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

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Abstract. *Nugroho Y, Suyanto, Makinudin D, Aditia S, Yulimasita DD, Afandi AY, Harahap MM, Matatula J, Wirabuana PYAP. 2022. Vegetation diversity, structure and composition of three forest ecosystems in Angsana coastal area, South Kalimantan, Indonesia. Biodiversitas 23: 2640-2647.* 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^2 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 at the study site. The highest species abundance was 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* L. had the highest IVI in BF in all vegetation stages, and *Rhizophora mucronata* Lam. consistently had the greatest IVI in MF in all stages. Species thet exhibited the highest IVI in HF were *Adina minutiflora* Valeton (seedlings), *Rhodedomia tomentosa* and *Premna serratifolia* L. (saplings), *Tristania maingayi* Duthie (poles), and *Vitex ovata* Thunb. (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%. Based on 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.

Keywords: Coastal ecosystems, environmental preservation, plant diversity, species abundance, vegetation characteristics

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

INTRODUCTION

Vegetation of coastal ecosystems is an emerging research topic because of its strategic role 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. 2021) and minimizing the rate of seawater intrusion into the land (Sadono et al. 2020b). Furthermore, 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 potential 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 terms of biodiversity conservation, understanding the vegetation structure becomes a fundamental requirement for developing alternative 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). However, 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 areas in South Kalimantan, Angsana beach is a unique coastal ecosystem with three different types of forests, including mangrove forest, beach forest, and heath forest. However, the information about vegetation characteristics in this area is still not documented even though it has a high potential to become the center of biodiversity conservation in the 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 the Angsana coastal area in South Kalimantan. We expect 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 the Angsana coastal area located in South Kalimantan, Indonesia with the 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 plantations, and bare land. Annual rainfall ranges 3,000 mm year^{-1} with a mean daily temperature of 29°C. Forest ecosystems dominated more than 70% of the landscape in the study area, with an 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 forest vegetation.

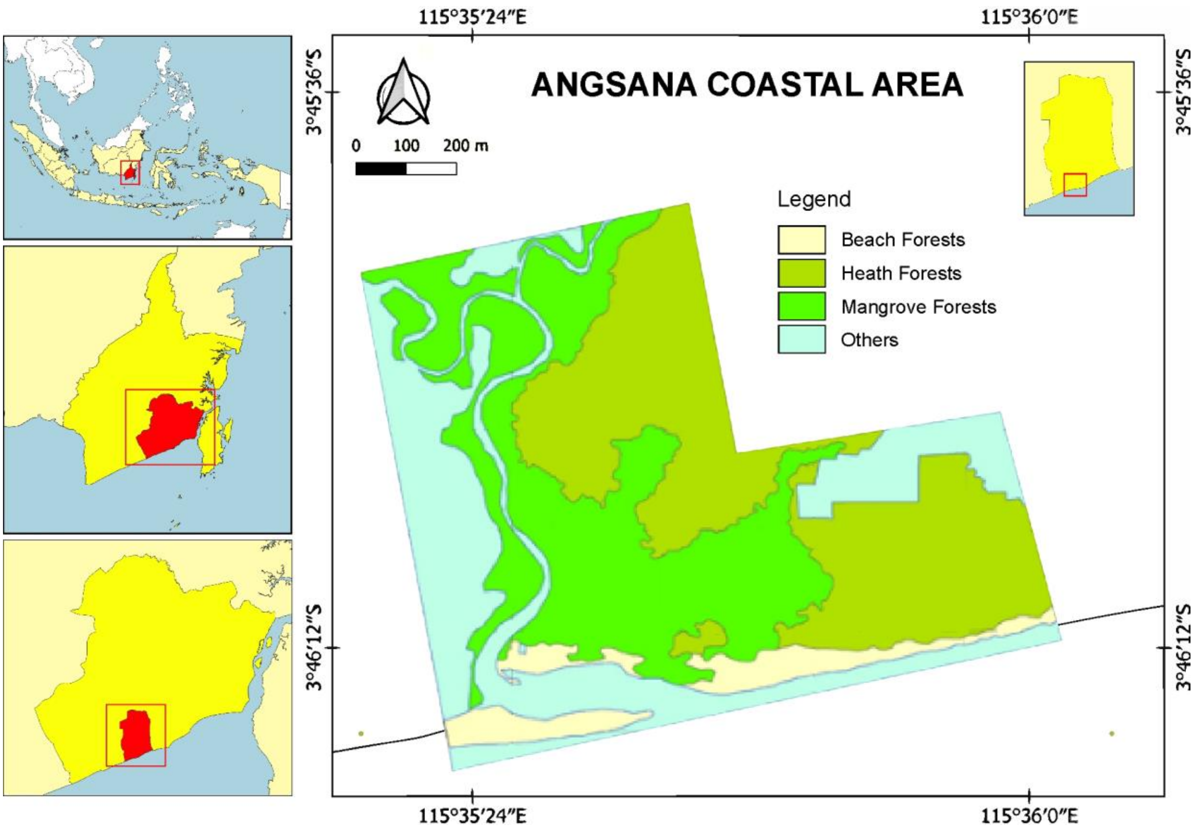

Figure 1. Location of Angsana coastal ecosystems in South Kalimantan, Indonesia. Different colors in the map indicate land cover variations

The Angsana coastal area is a unique ecosystem 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 of this site. Furthermore, 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 conducted in the mangrove forest, beach forest, and heath forest.

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).

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 values were then used to quantify every species's relative abundance, dominance, and frequency (Kasim et al. 2019). Finally, the 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 are presented below:

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

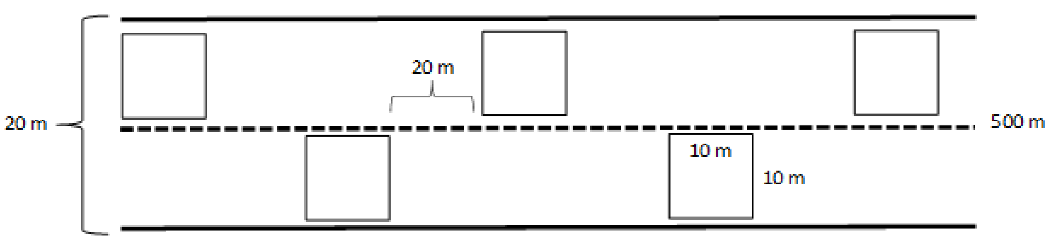

Figure 3. Visual illustration of a transect line method for vegetation survey

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

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

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

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

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

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

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

Vegetation diversity in the three forest ecosystems was assessed using three fundamental parameters, i.e., species richness calculated using 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:

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

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

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

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

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 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 will 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 decompose, they release nutrients into the soil layer.

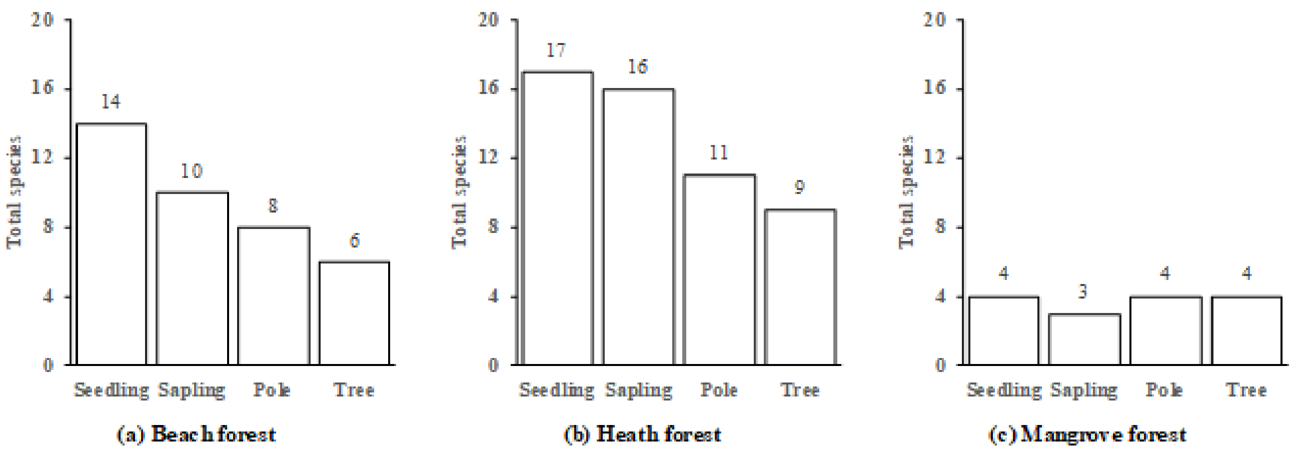

Figure 4. Number of species in every life form at three different forest ecosystems in Angsana coastal area, South Kalimantan, Indonesia

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 gymnorrhiza, Lumnitzera littorea, Nypa fruticans, Rhizophora mucronata,* and *Rhizophora apiculata* (Table 1). Differing 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.*

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%. The observation supported this result 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.

In ecosystem management, vegetation diversity is one of the most important parameters for assessing 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 to every forest type, especially in mangroves. Unlike other ecosystems, mangroves have many limitations for supporting plant growth, such as substrate conditions, 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 than that of other forest types in the 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 (Figure 6). 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.

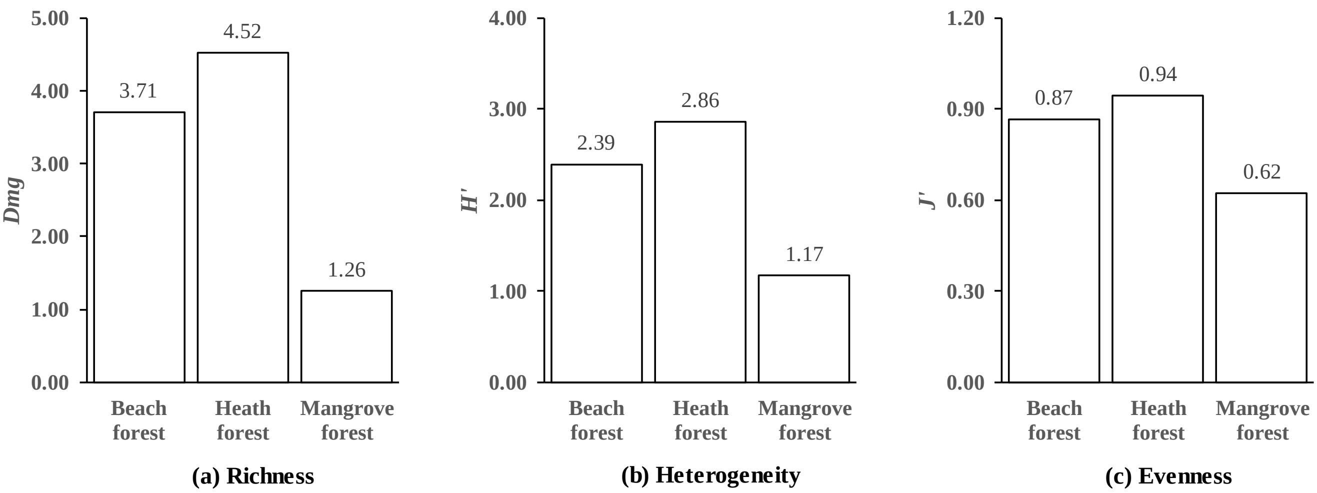

Figure 5. Biodiversity indices in term of richness, heterogeneity, and evenness in the three types of forest ecosystems in Angsana coastal area, South Kalimantan, Indonesia

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

Species	Family	Beach forests				Heath forest				Mangrove forest			
		Seedling	Sapling	Pole	Tree	Seedling	Sapling	Pole	Tree	Seedling	Sapling	Pole	Tree
Acrostichum aureum	Pteridaceae	8.55								22.02			
Adina minutiflora	Rubiaceae					**29.18**	17.09	36.00	18.69				
Artocarpus rafscens	Moraceae					5.70	8.55	20.87	26.95				
Avicennia marina	Acanthaceae	26.18	26.53	18.54									
Bruguiera cylindrica	Rhizophoraceae				24.24							42.38	33.22
Bruguiera gymnorrhiza	Rhizophoraceae		9.26	20.17							22.23		
Calamus erinaceus	Arecaceae						8.55	19.15	17.12				
Calophyllum inophyllum	Clusiaceae			23.06	34.12								
Casuarina equisetifolia	Casuarinaceae	12.55	18.53	20.17	30.23								
Chrysobalanus icaco	Chrysobalanaceae	18.82	18.53				8.55						
Diospyros buxifolia	Ebenaceae						8.55	21.81					
Evodia aromatica	Lauraceae					5.70		19.15	20.04				
Excoecaria agallocha	Euphorbiaceae	10.82											
Flagellaria indica	Flagellariaceae					5.70							
Garcinia sp	Clusiaceae					21.35	8.55	20.87	23.77				
Hibiscus tiliaceus	Malvaceae	**42.73**	**58.32**	**142.83**	**87.82**								
Ixora coccinea	Rubiaceae					17.78							
Litsea firma	Lauraceae					17.10	12.55	39.63	40.22				
Lumnitzera littorea	Combretaceae											25.35	16.01
Macaranga triloba	Euphorbiaceae					5.70							
Mangifera sp.	Anacardiaceae						8.55						
Melastoma malabathricum	Melastomataceae	8.55				14.21	8.55						
Morinda citrifolia	Cicadellidae	12.55	18.53										
Nypa fruticans	Arecaceae									12.93			
Podocarpus latifolius	Podocarpaceae					13.53	8.55	38.20	29.41				
Pandanus tectorius	Pandanaceae	6.27											
Peltophorum pterocarpum	Fabaceae						8.55	19.15					
Peronema canescens	Lamiaceae					5.70							
Premna serratifolia	Lamiaceae	17.09	18.53			5.70	**21.09**						
Rhizophora mucronata	Rhizophoraceae	6.27	13.26		46.06					**88.08**	**105.56**	**171.60**	**142.02**
Rhodomyrtus tomentosa	Myrtaceae	8.55				5.70	**21.09**						
Rhizophora apiculata	Rhizophoraceae	6.27	9.26	23.06	77.53					76.98	72.22	60.67	108.75
Schima noronhoe	Theaceae					16.34	17.09						
Terminalia catappa	Combretaceae			17.12									
Tristania maingayi	Myrtaceae					5.70	17.09	**46.03**	41.05				
Vismia cayennensis	Hypericaceae					19.22	17.09						
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

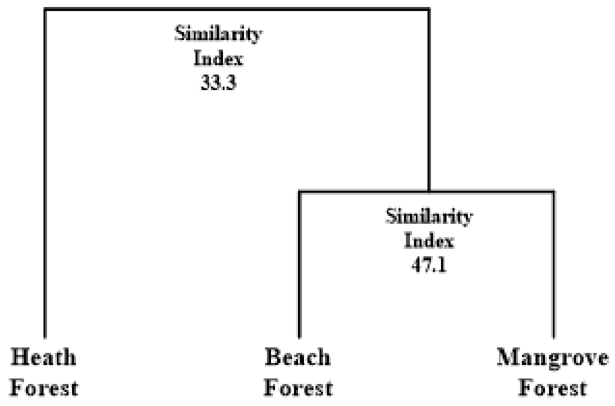

Figure 6. Similarity index of vegetation communities in the three forest ecosystems in Angsana coastal area

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 the coastal ecosystems of Borneo. However, only nine out of the 37 species observed in the Angsana coastal area exhibited good regeneration capacity. This circumstance should be anticipated as soon as possible to minimize the risk of species extinction. Therefore, 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 only be implemented by collaborating with the local community around the site.

Furthermore, additional efficient monitoring systems must be developed for measuring the dynamics of land cover in the 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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