BIODIVERSITAS
Volume 24, Number 7, July 2023
Pages: 3735-3742

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240710

Changes in density level and mangrove land cover on Teluk Pandan Coast, Lampung, Indonesia, after 10 years of community-based management

QADAR HASANI♥, AYU ANISA, ABDULLAH AMAN DAMAI, DARMA YULIANA, INDRA GUMAY YUDHA, DAVID JULIAN

Department of Aquatic Resources, Faculty of Agriculture, Universitas Lampung. Jl. Prof. Sumantri Brojonegoro No. 1, Gedong Meneng, Bandar Lampung 35145, Lampung, Indonesia. Tel/fax.: +62-721-770347, ♥email: masqod@fp.unila.ac.id

Manuscript received: 7 May 2023. Revision accepted: 7 July 2023.

Abstract. *Hasani Q, Anisa A, Damai AA, Yuliana D, Yudha IG, Julian D. 2023. Changes in density level and mangrove land cover on Teluk Pandan Coast, Lampung, Indonesia, after 10 years of community-based management. Biodiversitas 24: 3735-3742.* The mangrove ecosystem in the Teluk Pandan coastal area, Pesawaran District, Lampung Province, Indonesia, is part of the mega-biodiversity of mangroves in Indonesia. Specifically, the mangrove in this region has changed due to tourism, aquaculture, settlement activities and coastal abrasion. This study aimed to assess the changes in density level and area change of the mangrove forests at five coastal villages in Teluk Pandan during the period of community management from 2010 to 2020. The effort and success of the rehabilitation were reported in this study can be useful as a consideration of sustainable management of mangrove ecosystem both in Lampung and in other areas in Indonesia. Mangrove area was estimated through field surveys and data processing of satellite imagery from Landsat 5 in 2010 and Landsat 8 in 2020. The mangrove density level and area change were calculated by layering images of mangrove distribution from different years. The classification of mangrove density was determined based on the NDVI value. Satellite imagery was compared with field data collected from 20 observation points at five villages to ensure the density level and interpretation accuracy. Image data analysis showed the changes in mangrove area from 109.80 ha in 2010, an increase of 16.39% to 127.80 ha in 2020. The area of mangrove forest in the rare category decreased by 49.35%, the moderate category increased by 39.13%, and the dense category increased by 109.71%. The study confirmed the successful effort to manage and preserve mangroves in Teluk Pandan Sub-district. Eventually, community-based mangrove management (CBMM) and cross-sectoral and multi-stakeholder management (co-management) has become the core strategy in the successful management of mangrove at five coastal villages in Teluk Pandan Sub-district.

Keywords: Landsat, mangrove, management, satellite imagery, sustainability

INTRODUCTION

Mangrove ecosystem is a special feature of the intertidal zone on tropical and subtropical coasts (Srikanth et al. 2015; UNEP 2020). Mangroves play a vital role in estuary and coastal ecosystems (Kumar et al. 2014). Mangrove forests are among the most productive and biologically valuable ecosystems on Earth (Srikanth et al. 2015). Mangrove ecosystem is ecologically significant and provides socio-economic benefits in tropical and subtropical coastal areas (UNEP 2020; Nguyen et al. 2021; Arifanti et al. 2022). Mangrove forests help to stabilize coastlines and reduce the impact of severe natural disasters (Giri et al. 2011; Srikanth et al. 2015; Yuliana et al. 2019), such as tsunami and hurricane (Kumar et al. 2014; Arifanti et al. 2022). Ecologically, mangrove forests provide breeding and nursery grounds for various species of marine fish, shellfish and other wildlife (Kumar et al. 2014; UNEP 2020; Nyangoko et al. 2022). Furthermore, mangroves offer economic opportunities such as food, medicines, fuel and building materials (Giri et al. 2011; Srikanth et al. 2015; Tetelepta et al. 2020).

The total mangrove area in the world is around 160,000 km^2 (FAO 2003). Another source says the global area is 150,000 km^2 (UNEP 2009). Indonesia, Australia, Brazil, and Nigeria are home to approximately 43% of the world's mangrove forests (FAO 2003). More than 20% of the world's mangrove area is governed by Indonesia (Sarhan and Tawfik 2018). Over the archipelago, Indonesia holds 3.3 million hectares of "mega-diversity" mangrove forests. (Arifanti et al. 2022). Nonetheless, it is estimated that 10-33% of Indonesia's mangrove areas have been degraded and converted in recent decades (Kusmana 2011; Arifanti et al. 2019), primarily as a result of coastal development activities including aquaculture, logging, mining, reclamation and pollution (Arifanti et al. 2019; Arifanti et al. 2022). Global mangrove cover loss due to conversion to non-mangrove land uses such as shrimp pond cultivation and expansion, agricultural development, and mangrove clearing for human settlements is always happening (FAO 2007; Nguyen 2014; Nguyen et at. 2021). Therefore, it is important to monitor mangrove forests for changes in land use and to detect deforestation and mangrove degradation (Nguyen et al. 2021).

Teluk Pandan coastal area is part of the Pesawaran District, Lampung Province, Indonesia. According to Irawan et al. (2019), in 2010, the total area of mangrove forests on Teluk Pandan coast was 79.00 ha. This area is

part of 866.149 ha of mangroves in Lampung Province (Kusmana 2011). The area of mangroves in Teluk Pandan Sub-district has changed from year to year. The changes occur as a result of the use of mangrove forest land for settlement, tourism, and aquaculture, as well as natural factors such as beach abrasion (Emiyati et al. 2014; Firdaus et al. 2021; Hasani et al. 2022). In several locations, coastal areas in Lampung Province are also often used as sand mining lands (Hasani et al. 2021a; Hasani et al. 2021b). During this time, however, the government, state-owned enterprises (BUMN), non-governmental organizations (NGOs), the private sector and the environmental community carried out various programs and conservation activities such as mangrove restoration. This study aimed to assess the changes in density level and area change of the mangrove forest on Teluk Pandan coast during the period of community management from 2010 to 2020. This research also attempted to inform the efforts and success of mangrove rehabilitation and management at Teluk Pandan coast. Information on changes in mangrove area and density level is urgently needed to accelerate problem solving and seek steps to prevent mangrove forest degradation (Waiyasusri 2021), as well as important for sustainable management of the mangrove ecosystem and for improving the welfare of coastal communities in Teluk Pandan Sub-district.

MATERIALS AND METHODS

Research sites

This research was conducted at 5 (five) coastal villages in Teluk Pandan Sub-district, Pesawaran District, Lampung Province, namely Hurun Village, Hanura Village, Sidodadi Village, Gebang Village and Batu Menyan Village (Figure 1).

Research methods

In addition to using remote sensing technology with high-resolution satellite imagery, field observations were performed to validate the condition of the area through social-ecological interactions of coastal communities. The expected results are descriptively identifying changes in mangrove area and density levels in coastal areas with different time series (2010 and 2020), and formulating sustainable mangrove forest policy strategies at five coastal villages in Teluk Pandan Sub-district, Pesawaran District, Lampung, Indonesia.

Mangrove cover area estimation and mapping

Mangrove area data was estimated through field surveys and data processing of satellite imagery from Landsat 5 in 2010, and Landsat 8 in 2020 managed by National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS). The stages of data processing include: (i) Satellite imagery data downloading; (ii) Radiometric and atmospheric correction; (iii) Image cropping; (iv) Supervised classification; (v) Creating composite images or band combinations; (vi) imagery interpretation; (vii) Normalized difference vegetation index (NDVI) transformation; (viii) Overlay; and (ix) Map layouts (Ramdani et al. 2019; Nguyen et al. 2020a). Satellite imagery data from Landsat 5 and Landsat 8 are downloaded from http://earthesplorer.usgs.gov according to certain paths and rows. The coastal area of Teluk Pandan Sub-district, Pesawaran District, Lampung Province, Indonesia is located on path 123 and row 64. ArcGis 10.3, Google Earth, Microsoft Excel 2010 and Envi 5.3 were used for data processing. The flow chart of the main research methods is illustrated in Figure 2.

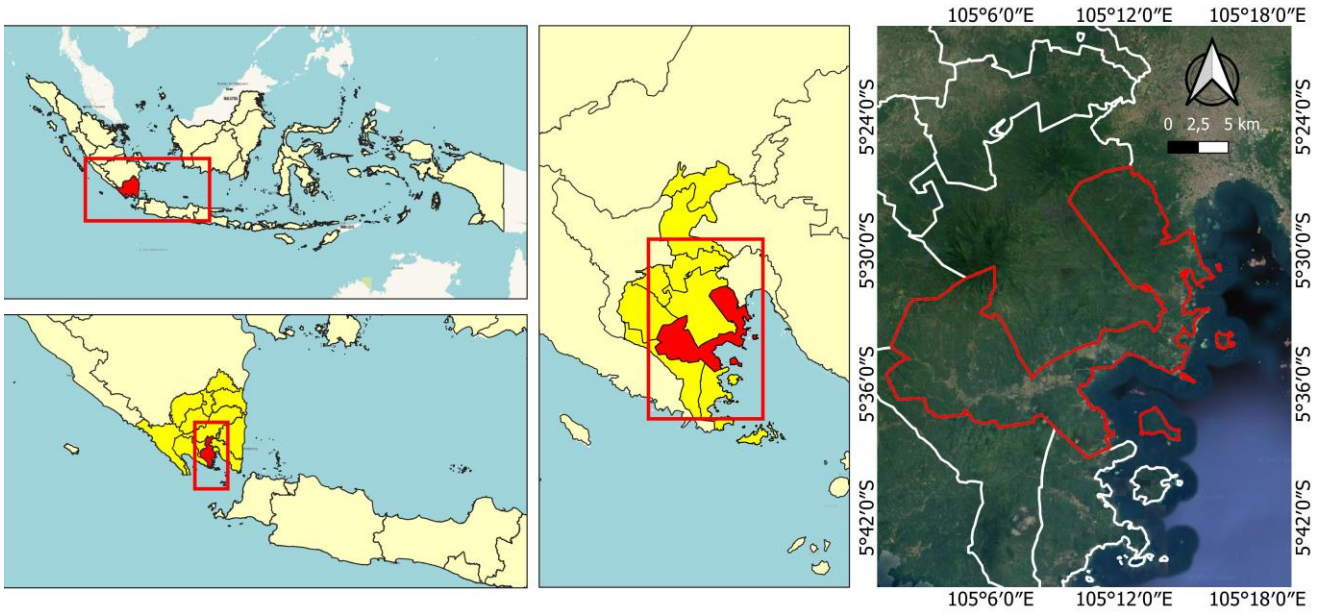

Figure 1. The study locations in Teluk Pandan Sub-district, Pesawaran District, Lampung Province, Indonesia

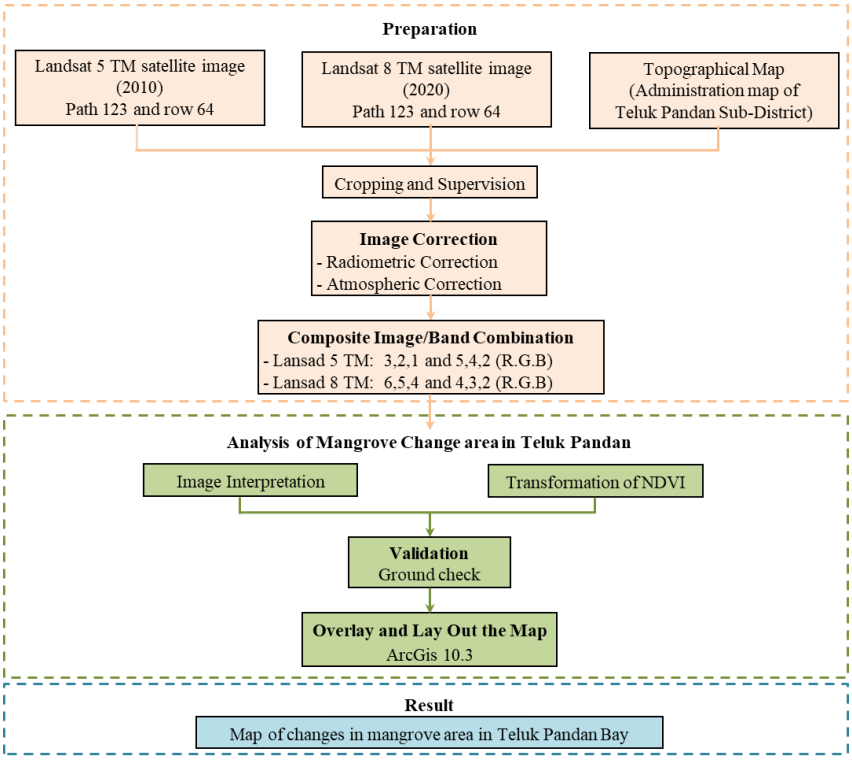

Figure 2. Flow chart of research methods (modified from Waiyasusri 2021)

The mangrove density level and area change were calculated by layering images of mangrove distribution from different years (Irawan et al. 2019), in this case, the distribution of mangroves in 2010 and 2020. Classification of mangrove density is obtained from NDVI which is calculated as the ratio between the near infrared radiation bands (NIR) with the red band (RED) in the electromagnetic wave (Ramdani et al. 2019; Nguyen et al. 2020b; Nguyen et al. 2021).

$$NDVI = \frac{(\rho NIR - \rho RED)}{(\rho NIR + \rho RED)}$$

Description:
NDVI : Normalized Difference Vegetation Index
NIR : Near Infrared Radiation band
RED : Red band

The NIR band has a wavelength range from 0.70 to 1.00 µm, while the red band is from 0.40 to 0.70 µm (Nguyen et al. 2021). Classification of mangrove density based on NDVI values refers to Papilaya (2013) and Irawan et al. (2019), namely rare-density vegetation (NDVI 0.01-0.32), moderate-density (NDVI 0.33-0.42) and dense (NDVI 0.43-1.00). A ground check was performed at 20 observation points to ensure the accuracy of the interpretation of Landsat 5 and 8 satellite imagery and field conditions (each village was represented by 4 observation points). According to the Regulation of Geospatial Information Agency of the Republic of Indonesia No. 15/2014, the accuracy value is considered good if the suitability of the image and field conditions is at least 85.00%. Equation 2 calculates the percentage of interpretation conformity.

$$\text{Interpretation conformity} = \frac{\text{The number of correct point}}{\text{The number of survey point}} \times 100\%$$

Examination of mangrove density in the field refers to the Decree of Environment Minister of the Republic of Indonesia No. 201/2004, i.e. dense category (mangrove cover area >75% or there are >1,500 trees per hectare); medium category (mangrove cover area ≥50-<75% or 1,000 < µ <1,500 trees per hectare) and rare category (mangrove cover area <50% or <1,000 trees per hectare). Envi 5.3 software was used for digital data processing while overlay and layout of the base map, satellite imagery and maps of changes in mangrove area were carried out using ArcGIS 10.3 software.

RESULTS AND DISCUSSION

This study included five coastal villages in Teluk Pandan Sub-district, Pesawaran District, Lampung Province, Indonesia. Teluk Pandan's coastal area is overgrown with mangroves and sea coral reefs, with a muddy sand beach type that has high genetic resources and is commonly used as a tourism destination (BPDASHL 2020). Teluk Pandan Sub-district is one of the most important coastal and beach tourism centers in Lampung Province (Purnomo et al. 2019; Hasani et al. 2022), including mangrove ecotourism. The coastal area of Teluk

Pandan is also an important aquaculture activities center in Pesawaran District (Hasani et al. 2012; Hasani et al. 2022).

According to satellite imagery, the area of mangroves at five coastal villages of Teluk Pandan in 2010 was 109.80 ha. The majority of it, or approximately 56.15 ha, is a rare category (NDVI 0.11-0.32). An area of 18.63 hais classified as moderate (NDVI 0.33-0.42) and 35.02 hais classified as dense (NDVI 0.43-1.00) (Table 1). In 2020, the area of mangroves increased by 16.39% (48.80 ha) to 127.8 ha. In comparison with 2010, the area of mangrove forest in the rare category decreased by 49.35%, the moderate category increased by 39.13%, and the dense category increased by 109.71% in 2020 (Table 1).

The highest increase in mangrove forest area during ten years of community management was in Batu Menyan Village, which was 5.80 ha or a 25.82% increase from the mangrove forest area in 2010, followed by Hanura Village, which increased by 5.10 ha (17.00%), Sidodadi Village increased by 4.00 ha (18.71%); Hurun Village increased by 3.10 ha (14.26%), while the mangrove area in Gebang Village was stagnant. In total, the area of mangrove forests in Teluk Pandan Sub-district increased by 18.00 ha or 16.39% compared to 2010 (Table 2).

Changes in mangrove area based on its density category in Teluk Pandan Sub-district can be seen in the map (Figure 3). In 2010, the thematic map shows mangrove area dominated by red and yellow colors indicating rare and moderate-density categories. Meanwhile, in 2020 the map shows a predominance of green, indicating dense mangrove categories. The ground check results for 20 observation points, based on significant changes in the color of the image map, there are 17 confirmed correct points. Therefore, the interpretation conformity shows a value of 85.00%. This value meets the requirements for the accuracy of image interpretation on maps and field observation data as stipulated in the regulation of the Geospatial Information Agency of the Republic of Indonesia No.15/2014.

Based on observations in the mangrove area at five coastal villages, Hanura Village had the highest increasing level in good/dense category, followed by Hurun Village. The area of dense mangroves at Hanura Village has increased by 854.84%, while it has increased by 160% at Hurun Village (Table 3). The area of mangrove in the dense category at Gebang Village has increased by 31.25%, while at Sidodadi Village, it has increased slightly by 2.53%, but the area of mangrove in the moderate category has increased sharply by 106.90%. As seen in Table 3, mangrove area in the rare-density category at those four villages has decreased. This shows that the government, the community and other stakeholders have been successful in managing the mangrove ecosystem. This is known as co-management (Aheto et al. 2016; Zaldívar-Jiménez et al. 2017; UNEP 2020), which is a multi-stakeholder and cross-sectoral approach to mangrove management (UNEP 2020; Arifanti et al. 2022).

Since 2010, the mangrove ecosystem at Sidodadi Village has been among the best of any other coastal villages. Most of the mangrove forests at Sidodadi Village were included in the dense category (high density). Mangrove forests in the dense category covered an area of 14.22 ha at Sidodadi Village, which was larger than the rare category (8.55 ha) and the moderate category (2.61 ha). The area of mangrove in the dense category at Gebang Village during the period 2010 to 2020 has increased by 24.00%. The area of mangroves in the rare category has decreased by 1.80 ha (-53.00%), while the area of mangroves in the moderate category has remained relatively constant (Table 3).

Table 1. Mangrove density and NDVI class intervals in five coastal villages in Teluk Pandan Sub-district, Pesawaran District, Indonesia between 2010 and 2020

NDVI	Class	Area (ha)		Change
		Year 2010	Year 2020	(%)
0.11-0.32	Rare	56.15	28.44	-49.35
0.33-0.42	Moderate	18.63	25.92	39.13
0.43-1.00	Dense	35.02	73.44	109.71
Total area		109.80	127.80	16.39

Note: The minus sign (-) indicates a decrease in the area of mangrove

Table 2. Total area changes of mangrove forests at five coastal villages in Teluk Pandan Sub-district, Pesawaran District, Indonesia

Village	Mangrove area (ha)		Area changes (m^2)	Percentage (%)
	2010	2020		
Hurun	21.74	24.84	3.10	14.26
Hanura	30.00	35.10	5.10	17.00
Sidodadi	21.38	25.38	4.00	18.71
Gebang	14.22	14.22	0.00	0.00
Batu Menyan	22.46	28.26	5.80	25.82
Teluk Pandan	**109.80**	**127.80**	**18.00**	**16.39**

Table 3. Mangrove forest area at five coastal villages in Teluk Pandan Sub-district, Pesawaran District, Indonesia based on density category

NDVI	Density category	Area (ha)		Area changes (ha)	Percentage (%)
		2010	2020		
	Hurun				
0.11-0.32	Rare	14.00	5.67	-8.30	-59.50
0.33-0.42	Moderate	2.34	5.13	2.79	119.23
0.43-1.00	Dense	5.40	1.40	8.64	160.00
	Hanura				
0.11-0.32	Rare	21.00	4.50	-16.5	-78.57
0.33-0.42	Moderate	6.21	3.96	-2.25	-36.23
0.43-1.00	Dense	2.79	26.64	23.85	854.84
	Sidodadi				
0.11-0.32	Rare	8.55	5.40	-3.15	-36.84
0.33-0.42	Moderate	2.61	5.30	2.69	105.90
0.43-1.00	Dense	10.22	14.68	4.46	42.66
	Gebang				
0.11-0.32	Rare	5.22	3.42	-1.80	-34.48
0.33-0.42	Moderate	3.24	3.24	0.00	0.00
0.43-1.00	Dense	5.76	7.56	1.80	31.25
	Batu Menyan				
0.11-0.32	Rare	7.38	9.45	2.07	28.05
0.33-0.42	Moderate	4.23	8.19	3.96	93.62
0.43-1.00	Dense	10.85	10.60	-0.25	-2.12

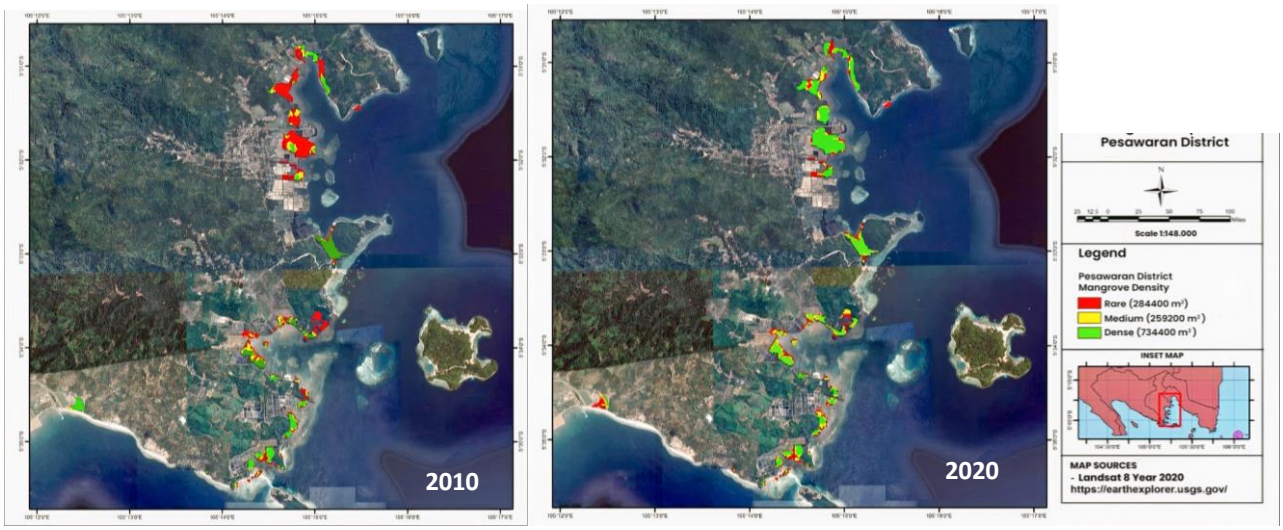

Figure 3. Mangrove Map of NDVI in the year 2010 and 2020 at five Coastal Villages in Teluk Pandan Sub-district, Pesawaran District, Indonesia

Figure 5. Mangrove forests condition at coastal villages of Teluk Pandan, Pesawaran District, Indonesia

Discussion

Before 2010, there had been a decrease in the area of mangrove forests in Teluk Pandan Sub-district. Coastal abrasion (Emiyati et al. 2014) and the logging of mangrove forests for the expansion of shrimp ponds (Irawan et al. 2015; Firdaus et al. 2021; Hasani et al. 2022), settlement (Emiyati et al. 2014; Tresiana et al. 2022) and tourism (Nabilah et al. 2021) have resulted in a low area of mangroves in dense category. In 2015, some of the ponds were no longer in operation, therefore replanting or rehabilitation of mangroves was carried out on vacant land by the Maritime Affairs and Fisheries Agency of Pesawaran District, mangrove activists, volunteers and some local communities so that currently, there is an increase in the area of mangrove forests. This type of management program is also known as collaborative management (Jhaveri et al. 2018; Hamzah et al. 2020) or "co-management" (Muqorrobin et al. 2013; Hamzah et al. 2020; Gnansounou et al. 2021; Gnansounou et al. 2022). This program has shown positive results, as indicated by a growth in the area of mangroves with an NDVI value of 0.43-1.00 (dense category).

Implementation of co-management between the government and coastal communities in the framework of

mangrove rehabilitation and management at coastal villages of Teluk Pandan begins with the formation of community groups that monitor mangrove conservation. The group cooperates with the government through the Mangrove Labor-Intensive Program (PEN-PKPM), which is a program of the Ministry of Environment and Forestry of the Republic of Indonesia through Drainage-Area Management Agency (BPDASHL) of Way Seputih-Way Sekampung, Lampung Province. Such collaborative management between the government, state-owned enterprises (BUMN) and community has already taken place in several regions in Indonesia (Kusmana 2011; Arifanti et al. 2022), for instance, mangrove management in Tanjung Puting and Bali Barat National Parks (Kusmana 2011); co-management of mangrove in the Pasarbanggi Village, Rembang District, Central Java (Muqorrobin et al. 2013); mangrove management in Rimau Island, South Sumatera (Yuliana et al. 2019); co-management for rehabilitation of mangrove in Langkat District (Hamzah et al. 2020), etc.

The increase of mangrove forests at Hurun and Hanura Villages was the result of a mangrove restoration program on abandoned pond areas. The program at Hurun Village was initiated by the Mangrove Management Group (KPM) Andana and KPM Sejahtera. Community-based mangrove rehabilitation and management program have proven successful in several management areas in Lampung, for example, Lampung Mangrove Center (LMC) in Margasari Village, East Lampung District (Kustanti et al. 2012; Qurniati et al. 2017); and Mangrove Forest Restoration by Fisheries Communities in Lampung Bay (Firdaus et al. 2021). The mangroves at Hurun Village are extensive and in good condition, growing along the coastline from Hurun Village to Hanura Village. In 2015, the Coca-Cola Euro Pacific Partners Program (CECEP) and PT Pelindo (Indonesian Port Corporation) each donated 1,000 mangrove seedlings to mangrove management and rehabilitation activities at Sidodadi Village, while Sumatra Institute of Technology (ITERA) students contributed 200 mangrove seedlings to the village. In addition, the village authority and the community independently also held a reforestation program of 200 trees along the coast of the village. Currently, Sidodadi Village has become one of the destinations for mangrove ecotourism in Pesawaran District. The development of mangrove ecotourism by the community since 2021 has raised the community's awareness about the importance of maintaining and rehabilitating mangroves in order to change or restore damaged mangrove ecosystems. Mangrove management programs at Sidodadi Village have achieved excellent results, with the area of rare-density mangrove forests reduced from 8.55 ha in 2010 to only 5.40 ha in 2020, as well as the area of moderate mangrove forests increased by 106.90%. According to ground check of mangrove species, it's found at least seven species growing in coastal areas at five research sites i.e. *Rhizophora mucronata*, *Rhizophora stylosa*, *Rhizophora apiculata*, *Avicennia* sp., *Bruguiera parviflora* and *Ceriops* sp. These species are the most common in the coastal areas of Lampung Province (Kustanti et al. 2012; Qurniati et al. 2017; Firdaus et al. 2021; Tresiana et al. 2021). The study of land cover change use NDVI in the mangrove area of Teluk Pandan can be used to study other coastal areas at the local and regional levels (Waiyasusri 2021). This approach can determine the boundaries of mangrove forests and other types of land cover accurately, quickly and efficiently in the context of changes that are occurring with mangrove forests around the world (Waiyasusri and Chotpantarat 2022).

The mangroves at Gebang Village are currently in the form of seedlings, saplings and trees that are scattered across the mangrove ecotourism site. Replanting mangroves with the assistance of stakeholders have frequently been carried out. PT. Indofood Sukses Makmur supplied 4,000 mangrove seedlings in 2014, the Deputy Governor of Lampung aided in planting 36,000 mangrove seedlings in 2015, KPM Artala planted 500 mangrove seedlings in 2018, and the PT. Perusahaan Listrik Negara (Indonesian State Electricity Company) Cares Program gave 3,500 mangrove seedlings in 2019. The success rate of planting mangroves at the village is estimated at 80.00%. The voluntary formation of community groups conserving mangroves contributes to the program's effectiveness. Furthermore, Gebang Village has initiated the establishment of village-owned enterprises (BUMDes) involved in mangrove ecotourism management. In several countries, community-based management of mangrove forests has been quite successful, with management groups based on local wisdom, such as the establishment of a natural resource management committee (NRMC) for mangroves in Nhagau Mozambik (UNEP 2020); shore management unit (BMU) in Pangani Magharribi and Bweni Tanzania (Nyangoko et al. 2021); and community-based mangrove management (CBMM) for mangrove rehabilitation in Nga Son and Hau Loc District, Vietnam (Datta et al. 2012; Kongkeaw et al. 2019); co-management-based mangrove rehabilitation in Volta Estuary, Ghana (Aheto et al. 2016) and Terminos Lagon, Meksiko (Zaldívar-Jiménez 2017). This management strategy, which focuses on user decision-making and distribution of mangrove resources, can assure local engagement (Kongkeaw et al. 2019; Nguyen et al. 2020a).

The area of mangrove forest in the dense category at Batu Menyan Village has decreased slightly by 0.25 ha (-2,12%), while in the rare-density category has increased by 28.05%. Land conversion into settlements, expansion of shrimp ponds, and abrasion appear to be responsible for such conditions (Hasani et al. 2012; Emiyati et al. 2014; Firdaus et al. 2021; Hasani et al. 2022). This situation has raised concerns among the community. Following this, the people, the government and the private sector have worked together to restore the ecological status of mangrove forests by replanting or rehabilitating them. Among the efforts that have been made are the planting of 600 mangrove seedlings by the University of Lampung's environmentalist student group in 2015 and the planting of 1,000 mangrove seedlings by Bandar Lampung University in collaboration with PT. Pertamina (Indonesian State Oil and Natural Gas mining Company) in 2016. The Government of Pesawaran District also took part in mangrove rehabilitation activities by donating 3,000 mangrove seedlings in 2018. These

efforts have succeeded in increasing the area of mangroves in moderate category by 3.90 ha or 93.62% compared to 2010. In this case, Qurniati et al. (2017) and Firdaus et al. (2021) have reviewed the success of co-management and CBMM in Teluk Pandan Sub-district and Pesawaran District. This recent study also confirmed the success of CBMM and conservation efforts at five coastal villages in Teluk Pandan Sub-district, Pesawaran District, Lampung, Indonesia. However, an increase in tourism activity in the Teluk Pandan mangrove area deserves attention, because it can result in the expansion of villages and indigenous communities into dense communities to support tourism services (Waiyasusri 2021). For example, due to the development of tourism, the coastal area which was once a mangrove, agricultural and community area along the west coast of Koh Chang in Thailand has now mostly turned into hotels and resorts (Waiyasusri and Chotpantarat 2022).

In conclusion, apart from being popular as a mangrove ecotourism center, the coastal area of Teluk Pandan is also an important aquaculture center in Lampung Province. Collaborative (co-management) and community-based management and rehabilitation of mangroves (CBMM) during 2010-2020 has proven to increase the area and quality of mangrove cover at five coastal villages in Teluk Pandan Sub-district, as shown in the analysis of satellite imagery. The area of mangroves in the dense and moderate categories has increased significantly, while in the rare density has drastically decreased. The accomplishment was the result of rehabilitation programs and mangrove conservation efforts carried out by the government, state-owned enterprises (BUMN), non-governmental organizations (NGOs) and the private sector as well as the environmentalists during this period.

A cross-sectoral and multi-stakeholder participatory approach to mangrove management has become a core strategy in Teluk Pandan Sub-district, as well as in many other countries. Brazil, Ghana, Mozambique, Tanzania, Vietnam, Mexico, and Indonesia are among the countries that have succeeded in developing collaborative management of mangrove forests. The successful rehabilitation and management of mangroves in Teluk Pandan, Lampung, is an example of co-management and optimizing local community participation. With this management approach, the area of mangrove forests in Teluk Pandan Sub-district not only increased, but it was also possible to reduce the mangrove area in rare density and increase the dense category. The success and/or failure of community-based mangrove management on the coast of Teluk Pandan can serve as an example and lesson for mangrove management and conservation efforts, not only in Lampung Province, also in Indonesia. Consistent and continuous management efforts by all stakeholders are required to create a sustainable and well-maintained mangrove ecosystem in the coastal area of Teluk Pandan Sub-district and provide maximum benefits for the community's welfare.

ACKNOWLEDGEMENTS

The authors would like to acknowledge and give sincere gratitude to the village apparatus and community of Hurun, Hanura, Sidodadi, Gebang and Batu Menyan Villages, Teluk Pandan Sub-district, Pesawaran District, Lampung, Indonesia, for the information provided for this study.

REFERENCES

Aheto DW, Kankam S, Okyere I, Mensah E, Osman A, Jonah FE, Mensah JC. 2016. Community-based mangrove forest management: Implications for local livelihoods and coastal resource conservation along the Volta estuary catchment area of Ghana. Ocean Coastal Manag 127: 43-54. DOI: 10.1016/j.ocecoaman.2016.04.006.

Arifanti VB, Sidik F, Mulyanto B, Susilowati A, Wahyuni T, Subarno, Yulianti, Yuniarti N, Aminah A, Suita E. 2022. Challenges and strategies for sustainable mangrove management in Indonesia: A Review. Forests 13: 695. DOI: 10.3390/f13050695.

Arifanti VB, Kauffman JB, Hadriyanto D, Murdiyarso D, Diana R. 2019. Carbon dynamics and land use carbon footprints in mangrove-converted aquaculture: The case of the Mahakam Delta, Indonesia. For Ecol Manageent 432: 17-29. DOI: 10.1016/j.foreco.2018.08.047.

BPDASHL [Balai Pengelolaan Daerah Aliran Sungai dan Hutan Lindung]. 2020. Laporan Akhir Kegiatan Pemulihan Ekonomi Nasional Padat Karya Penanaman Mangrove. Badan Pengelola Daerah Aliran Sungai Way Seputih-Way Sekampung. Lampung. [Indonesian]

Datta D, Chattopadhyyay RN, Guha P. 2012. Community based mangrove management: A review on status and sustainability. J Environ Manag 107: 84-95. DOI: 10.1016/j.jenvman.2012.04.013.

Emiyati S, Budhiman S, Parwati E. 2014. Digital image processing of Spot-4 for shoreline extraction in Lampung Bay. Intl J Remote Sensing Earth Sci 11 (1): 1-10.

FAO [Food and Agriculture Organization]. 2003. Status and Trends in Mangrove Area Extent Worldwide. Forest Resources Assessment Working Paper 63. Forest Resources Division, Rome.

FAO [Food and Agriculture Organization]. 2007. The World's Mangroves 1980-2005. FAO Forestry Paper no 153. Food and Agriculture Organization of the United Nations, Rome.

Firdaus M, Hatanaka K, Saville R. 2021. Mangrove forest restoration by fisheries communities in Lampung Bay: A study based on perceptions, willingness to pay, and management strategy. For Soc 5 (2): 224-244. DOI: 10.24259/fs.v5i2.12008.

Giri C, Ochieng E, Tieszen LL, Zhu Z, Singh, A, Loveland T, Masek J, Duke N. 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. Global Ecol Biogeography 20: 154-159. DOI: 10.1111/j.1466-8238.2010.00584.x.

Gnansounou CS, Sagoe AA, Mattah PAD, Salako VK, Aheto DW, Kakaï RG. 2021. Is the co-management approach effective for mangrove conservation in West Africa?. Research Square 1-27.

Gnansounou CS, Sagoe AA, Mattah PAD, Salako KV, Aheto DW, Kakaï RG. 2022. The co-management approach has positive impacts on mangrove conservation: Evidence from the mono transboundary biosphere reserve (Togo-Benin), West Africa. Wetlands Ecol Manag 30: 1245-1259. DOI: 10.1007/s11273-022-09894-0.

Hamzah AHP, Anggoro S, Puryono S. 2020. Co-management in mangrove rehabilitation at langkat district. E3S Web of Conferences 202: 02001. DOI: 10.1051/e3sconf/202020202001.

Hasani Q, Adiwilaga EM, Pratiwi NTM. 2012. The relationship between the Harmful Algal Blooms (HABs) phenomenon with nutrients at shrimp farms and fish cage culture sites in Pesawaran District, Lampung Bay. Makara J Sci 16: 183-191. DOI: 10.7454/mss.v16i3.1480.

Hasani Q, Pratiwi NTM, Wardiatno Y, Effendi H, Martin AN, Efendi E, Pirdaus P, Wagiran. 2021a. Phytoremediation of iron in ex-sand mining waters by water hyacinth (*Eichhornia crassipes*). Biodiversitas 22 (2): 838-845. DOI: 10.13057/biodiv/d220238.

Hasani Q, Pratiwi NTM, Wardiatno Y, Effendi H, Yulianto H, Yusuf MW, Caesario R, Farlina. 2021b. Assessment of water quality of the ex-sand mining sites in Pasir Sakti Sub-District, East Lampung for

tilapia (*Oreochromis niloticus*) culture. J Degraded Mining Lands Manag 8 (4): 3007-3014. DOI: 10.15243/jdmlm.2021.084.3007.

Hasani Q, Yusup MW, Caesario R, Julian D, Muhtadi A. 2022. Autoecology of *Ceratium furca* and *Chaetoceros didymus* as potential harmful algal blooms in tourism and aquaculture sites at Teluk Pandan Bay, Lampung, Indonesia. Biodiversitas 23: 5670-5680. DOI: 10.13057/biodiv/d231117.

Irawan A, Hasani Q, Yuliyanto H. 2015. Fenomena Harmful Algal Blooms (HABs) di Pantai Ringgung Teluk Lampung, pengaruhnya dengan tingkat kematian ikan yang dibudidayakan pada karamba jaring apung. Jurnal Penelitian Pertanian Terapan 15 (1): 48-53. DOI: 10.25181/jppt.v15i1.111. [Indonesian]

Irawan A, Isnaini, Agussalim A. 2019. Analisis perubahan luasan dan kerapatan mangrove menggunakan data citra satelit Spot di Pesisir Teluk Pandan Kabupaten Pesawaran Provinsi Lampung. Jurnal Penelitian Sains 21: 49-58. DOI: 10.56064/jps.v21i1.529. [Indonesian]

Jhaveri N, Dzung NY, Dung NK. 2018. Mangrove Collaboratif Management in Vietnam and Asia. Washington, DC: USAID Tenure and Global Climate Change Programe.

Keputusan Menteri Lingkungan Hidup Republik Indonesia, No 201, tahun 2004, tentang Kriteria Baku dan Pedoman Penentuan Kerusakan Mangrove. [Indonesian]

Kongkeaw C, Kittitornkool J, Vandergeest P, Kittiwatanawong K. 2019. Explaining success in community based mangrove management: Four coastal communities along the Andaman Sea, Thailand. Ocean Coastal Manag 178: 104822. DOI: 10.1016/j.ocecoaman.2019.104822.

Kumar J, Kumar VME, Rajanna KB, Mahesh V, Kumar NAS, Pandey AK, Manjappa N, Pal J. 2014. Ecological benefit of mangrove. Life Sci Leaflets 48: 85-88.

Kusmana C. 2011. Management of mangrove ecosystem in Indonesia. J Nat Res Environ Manag 1 (2): 152-157.

Kustanti A, Nugroho B, Darusman D, Kusmana C. 2012. Integrated management of mangrove ecosystem in Lampung Mangrive Center (LMC) East Lampung District, Indonesia. J Coastal Develop 15 (2): 209-216.

Muqorrobin A, Yulianda F, Kodiran T. 2013. Co-management mangrove ecosystem in the Pasarbanggi Village, Rembang District, Central Java. Bonorowo Wetlands 3: 114-131. DOI: 10.13057/bonorowo/w030204.

Nabilah R, Sitanggang FI, Rahayu Y. 2021. Mangrove species diversity, stand structure, and zonation—a case study at Pahawang Kecil Island. IOP Conf Series Earth Environ Sci 830: 012004. DOI: 10.1088/1755-1315/830/1/012004.

Nguyen HH. 2014. The relation of coastal mangrove changes and adjacent land-use: A review in Southeast Asia and Kien Giang, Vietnam. Ocean Coastal Manag 90: 1-10. DOI: 10.1016/j.ocecoaman.2013.12.016.

Nguyen HH, Tran LTN, Le AT, Nghia NH, Duong LVK, Nguyen HTT, Bohm S, Premnath CFS. 2020a. Monitoring changes in coastal mangrove extents using multi-temporal satellite data in selected communes, Hai Phong City, Vietnam. For Soc 4 (1): 256-270. DOI: 10.24259/fs.v4i1.8486.

Nguyen HH, Nghia NH, Nguyen HTH, Le AT, Tran LTN, Duong LVK, Bohm S, Furniss MJ. 2020b. Classification methods for mapping mangrove extents and drivers of change in Thanh Hoa Province, Vietnam during 2005-2018. For Soc 4 (1): 225-242. DOI: 10.24259/fs.v4i1.9295.

Nguyen HH, Vu HD, Röder A. 2021. Estimation of above-ground mangrove biomass using Landsat-8 data-derived vegetation indices: A case study in Quang Ninh Province, Vietnam. For Soc 5 (2): 506-525. DOI: 10.24259/fs.v5i2.13755.

Nyangoko BP, Berg H, Mangora MM, Gullström M, Shalli MS. 2021. Community percep,tions of mangrove ecosystem services and their determinants in the Rufiji Delta, Tanzania. Sustainability 13: 63. DOI: 10.3390/su13010063.

Nyangoko BP, Shalli MS, Mangora MM, Gullström M, Berg H. 2022. Socioeconomic determinants of mangrove exploitation and management in the Pangani River Estuary, Tanzania. Ecol Soc 27 (2): 32. DOI: 10.5751/ES-13227-270232.

Papilaya EPP. 2013. Pemilihan kombinasi band citra Landsat 5 TM untuk menganalisa tutupan lahan hutan mangrove di Teluk Dalam Pulau Ambon. Jurnal Ekosains 2 (1): 77-89. [Indonesian]

Purnomo A, Farida I, Vandika AY. 2019. Potensi Pariwisata di Kabupaten Pesawaran Provinsi Lampung. Penerbit Pusaka Media, Bandar Lampung. [Indonesian]

Qurniati R, Hidayat W, Kaskoyo H, Firdasari, Inoue M. 2017. Social capital in mangrove management: A case study in Lampung Province, Indonesia. J For Environ Sci 33: 8-21. DOI: 10.7747/JFES.2017.33.1.8.

Ramdani F, Rahman S, Giri C. 2019. Principal polar spectral indices for mapping mangroves forest in South East Asia: Study case Indonesia. Intl J Digital Earth 12 (10): 1103-1117. DOI: 10.1080/17538947.2018.1454516.

Sarhan M, Tawfik R. 2018. The economic valuation of mangrove forest ecosystem services: Implications for protected area conservation. The George Wright Forum 35 (3): 341-349.

Srikanth S, Lum SKY, Chen Z. 2015. Mangrove root: Adaptations and ecological importance. Trees 10: 15-23. DOI: 10.1007/s00468-015-1233-0.

Tetelepta JMS, Loupatty SR, Wawo M. 2020. Sustainable management strategy for mangrove forest of Pelita Jaya Bay and Kotania bay, Western Seram, Indonesia. Jurnal Triton 16 (2): 53-67. DOI: 10.30598/TRITONvol16issue2page53-67.

Tresiana N, Duadji N, Febryano IG, Maharani MK, Rahmat A. 2021. Regulatory impact analysis on mangrove forest in the coastal area of the Bandar Lampung. IOP Conf Ser Earth Environ Sci 1027: 012027. DOI: 10.1088/1755-1315/1027/1/012027.

Tresiana N, Duadji N, Febryano IG, Zenitha SA. 2022. Saving mangrove forest extinction in urban areas: Will government interventions help? Intl J Sustain Develop Planning 17 (2): 375-384. DOI: 10.18280/ijsdp.170203.

UNEP [United Nations Environment Programme]. 2009. Transboundary Diagnostic Analysis of Land-based Sources and Activities Affecting the Western Indian Ocean Coastal and Marine Environment. UNEP, Nairobi, Kenya.

UNEP-Nairobi Convention/USAID/WIOMSA. 2020. Guidelines on mangrove Ecosystem Restoration for the Western Indian Ocean Region. UNEP, Nairobi.

Yuliana, Hewindati YT, Winata A, Djatmiko WA, Rahadiati A. 2019. Diversity and characteristics of mangrove vegetation in Pulau Rimau Protection Forest, Banyuasin District, South Sumatra, Indonesia. Biodiversitas 20 (4): 1215-1221. DOI: 10.13057/biodiv/d200438.

Waiyasusri K. 2021. Monitoring the land cover changes in mangrove areas and urbanization using Normalized Difference Vegetation Index and Normalized Difference Built-up Index in Krabi Estuary Wetland, Krabi Province, Thailand. Appl Environ Res 43 (3): 1-16. DOI: 10.35762/AER.2021.43.3.1.

Waiyasusri K, Chotpantarat S. 2022. Spatial evolution of Coastal Tourist City Using the Dyna-CLUE Model in Koh Chang of Thailand during 1990-2050. ISPRS Intl J Geo-Information 11: 1-23. DOI: 10.3390/ijgi11010049.

Zaldívar-Jiménez A, de Guevara-Porras PL, Pérez-Ceballosc R, Díaz-Mondragón S, Rosado-Solórzanoe R. 2017. US-Mexico joint Gulf of Mexico large marine ecosystem based assessment and management: Experience in community involvement and mangrove wetland restoration in Términos Lagoon, Mexico. Environ Develop 22: 206-213. DOI: 10.1016/j.envdev.2017.02.007.