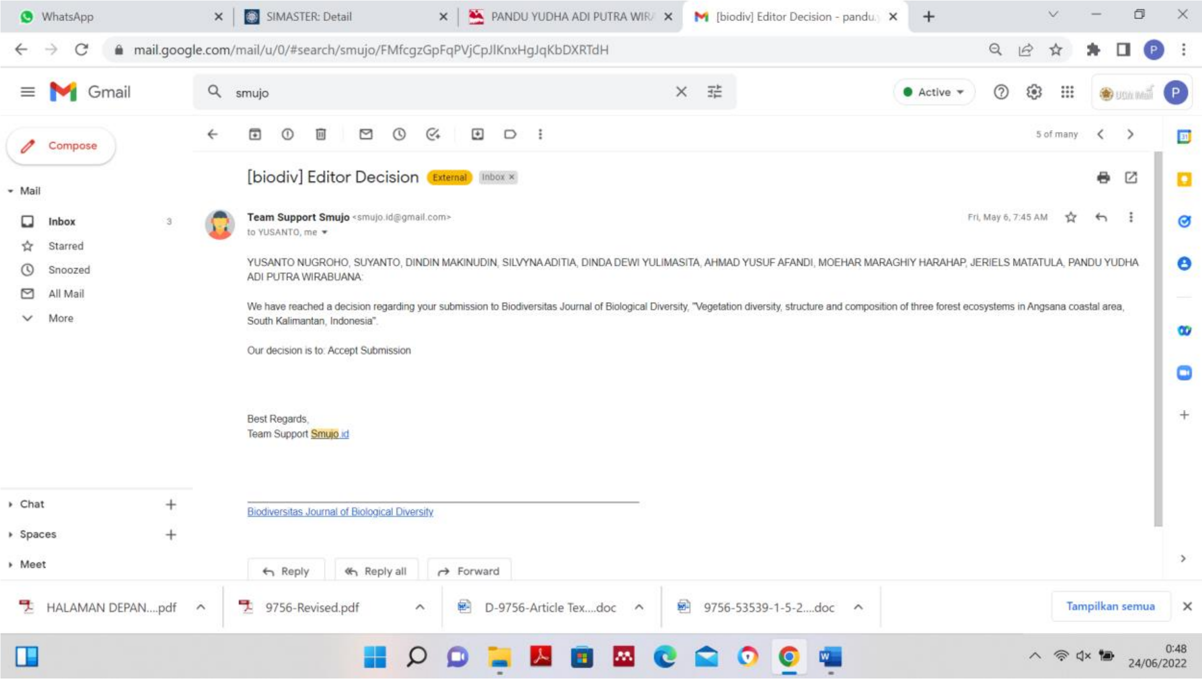

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