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

by Pandu Yudha Adi Putra Wirabuana

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

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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.

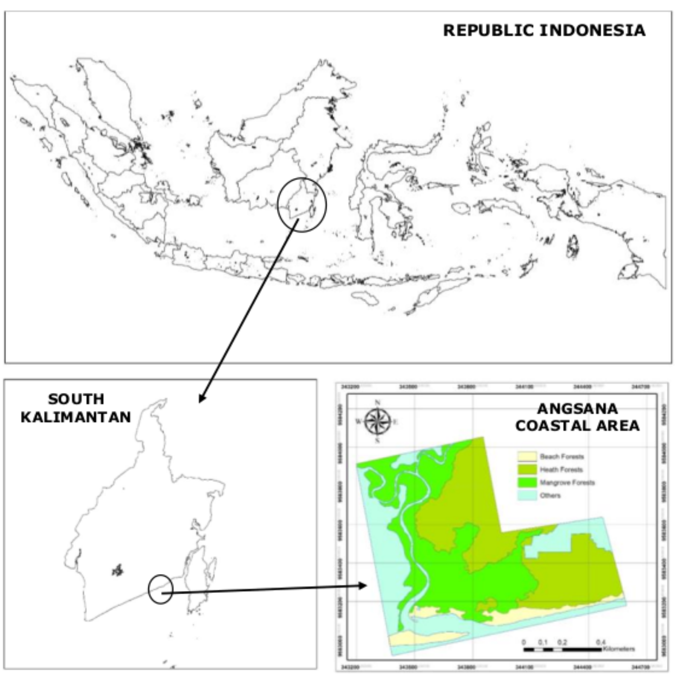


Figure 1. Location of Angsana coastal ecosystems in South Kalimantan. The different color in the map indicates land cover variations.

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.

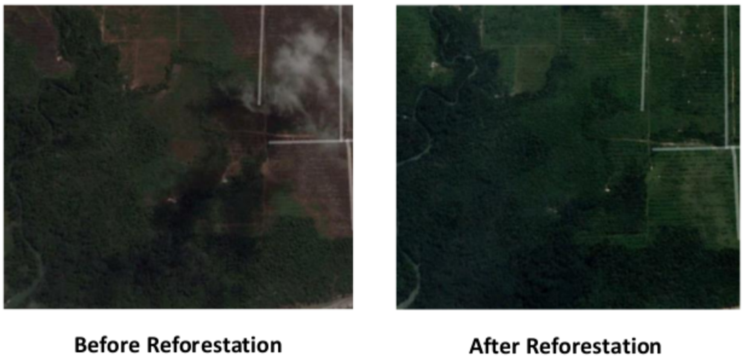


Figure 2. Comparison of landscape conditions in Angsana coastal ecosystems before and after reforestation program managed by collaboration between the local community and CSR-BIB based on Google Earth satellite imagery. The brown color indicated degraded land without vegetation cover.

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).

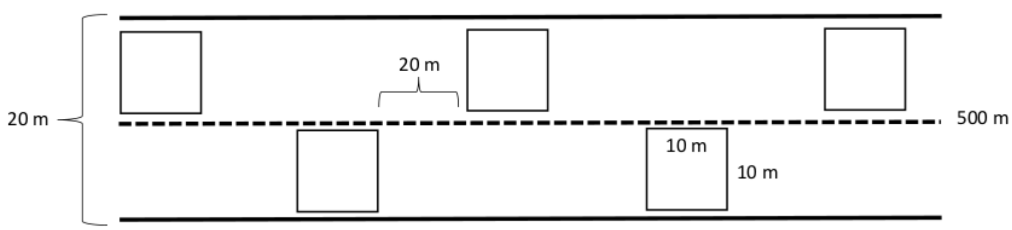


Figure 3. Visual illustration of a transect-line method for vegetation survey in this study

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.

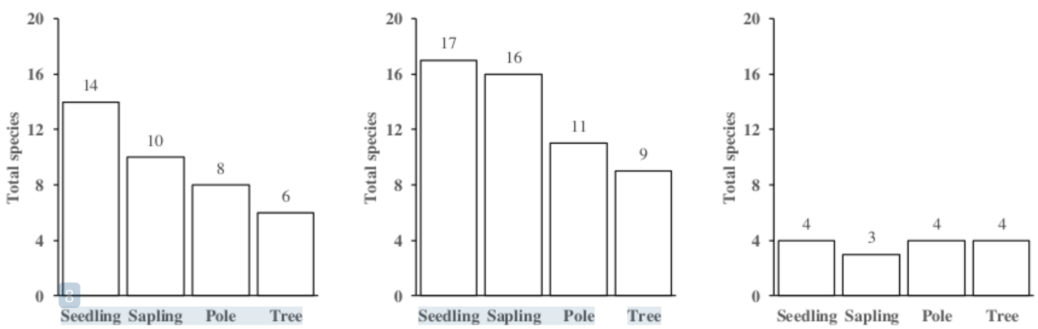
Meanwhile, the diversity of vegetation from three forest ecosystems was assessed using three fundamental parameters: richness, heterogeneity, and evenness (Singh 2020). First, species richness was assessed by Margalef Index (*Dmg*), while species heterogeneity was estimated by Shannon-Winner Index (*H'*) (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.



(a) Beach forest **(b) Heath forest** **(c) Mangrove forest**

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.

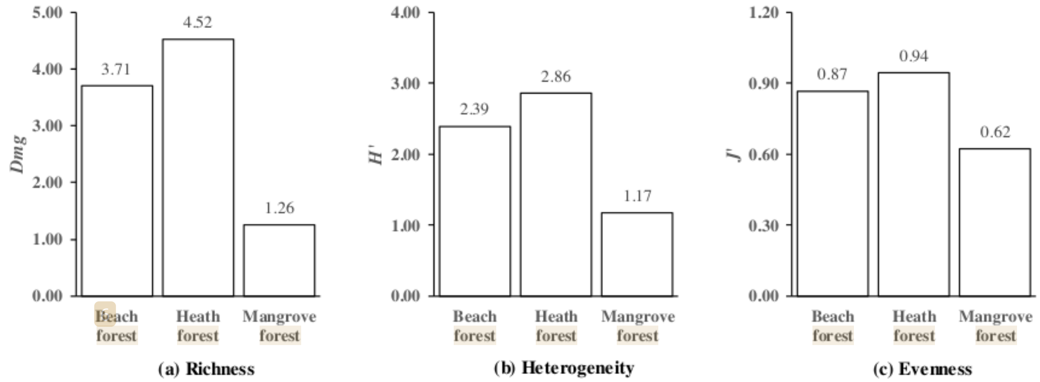


Figure 5. The trend of richness, heterogeneity, and evenness from three types of forest ecosystems in the Angsana coastal area

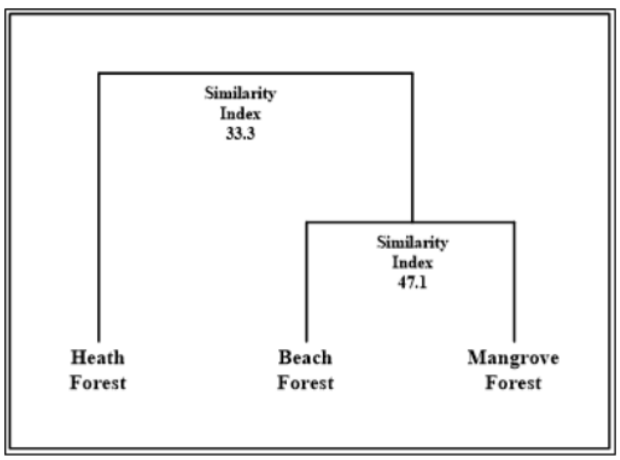


Figure 6. Similarity index of vegetation communities among three forest ecosystems in Angsana coastal area

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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