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Enabling conditions for the rehabilitation and preservation of mangrove ecosystem in Sampang, Madura Island, Indonesia

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Abstract. *Aftsari I, Pramono CL, Alyodya DA, Nurwulandari M, Sujarta P, Dadiono MS, Yap CK, Setyawan AD. 2024. Enabling conditions for the rehabilitation and preservation of mangrove ecosystem in Sampang, Madura Island, Indonesia. Indo Pac J Ocean Life 8: 1-9.* Mangroves are a very productive ecosystem that is important to the environment and human welfare. Rehabilitation activities need to be carried out to restore mangrove forests that have experienced degradation. In doing so, local communities have an important role because their involvement can minimize human disturbance and realize sustainable mangrove management. This research aims to determine the circumstances that can facilitate or prohibit local communities in the rehabilitation of mangrove forests in Sampang District, Madura Island, East Java Province, Indonesia. This research was conducted in two villages in Sampang District, i.e.: Taddan and Gulbung in December 2023 using two methods, namely remote sensing analysis to determine changes in mangrove cover from 2008 to 2023 and in-depth interviews to determine the role and strategies of the community in mangrove rehabilitation. The remote sensing analysis shows significant increase in mangroves in Taddan Village from 54.7757 ha in 2008 to 101.718 ha in 2023 (+46.9422 ha). During the same period, mangroves in Gulbung Village increased from 21.6928 ha to 30.6723 ha (+8.9795 ha), although there was a decreasing trend during the period of 2013-2023. There is a difference in situation between the two villages, where in Taddan there are rehabilitation and conservation activities, increasing mangroves, while in Gulbung some mangroves have been converted into salt ponds, especially during the last decade. The results of the interviews revealed that public knowledge and awareness regarding the benefits and importance of mangrove management are still low. We also found that the facilitation from governments and the formation of community groups might enable the preservation and rehabilitation of mangrove forests.

Keywords: Mangrove, rehabilitation, remote sensing

INTRODUCTION

Mangroves are a very productive ecosystem found in tidal zones in tropical and subtropical regions. Mangroves play an important function in protecting coastlines from abrasion and flooding, as well as protecting buildings and crops from damage caused by storms containing salt water (Gumay 2022). In addition, it reduces storm surge water levels by slowing water flow and reducing strong waves and wind (Deb and Ferreira 2017). Mangroves are also essential in mitigating climate change by absorbing carbon three to five times higher than carbon storage in terrestrial forests (Eddy et al. 2021). Takarendehang et al. (2018) state that mangrove ecosystem has important ecological and socio-economic roles. From an ecological perspective, mangroves serve as habitat for various marine biotas and play an important role in maintaining the food chain (Singh 2020). From an economic perspective, mangroves provide various resources for local communities, from fisheries to timber for charcoal or building materials (Safe'i 2022). More recently, mangrove ecosystems have increasingly developed to play role in the social aspect, namely as a place for tourism, recreation and education (Quinn et al. 2017).

Mangroves can respond to climate change, geological, chemical, biological and physical phenomena with spatial and temporal patterns (Mandal and Bar 2018). They have specialized morphological adaptations for survival and have special mechanisms for salt tolerance (Sudhir et al. 2022). Mangrove forests consist of vegetation communities, ranging from mixed to pure stands. Mangrove communities worldwide are dominated by four genera, namely *Sonneratia*, *Rhizophora*, *Bruguiera*, and *Avicennia* (Veettil et al. 2019).

Malaysia and Indonesia are countries in Asia with the largest mangrove areas (Romañach et al. 2018). Indonesia alone has the largest mangrove forests in the world, with a total area of 3.31 million ha (Arifanti 2020). In Indonesia, mangrove forests are spread across five large islands: Java, Kalimantan, Sulawesi, Papua, and Sumatra (Kusmana 2014). Basyuni et al. (2022) state that most mangrove forests are spread across eastern part of Indonesia. Despite the large extent and high importance, mangrove forests in Indonesia have been degraded and converted into other land uses in the last few decades. According to the Ministry of Forestry and Environment, 430,000 ha mangrove forests

have been degraded in the period 1985 to 2019.

Mangrove forests have been heavily impacted by degradation and deforestation (Goldberg et al. 2020). This is due to forest clearing for fish pond development and exploitation for producing wood and raw materials, as well as rapid coastal population growth and urban expansion (Thomas et al. 2017). Therefore, mangrove rehabilitation is promoted to reverse mangrove loss and degradation. In Indonesia, community-based mangrove management and rehabilitation are considered successful in providing benefits for ecology, economy, socio-cultural, and institutional sustainability (Damastuti and Groot 2017). However, several problems remain, including the high death rate of planted mangrove seedlings especially when the planting is carried out in permanently flooded areas (Hilmi et al. 2022).

Madura Island is among the islands in Indonesia with the presence of mangroves. The area of mangrove forests in Madura Island is 15,118.2 ha (Muhsoni 2014). However, over 10 years, there has been continuous degradation of the mangrove area in Madura, for example, 276.38 ha of mangroves in Sampang District are degraded due to land conversion and coastal reclamation (Hidayah et al. 2015). According to Hidayah and Rosyadi (2019), high mangrove degradation in Madura Island makes it necessary to rehabilitate mangrove forests. This rehabilitation activity can positively impact the economic development of communities around the coastal area (Wahyurini and Harisudin 2021). Local communities have an important role in mangrove management because their involvement can minimize human disturbance and realize sustainable use of mangrove resources (Martuti et al. 2018). So, further research is necessary to determine the level of community participation in conserving and rehabilitating mangrove forests to manage sustainably.

This research aims to determine the situation and conditions faced by the coastal communities in Sampang, Madura Island which leads to the rehabilitation and preservation of mangrove forests on the coast of Sampang.

MATERIALS AND METHODS

Study area and period

This research was conducted in Taddan Village, Pangarengan Sub-district and Gulbung Village, Camplong Sub-district of Sampang District, Madura Island, East Java Province, Indonesia (Figure 1), in December 2023. The research was conducted in two villages, namely Gulbung and Taddan villages. Data collection was carried out in the mangrove area along the coast of the two villages and adjusted to field conditions based on accessibility (Figure 2). The area of mangroves in Sampang District is 362.177 ha, covering Sreseh, Pangarengan, Sampang, and Camplong Sub-districts (Tsani and Muhsoni 2022) with mangrove extent in Camplong reaching 48 ha (Pratiwi and Muhsoni 2021).

Data collection procedures

The data used in this research were primary and secondary data obtained through two methods: in-depth interviews and remote sensing. Remote sensing was used to determine the changes in mangrove areas from 2008 to 2023. Primary data was collected through semi-structured questionnaires regarding community knowledge and contributions to mangrove preservation and rehabilitation and in-depth interviews with respondents determined using a purposive sampling method with one key informant in *Tagana* (*Taruna Siaga Bencana* or Disaster Preparedness Youth Group) of Taddan Village and 60 respondents (30 people for each village); there were no special criteria for the respondents selected, and all people had the same opportunity to become respondents. The interview aimed to obtain community knowledge about the importance of sustainable mangrove forest management. Besides the interviews, field observations were carried out to obtain supporting data on the actual condition of mangrove forests on the coast of Sampang, Madura Island.

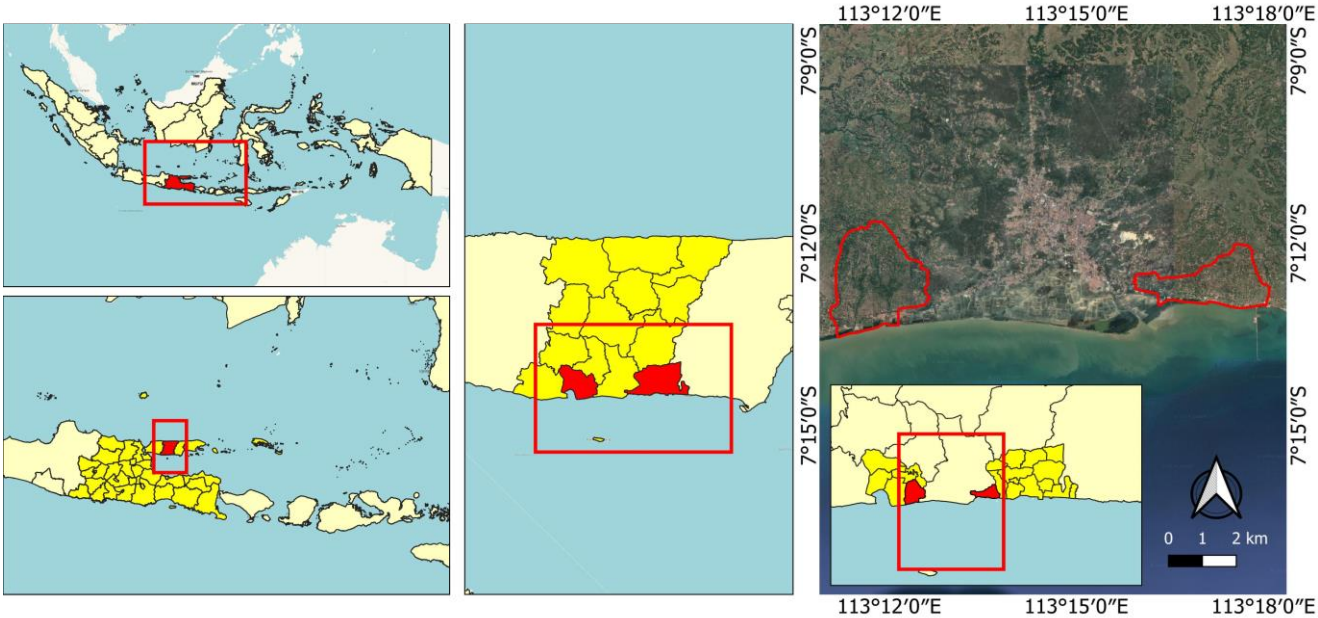

Figure 1. Map of research locations in Taddan and Gulbung villages, Sampang District, East Java Province, Indonesia

Figure 2. The condition of mangrove ecosystem in A. Taddan Village, Pangarengan Sub-district and B. Gulbung Village, Camplong Sub-district of Sampang District, East Java Province, Indonesia

Meanwhile, secondary data was obtained from remote sensing and literature studies relevant to the topic discussed. This study used Landsat 7 and 8 satellite images in the last 15 years (2008 to 2023). This time range was chosen to map the distribution of mangrove density every 5 years, namely in 2008, 2013, 2018, and 2023. Landsat 7 satellite images were used in 2008, while Landsat 8 satellite images were used in 2013, 2018, and 2023. The Landsat image used is Landsat Collection 2 Level 1 on the coast of Taddan and Gulbung villages. Landsat 7 and 8 satellite images were freely downloaded from https://www.earthexplorer.usgs.gov/. Satellite imagery is used to evaluate mangrove land changes over 15 periods.

Data analysis

NDVI calculation

The NDVI (Normalized Difference Vegetation Index) is used to analyze the changes in vegetation cover (Hashim et al. 2019). The NDVI is often used to determine the state of vegetation in an area because it can capture the density of green vegetation at a spatial resolution of 30 meters (Bid 2016). The NDVI was calculated as follows (Barbosa et al. 2006):

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad [1]$$

Where:
NDVI : Normalized Different Vegetation Index
NIR : Near Infrared

NDVI ranges from -1 to 1, and non-vegetation objects such as clouds, water, and other objects have values less than zero. Meanwhile, objects representing vegetation have a value range of 0.1 to 0.7. The NDVI range for mangrove forest density has a value range of 0.1-0.6. The higher the value, the healthier the vegetation cover (Hardianto et al. 2021).

In-depth interviews and questionnaire

The results of in-depth interviews and literature studies data were analyzed descriptively through historical explanations. Then, such results were compared with the remote sensing data analyzed using the NDVI method to compare mangrove cover changes between 2008, 2013, 2018, and 2023.

RESULTS AND DISCUSSION

The extent and dynamics of mangrove forests in coastal areas in Sampang District

The result of remote sensing analysis shows that the area of mangrove forests in Taddan Village is quite high with 101.718 ha in 2023 (Table 1). Every year, the area of mangrove forests in Taddan Village increased significantly. Table 1 and Figure 3 shows that between 2008-2013, the area of mangrove forests in this village increased by 15.0762 ha, from 54.7757 ha to 69.8519 ha. Furthermore, in 2013-2018, there was an increase of 31.7121 ha, from only 69.8519 ha to 101.564 ha. Meanwhile, in 2018-2023, there was an increase of 0.1540 ha, from 101.564 ha to 101.718 ha. The total increase in mangrove forest area from 2008 to 2023 is 46.942 ha.

Based on the results of interviews, the increase in the area of mangrove forests in Taddan Village was due to several factors, including the rehabilitation program by planting mangrove seedlings arranged by the Ministry of Marine and Fisheries and the formation of a mangrove rehabilitation group. Apart from that, another factor is that village communities were also invited to clean the mangrove forest and plant mangrove seedlings. The increasing mangrove forest in Taddan Village positively impacts the community by minimizing abrasion and increasing the village economy because the mangrove forest in this village is used as an educational tourism site (Purwanti et al. 2020).

Meanwhile, in Gulbung Village, the area of mangrove forest in 2023 is only 30.6723 ha (Table 1, Figure 4). Between 2008 and 20123, the mangrove forest in this village experienced decrease and increase. Table 1 revealed that in the 2008-2013 period, there was an increase of 16.6217 ha, from 21.6928 ha to 38.3146 ha. However, from 2013 to 2018, the area of mangrove forests decreased by 6.8285 ha, which became 31.4860 ha. Then, during 2018-2023, the area of mangrove forests in this village decreased by 0.8137 ha, resulted in 30.6723 ha of mangrove forest in 2023. In summary, from 2008 to 2023, the area of mangrove forests increased by 8.9795 ha, but there is a decreasing trend toward nowadays. This loss of mangroves is because of the expansion of salt ponds in this village. Other influencing factors are the absence of conservation groups, followed by the lower public's understanding of the ecological importance of mangrove forests. If it continues unabated, this condition will increase the risk of abrasion and land subsidence in Gulbung Village (Alfandi et al. 2019).

Table 1. The extent and changes of mangrove forests along the coast of Taddan and Gulbung villages, Sampang District, East Java Province, Indonesia

Year	Extent of mangrove forest (ha)		Changes of mangrove forest (%)	
	Taddan	Gulbung	Taddan	Gulbung
2008	54.7757	21.6928	-	-
2013	69.8519	38.3146	+15.0762	+16.6217
2018	101.5640	31.4860	+31.7121	-6.8285
2023	101.7180	30.6723	+0.1540	-0.8137
2008-2023			+46.9422	+8.9795

Note: positive means increase in extent; negative means decrease in extent

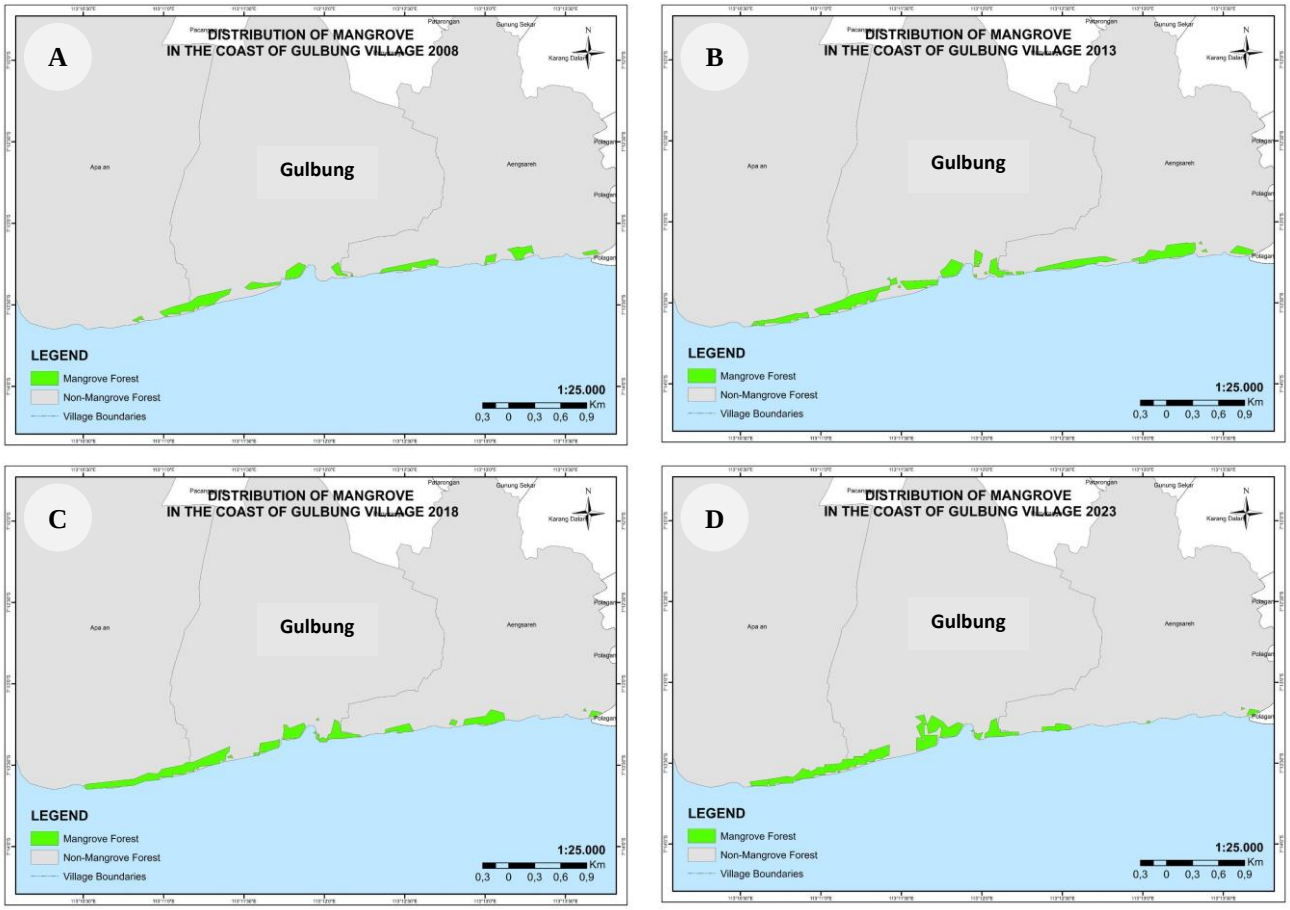

Figure 3. Spatial distribution of mangrove forests along the coast of Gulbung Village, Sampang District, East Java Province, Indonesia in: A. 2008, B. 2013, C. 2018, D. 2023

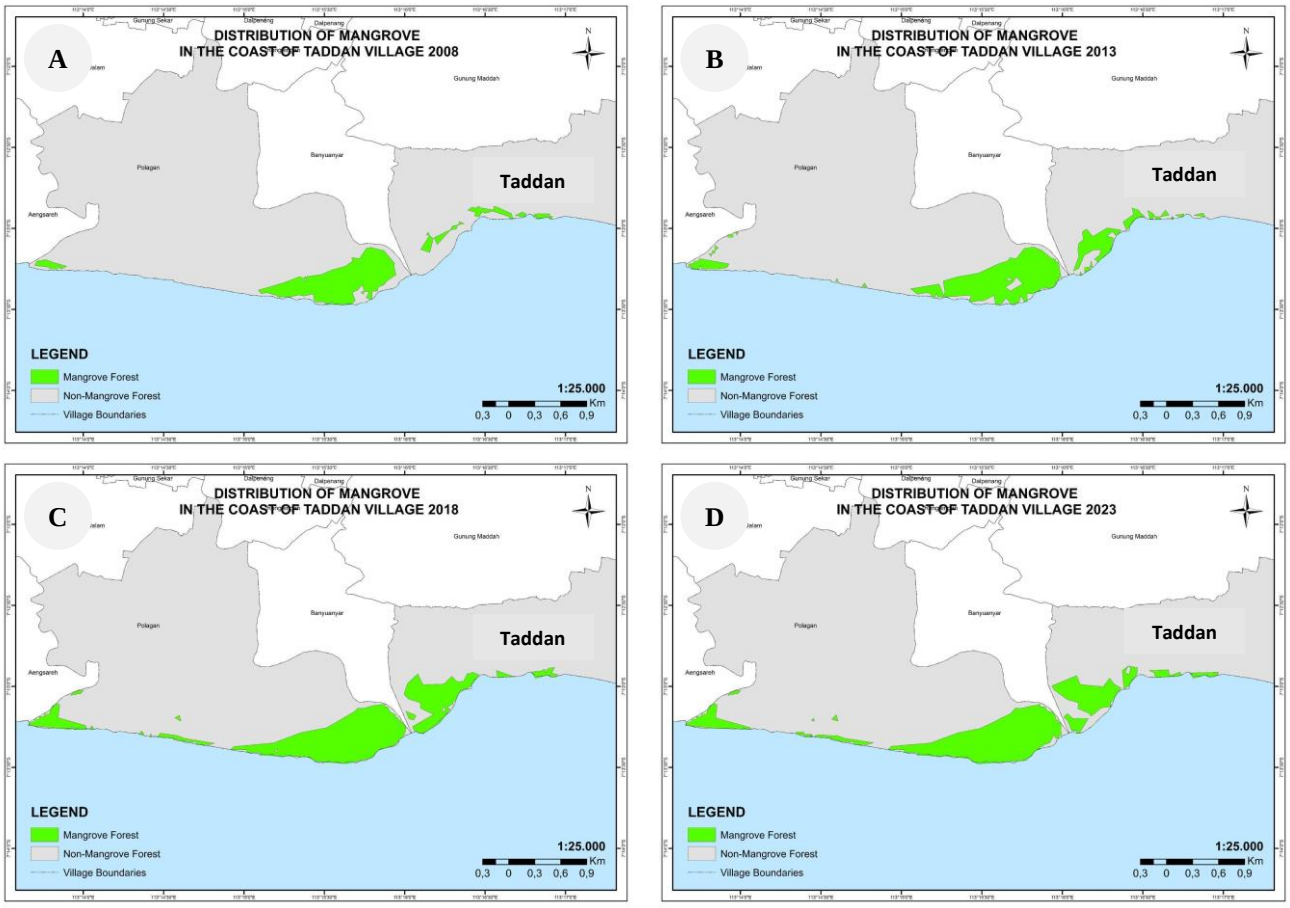

Figure 4. Spatial distribution of mangrove forests along the coast of Taddan Village, Sampang District, East Java Province, Indonesia in: A. 2008, B. 2013, C. 2018, D. 2023

The difference in result between the two villages is related to several factors, but mainly due to the presence of salt ponds. Salt ponds in Gulbung Village have essential socio-economic roles (Bachri et al. 2020) where the many salt ponds in this village improve the economy of the surrounding community so that Madura Island is known as a salt-producing island (Widyanti and Setiyonugroho, 2022). However, the uncontrolled growth of salt ponds has disrupted the mangrove ecosystem, affecting biodiversity and communities (Siddig et al. 2020). The other factor was the very low public understanding of the importance of mangrove forests (Dharmawan et al. 2016). The low knowledge of the importance of mangroves led to their degradation since they could not manage them (Cahyaningsih et al. 2022).

Community's knowledge regarding the benefits of mangrove forests

The result of interviews shows that some people are aware of the existence of mangrove forests on the coast of Sampang, Madura Island. However, public knowledge regarding the benefits of mangrove forests, both in terms of ecological and economic aspects, is still limited. The interviews with coastal communities in Sampang, Madura Island, revealed a low understanding, especially regarding the benefits of mangrove forests as a place for animals to grow and breed and the benefits to their economy. Most people do not know about these benefits. Around 72.1% of people do not know the benefits of mangroves as an animal habitat, and 65.6% do not know the benefits of mangrove forests for the community's economy (Table 2). This is particularly eminent among the people in Gulbung Village, whose knowledge about the benefits of mangrove forests is lower than those in Taddan Village, resulting in the people not preserving the existence of mangrove forests because they do not know the importance and many benefits of mangrove forests (Nanlohy and Masniar 2020).

There are differences between the mangrove forests in Gulbung and Taddan villages. The mangrove forest in Gulbung Village has experienced degradation due to its conversion to salt ponds. The managers consider salt ponds more profitable than preserving mangroves, so the mangrove forest is converted into salt ponds to increase economic benefits (Friess et al. 2020). The remaining mangrove forests are only to protect the salt ponds from being affected by abrasions. Furthermore, this coastal community does not deeply understand the benefits of mangrove forests, such as a habitat for various animals, protection from tsunamis, benefits for the economy, and others (Indarsih and Masruri 2019). Meanwhile, in Taddan

Village, the community said they usually use mangroves as animal feed, firewood, cigarette paper, and fishing in the mangrove ecosystem. According to Sri et al. (2023), mangrove leaves can be used in making cigarette paper. Therefore, the interviews show that the knowledge of coastal communities in Taddan Village regarding the benefits of mangroves is higher than that of communities in Gulbung Village. Overall, the awareness among the coastal communities in Sampang, Madura Island regarding the importance of mangrove forests for the balance of the coastal environment and the various benefits of mangroves for life is still relatively low.

Table 2 shows that most people know the benefits of mangroves as protection against tsunamis, preventing water intrusion, and protecting settlements from abrasion and sea winds. However, the community does not understand the benefits of mangroves as animal habitats and supporting their economy. So that people know more about the ecological benefits than the economic benefits of mangrove forests for their living. This result differs from the research conducted by Iswandaru and Febryano (2021), who found that people tend to know that mangroves can be used to generate livelihoods including the harvesting of crabs, shrimp, and leaves or fruit that can be used as medicine.

The roles of coastal community in mangroves rehabilitation

According to Amal and Baharuddin (2016), the community's role in mangrove rehabilitation is their involvement, starting from thinking, planning, implementing, monitoring, and evaluating. The participation of the coastal community in Sampang, Madura Island in mangrove rehabilitation is relatively low because community's knowledge about the importance of mangroves is also still low. This is supported by interview results, which show that 85.2% of the community did not participate in mangrove forest rehabilitation (Table 3). In Taddan Village, several efforts to preserve and rehabilitate mangrove forests are mostly conducted by a special group called *Pokmaswas Permata* (Permata Supervisory Community Group). Based on information from *Tagana* as a key informant interview, *Pokmaswas Permata* was formed in 2019, starting with the awareness of Sampang youth on the importance of mangrove forests for the sustainability of Madura's coastal areas. Apart from *Pokmaswas Permata*, *Tagana* Sampang also plays a role in rehabilitating mangrove forests on the coast of Sampang, Madura Island.

The mangrove rehabilitation program was carried out in 2020 with the planting of 130,000 seedlings arranged by the Ministry of Marine and Fisheries (*Kementerian Kelautan dan Perikanan*/KKP 2020). The background that drove this rehabilitation activity was the awareness of mangroves' extraordinary benefits and potential. Moreover, the degradation of mangrove forests reduces the mangrove ecosystem's biota and affects some road networks. Therefore, some people know the importance of rehabilitation, starting a movement to conserve mangroves and maintain their survival. Then, they proposed the local Marine and Fishery Services (*Dinas Kelautan dan Perikanan*/DKP) to form a mangrove rehabilitation and conservation group, namely *Pokmaswas Permata*. Next, the DKP continued the proposal to the KKP. Finally, the KKP provided 130,000 mangrove seedlings, and *Pokmaswas Permata* was formed in 2019 and then they carried out a rehabilitation program. The mangroves planted were *Rhizophora stylosa*, *Sonneratia alba*, and *Avicennia marina*.

Before the rehabilitation program, mangrove forest conservation activities conducted by the community were only in the form of cleaning and establishing nursery in 2017. However, after being established in 2019, the nursery activities were still only carried out by the *Pokmaswas Permata* group and did not involve community participation. So, the coastal communities in the studied area have not been fully involved in mangrove forest rehabilitation, and most of the rehabilitation activities were carried out by *Pokmaswas Permata*. Therefore, the limitations to managing mangrove forests on the coast of Sampang, Madura Island, were the lack of land permits and low public awareness. Also, barnacle disease which attacked mangroves hindered mangrove growth. Risnasari et al. (2021) state barnacles (subclass Cirripedia; subphylum Crustacea) are invertebrates attached to wood or other hard objects in sea and brackish waters. Barnacles are a type of pest which attacks seedlings to sapling levels in mangroves that generally stick to the stems, and their presence is a serious problem because it inhibits growth and damages mangroves (Haneda and Suheri 2018). The barnacle pests can be eradicated by spraying with crustacean repellent (Mustafirin 2016). To increase public awareness, it is necessary to carry out more regular campaigns regarding the benefits and importance of mangrove forest conservation efforts and make written regulations prohibiting all things that can damage mangrove forests. Based on the interviews in Gulbung Village, the local community does not manage the mangrove forest. Mangrove forests are only managed by the government and salt pond owners to protect their ponds; the community does not know more about the activities carried out to rehabilitate mangroves in that they are not directly involved.

Table 2. The knowledge of communities in Taddan and Gulbung villages, Sampang District, Indonesia regarding the benefits of mangrove forests

Aspect	Yes (%)	No (%)
Mangrove forests are a place for animals to grow and breed (shrimp, crabs, squid, etc.)	27.9	72.1
Mangrove forests function and importance for protecting coastal area against tsunami disasters	72.1	27.9
Mangrove forests function and importance for preventing water intrusion	59.0	37.7
Mangrove forests function for protecting settlements from abrasion and sea winds	62.3	36.1
Mangrove forests are useful to the community's economy	34.4	65.6

Table 3. Results of interviews regarding community participation in mangroves rehabilitation

Question	Yes (%)	No (%)
Are you aware of any mangrove rehabilitation activities?	50.8	49.2
Do you participate in mangrove rehabilitation activities?	13.1	85.2

Strategies of coastal community to maintain the existence of mangroves

Strategies to maintain the existence of mangroves are very necessary (Hillary et al. 2019), and one solution that can be done is through conservation. However, the mangrove forests in Taddan and Gulbung villages do not yet have conservation permits. Thus, providing regulations for the community is a little bit hampered. There should be also cooperation between the government, conservation managers, and the community (Mahifa et al. 2018). Based on the results of interviews with *Tagana* as a key informant, socialization has been carried out regarding the function of mangrove forests as of 2021. Many people are aware of the mangrove forest rehabilitation movement in *Pokmaswas Permata*, but only a few people are participating in this activity. This is because people's understanding of the function of mangroves is still very low; thus many people still illegally cut down mangroves, which are used for animal feed, firewood, building materials, and much more.

Mangrove forest management strategies include the implementation of government policies to maintain the potential of mangrove ecosystem resources, utilization of the potential of mangroves as ecotourism and educational activities, revitalization of traditional institutions as an effort to manage mangrove forest areas, and increase knowledge and awareness of local communities regarding the function of mangrove forests. For example, in Taddan Village, the strategy that can be implemented is collaboration between the community and the government. By granting a conservation land permit, the management of mangrove forests at the village level will lead to better and greater community involvement in conservation. The community is expected to participate in managing mangrove forests directly or indirectly, such as through outreach activities to clean the coast. Meanwhile, in Gulbung Village, an effort must be conducted to reach the entire community to increase public awareness of the importance of mangrove forests for their lives.

Important lessons from sustainable mangrove management in Sampang

The success story of sustainable mangrove management in Taddan Village started with reforestation and conservation. Activities conducted successfully minimize abrasion, maintain seawater levels to become not too salty, and apply the mangrove area as an educational tourism site. Community has an important role in managing natural resources to maintain the existence of mangrove forests on the coast of Sampang, Madura Island (Hidayah et al. 2020). Some people already understand that mangrove forests must be preserved and cannot be cut down haphazardly. The community has also started to participate in the movements organized by *Pokmaswas Permata*, such as counseling, community service, cleaning mangrove forests, and much more. Furthermore, many actions have been taken to support mangrove conservation, including routine beach clean-ups, collaboration with organizations and communities for mangrove planting activities, collaboration with state-owned companies (BUMN) to obtain CSR (Corporate Social Responsibility), and conducting training to process mangrove byproducts. Based on the results of interviews with *Tagana* as a key informant, sustainable mangrove management in the studied area occurs through a bottom-up scenario, which the village youth promoted during the initial stage. The early stages initiated by the village's youth improved their knowledge, skills, and social attitudes toward preserving and managing the mangrove area so that it can be properly managed and used wisely (Hur et al. 2021).

Based on the research results, the area of mangrove forests in Taddan and Gulbung villages, Sampang District, Madura Island, experienced changes between 2008 and 2023 with dynamics of both increasing and decreasing. The most significant increase was in Taddan Village, which previously was only 54.7757 ha in 2008 but is now 101.718 ha. During the same period, the area of mangrove forest in Gulbung Village was only 21.6928 ha and increased to 30.6723 ha, although there was a decreasing trend from 2013 to 2023. There are distinct differences between the two research locations, namely that mangroves in Taddan Village increased due to the rehabilitation movement. Conversely in Gulbung Village, the decrease of mangroves was due to the conversion of mangroves into salt ponds. Some people in the coastal area in Sampang, Madura Island still do not understand mangroves' function and important role in their lives. The results of interviews show that community knowledge regarding the benefits of mangrove forests is still relatively low. The rehabilitation movement that was carried out in 2020 involved planting of 130.000 seedlings. However, in the rehabilitation movement, the involvement of the community is still limited and relatively low. Therefore, further efforts are important to increase public understanding and awareness of preserving and rehabilitating mangrove forests. Many efforts to rehabilitate mangrove forests can be carried out by implementing government policies to maintain the potential of mangrove ecosystem resources, utilizing the potential of mangroves as ecotourism and educational activities, revitalizing traditional institutions as an effort to manage mangrove forest areas, and increasing knowledge and awareness of local communities regarding the function of mangrove forests.

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