

Mangrove forest in Batu Bara Regency, Indonesia: dynamics of forest area changes and perception of coastal communities in mangrove ecosystem management

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Abstract. Batu Bara Regency is one of the regencies in North Sumatra Province with mangrove forests. Since 2013, there has been a change in the coastline where the mangrove forest is located. This study aims to evaluate the correlation between perception of coastal populations near mangrove forests and the mangrove forest area changes in Batu Bara Regency from 2013 to 2022. This study was conducted for five months, from June to October 2022, in Talawi, Tanjung Tiram, and Lima Puluh Pesisir Districts. This research uses a mangrove map generated from the Indonesian Geospatial Information Agency data for the year 2013, data from Landsat 8 OLI/TIRS Collection 2 Tier 1 Raw Scenes satellite imagery for the year 2017, and data from Landsat 9 OLI/TIRS Collection 2 Tier 1 Raw Scenes satellite imagery for the year 2022. The Google Earth Engine and ArcGIS 10.5 platforms were used in this work to acquire and process satellite image data. Meanwhile, the public's perception of the mangrove environment was measured using a questionnaire. The information was then examined using the Simple Multi-Attribute Rating Technique (SMART). The categorization results showed that public perceptions of the plants are positive. This, however, contradicts observations indicating a decline in mangrove forest area. This may occur due to the community's business acquisition of mangrove forest land. Therefore, government support is required to educate and assist coastal communities in the preservation of mangrove forests so that the decline in mangrove forest area can be reduced or even prevented in the future years.

Key Words: coastline change, community engagement, mangrove forest, sustainable management.

Introduction. Indonesia, along with Australia, Brazil, Nigeria, and Mexico, accounts for 48% of the world's mangroves (Akpoovwo 2020). At the end of 2000, it was estimated that Indonesia's mangrove forests covered 3,112,989 hectares, which accounted for 22.6% of the world's total mangrove area (Dsikowitzky et al 2019). In addition to their large size, the mangroves in Indonesia are renowned for their incredible biodiversity, making the discovery of undocumented species highly probable. According to Wardani et al (2016), in Indonesia, there are 202 mangrove species, of which 33 are tree species and 10 are true mangrove species categorized as shrubs, while the remaining species are classified as mangrove associates. However, the area of mangrove distribution has reduced. The decline was might due to land conversion into ponds and illegal logging activities (Eddy et al 2015). In 2001, Batu Bara Regency in North Sumatra had 1,598.38 hectares of mangrove forest (Lubis et al 2017). However, according to the Batu Bara Forestry Service, there was a decline (45.2%) in the mangrove forest area, which became 876.06 hectares in 2010 (Sitompul et al 2014).

The government has developed sectoral management of coastal areas to monitor a particular type of coastal resource (Muñoz 2020). Although the management of this

coastal area serves a specific goal, its implementation disregards ecological, topographical, and socio-cultural considerations, resulting in a lack of public awareness (Dale et al 2019). This management method can lead to conflicts of interest amongst sectors with development interests in the same coastal region. Moreover, this type of sectoral approach typically pays less attention to the implications of managing other resources, which might harm enterprises in other industries (Nanlohy et al 2014).

It is easier to successfully manage mangrove forest resources by first comprehending the perceptions and attitudes of the general populace. Perception is becoming aware of the surrounding environment, which includes the organization and interpretation of psychological experiences as stimuli. According to Kowalski & Conway (2019) and Sondakh et al (2019), community awareness and participation aid in developing effective mangrove forest management plans. In addition, community support and active participation in mangrove forest protection are determined by public understanding, opinion, and acceptance of mangrove protection activities (Begum et al 2012; Thompson & Friess 2019). These activities necessitate natural shelters for all participants inside and beyond the community (Mahmood et al 2021). This activity is conducted primarily to satisfy the needs of various interests. Several researchers cite the need for more knowledge on the use of mangroves at the local level as a significant barrier to implementing community-based mangrove management.

As part of a more significant movement advocating for community-based forest management, community-based mangrove management has been extensively pushed. This strategy has been proposed as a solution to the shortcomings of state forest management, as state forestry agencies are frequently viewed as incapable of conserving forest resources independently. Over the past three decades, numerous nations have implemented regulations and begun projects encouraging locals to participate in community-based forest management. Numerous studies have found that forest management involving local people and communities is more effective than state agencies without community participation, as evidenced by lower deforestation rates and forest degradation in community forests (Stone et al 2008; Roy et al 2013; Sattayapanich et al 2022). This study does not consider community involvement, however, because data or indicators of successful management of the mangrove forest area must be supported by a growth of the forest area. This research is a preliminary investigation into how coastal communities perceive mangrove forests and how these perceptions may influence changes in mangrove forest area. Therefore, this research aims to examine whether perception of coastal communities in mangrove ecosystem management in Batu Bara Regency, Indonesia affects mangrove forest area changes.

Material and Method

Study sites. The research was conducted for five months from June to October 2022 in three districts: 1) Talawi District, specifically Mesjid Lama, Indramayu, and Dahari Selebar Villages; 2) Tanjung Tiram District, specifically Bogak, Bandar Rahmat, and Pahlawan Villages; and 3) Lima Puluh Pesisir District, specifically the coastal regions of Perupuk, Gambus Laut, and Guntung Villages. Figure 1 depicts the locations of the research.

Data collection. This study shows the dynamics of forest area changes using mangrove data from the National Mangrove Map 1:25,000 of the Indonesian Geospatial Information Agency for the year 2013, Landsat 8 OLI/TIRS Collection 2 Tier 1 Scene Raw Scenes satellite imagery for the year 2017, Landsat 9 OLI/TIRS Collection 2 Tier 1 Scene Raw Scenes satellite imagery for the year 2022 and the topographical map of Indonesia at a scale of 1:25,000. This study used the Google Earth Engine and ArcGIS 10.5 platforms to collect and interpret satellite image data.

The assessment of public perception was conducted through questionnaire-guided interviews. This study examined public opinion regarding the function and significance of mangrove ecosystems along the coasts of Talawi, Tanjung Tiram, and Lima Puluh Pesisir Districts in Batu Bara Regency. The participants were the communities in 9 villages of 3

districts, namely Talawi, Tanjung Tiram, and Lima Puluh Pesisir Districts (Batu Bara Regency). The participants consist of 973 people, which were selected using purposive sampling technique, with the following criteria: participants were residents who live in 3 districts and participate in the socialization of mangrove ecosystem management organized by researchers.

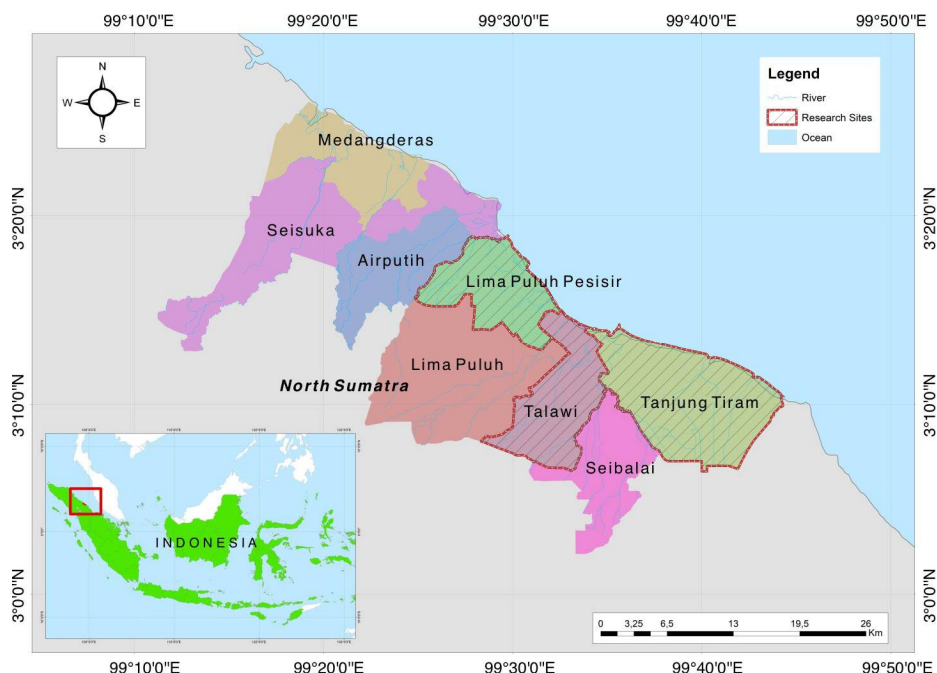


Figure 1. Map of research site: Batu Bara Regency, North Sumatra, Indonesia.

Data analysis. Comparative data on mangrove areas in 2013, 2017, and 2022 were assessed in many stages: 1) selection of satellite imagery with the least amount of cloud cover at the research site; 2) processing and digitization of satellite image data; and 3) mapping and estimating the area of mangrove regions. In the first stage, satellite imagery is visually analyzed using data organized by year in the research location. The selected data must be without cloud cover or has the least amount of cloud cover.

Furthermore, mangrove digitization of satellite image data was done to transform raster data into vector data. Vector data serves as the foundation for a variety of analyses and operations. Digitization was conducted using ArcGIS software (Nugroho & Kusuma 2018). The results of the digitization were saved as a shapefile (file.shp). The digitizing procedure is utilized to establish the observable area's size. In addition, the identification of mangroves in an image is accomplished by visually inspecting the image.

Eventually, mangrove area mapping was done by combining sub-district characteristics with the same attribute in a single file using merging tools. This method was applied in the calculate geometry column to select the area option and the coordinate system option, namely WGS 1984 UTM Zone 47N with hectare units. In addition, the source of the administrative area boundary data is the Indonesian Geospatial Information Agency portal.

The perception of the public in the mangrove environment were measured using a questionnaire. The information was then examined using the Simple Multi-Attribute Rating Technique (SMART). SMART is a multi-criteria decision-making technique based on the notion that each option consists of a set of criteria with values and weights indicating the relative importance of each standard to the others (Borissova & Keremedchiev 2019). Furthermore, the perception categories were analyzed using a Likert scale. The Likert scale is a measurement for assessing the attitudes, thoughts, or perceptions of people or groups about a particular topic (Sugiyono 2009; McNabb 2020). Table 1 shows score categorization used on a Likert scale to gauge public opinion. Respondents' answers were then arranged in categories following the criteria in Table 2. The class interval is 0.8, obtained using the following equation:

$$\text{Class interval} = \frac{\text{highest score} - \text{lowest score}}{\text{number of classes}}$$

Table 1

Respondents' answers based on the Likert scale

<i>Respondent's answer</i>	<i>Score</i>
Strongly disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly agree	5

Source: Cahyadinata et al (2019).

Table 2

Categories of public perception

<i>Average score (x)</i>	<i>Perception category</i>
$1.00 \geq x \geq 1.80$	Poor
$1.80 > x \geq 2.60$	Somewhat good
$2.60 > x \geq 3.40$	Good enough
$3.40 > x \geq 4.20$	Good
$4.20 > x \geq 5.00$	Very good

Source: Saptorini (2003).

Results

Dynamics of mangrove forest area changes. The distribution of mangroves along the Batu Bara Regency coastline is depicted in Figure 2. The mangrove areas along the coast of Batu Bara Regency were 2,390.4, 1,851.4, and 1,643.3 hectares for 2013, 2017, and 2022, respectively. Therefore, there is a decline of mangrove forest area by 31.3% from 2013 to 2022. Based on Figure 2, the mangroves along the coast of Batu Bara Regency have declined at many locations while others have grown in size. However, the trend of changes in the number of mangroves along the coast of Batu Bara Regency has reduced.

Public perception. Figure 3 shows the differences in the community's education levels. There are 409 unschooled people, 341 people with elementary school backgrounds, 146 people with junior high school backgrounds, 48 with senior high school backgrounds, and 29 with undergraduate school backgrounds. These data clearly state that people with no educational background are the majority of respondents.

Meanwhile, the age of the respondents varied considerably from 20 to more than 60 years old. The survey results were grouped into five age groups, as illustrated in Figure 4.

According to the survey, fishing is the most occupation in the community. Most respondents rely on fishing as their primary source of income. This profession is the highest due to the proximity of this area to the coast and mangroves, where people can take advantage of employment opportunities with marine products and mangroves. Figure 5 presents the variety of community occupations in the research area.

In addition, the survey reveals income of the respondents varied from lower than Rp250,000 to more than Rp1,000,000, which can be summarized in Table 3. Meanwhile, data regarding the duration of stay in the village are presented in Figure 6.

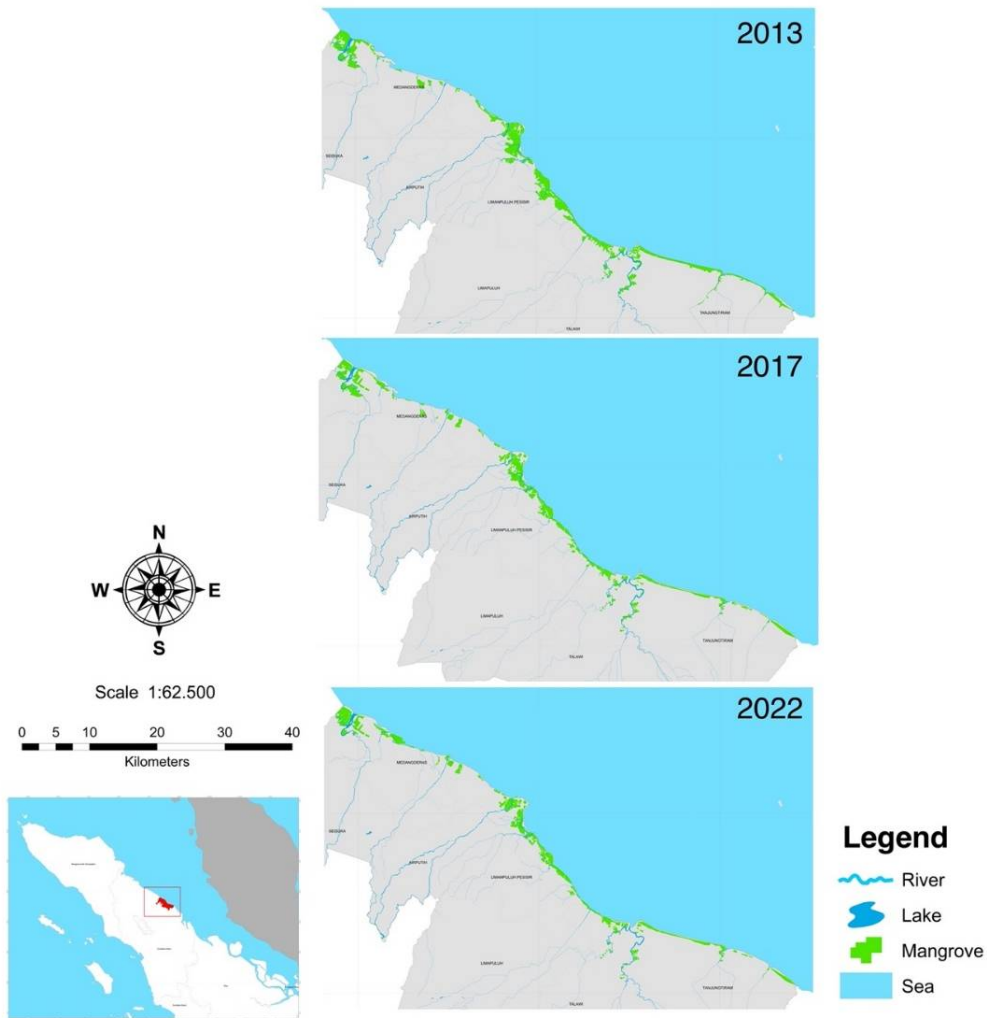


Figure 2. Dynamics of mangrove forest area changes in Batu Bara Regency (2013-2022).

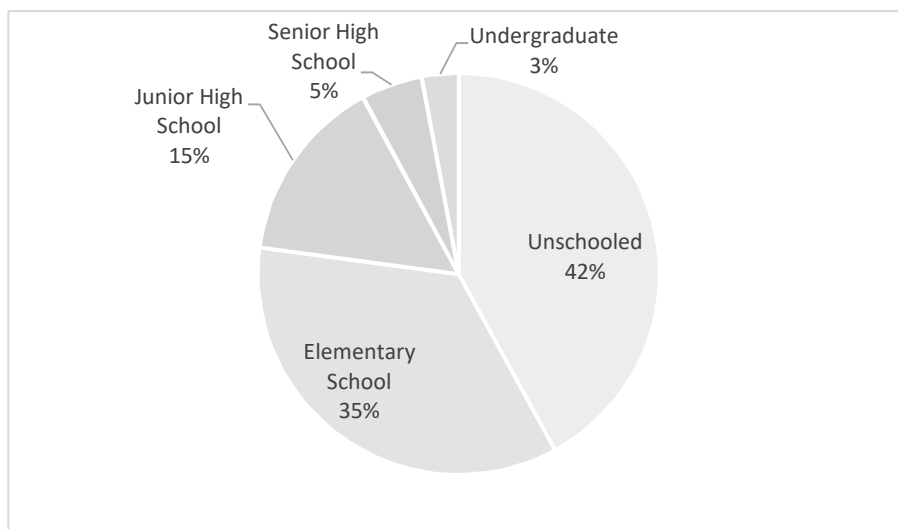


Figure 3. Characteristic of respondents based on educational background.

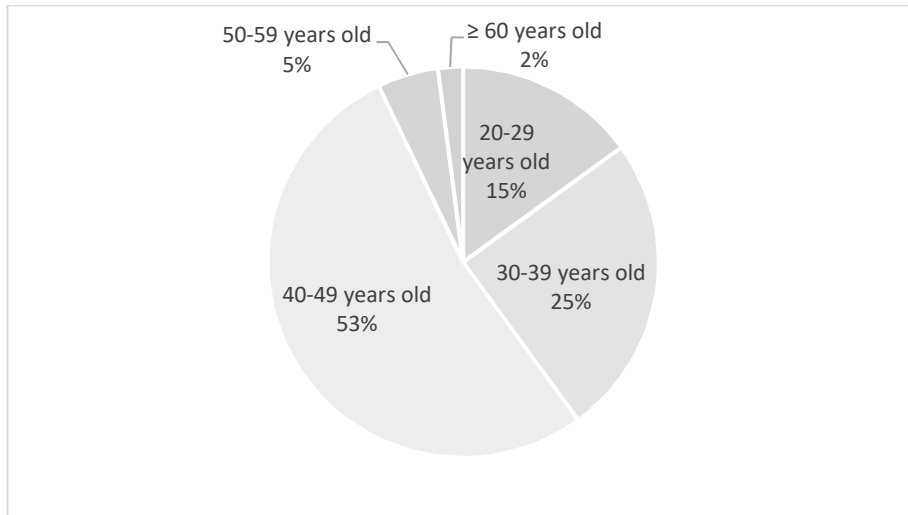


Figure 4. Characteristic of respondents based on age group.

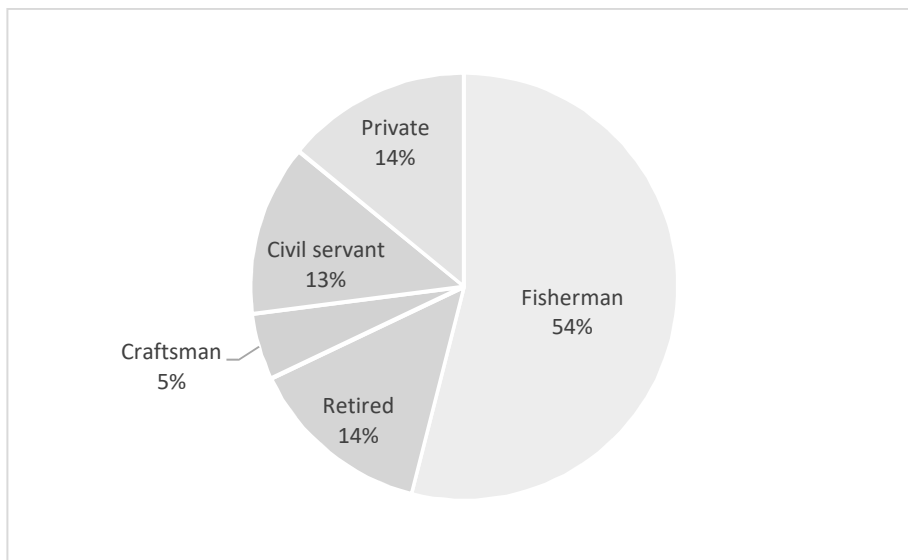


Figure 5. Characteristic of respondents based on occupation.

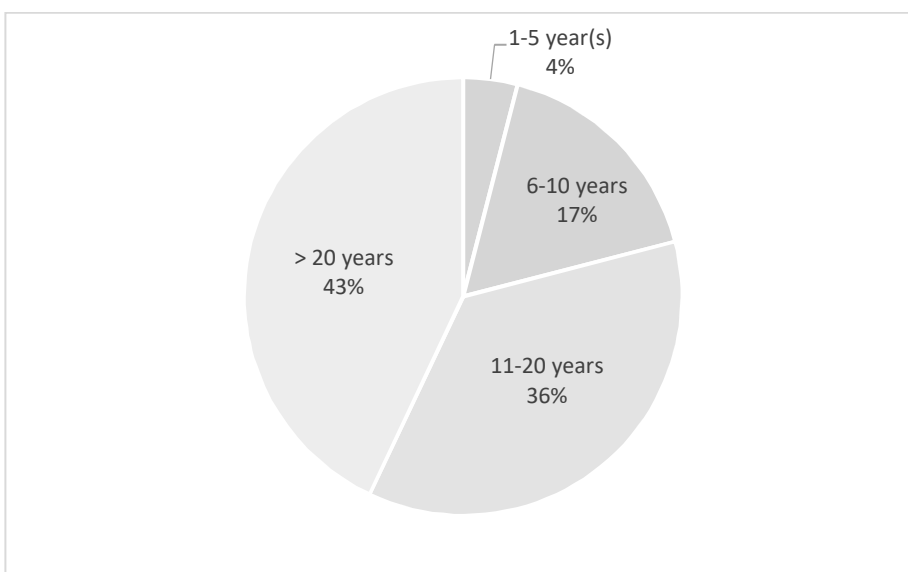


Figure 6. Duration of stay of the respondents in the villages.

Table 3

Characteristics of respondents based on income

<i>Income (Rp/month)</i>	<i>Number of respondents</i>	<i>Percentage (%)</i>
< 250,000	29	3
250,000-499,999	156	16
500,000-749,999	117	12
750,000-1,000,000	126	13
> 1,000,000	545	56

Public perception of the mangrove ecosystem is a vital indicator of understanding the ecological, social, and economic aspects of this ecosystem. This study used 16 questions to assess coastal community perception. Figure 7 shows the respondents' responses regarding their perception of the mangrove ecosystem. The average public perception score was 4.12 (Good) based on the responses of 973 individuals to the questionnaire. Figure 7 indicates that the community's highest perception of mangroves is that mangroves can be used as a spawning ground for fish, crabs, and shrimp (average score = 4.66). In addition, the indicator of mangrove as firewood has the lowest perception (average score = 3.20).

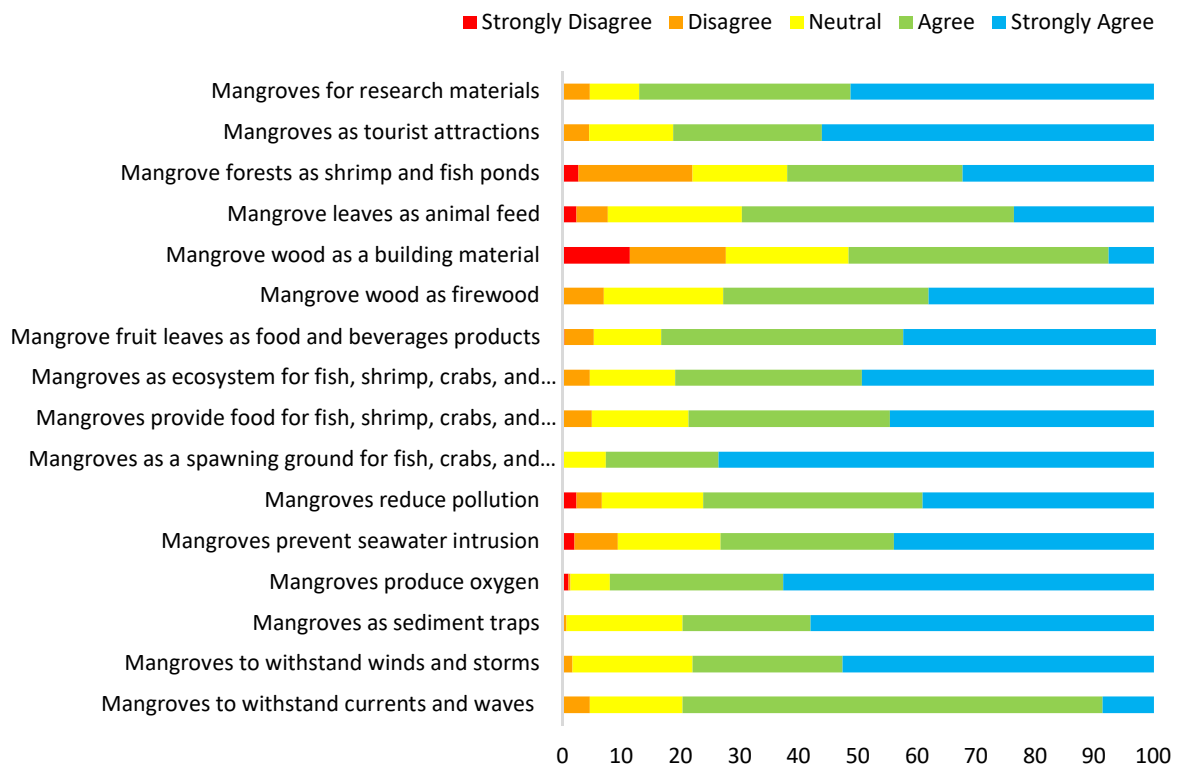


Figure 7. Public perception of the mangrove ecosystem.

Discussion. From 2013 to 2022, the trend of mangrove forest cover change in Batu Bara Regency decreases. According to Rumondang et al (2022), a very dynamic change in Batu Bara Regency occurred between 2017 and 2022. Most of the coasts of Batu Bara Regency exhibit changes indicative of coastal erosion. Based on the collected data, it is known that this could result from Ministry of Forestry policies and programs, such as changes in area management status and restrictions on community access to the forest. From an ethnoecological perspective, changes in area management status and restrictions on community access to areas that tend to lead to area conservation initiatives are beneficial interactions for the local mangrove cover to preserve and expand its growth.

Observations indicate that coastal abrasion and community activities, such as the use of mangrove land for shrimp aquaculture, can contribute to the reduction in mangrove forest area in this research area. Nevertheless, since 2018, community groups known as the *Tani Cinta Mangrove* have helped protect and preserve the mangrove forest area. This group is one of the factors that, despite not being able to prevent the decline in mangrove forest area, have at least contributed to delaying this decline. The area of mangrove forests declined by 22.6% from 2013 to 2017 prior to 2018 as evidenced by data on mangrove forest coverage. In the subsequent period, from 2017 to 2022, the decline in mangrove forest area was only 11.2%.

In general, the perceptions of coastal communities can be attributed to the decline in mangrove forest area. The indicator with the greatest score, according to the questionnaire data, is mangroves as a spawning ground for fish, crabs, and shrimp (average score = 4.66). As indicated previously, this supports the factors causing the decline in the area of mangrove forests due to shrimp farming on mangrove forest land. A high score on public perception is typically interpreted as a positive trend, but this can also be interpreted differently. The view that mangroves serve as a spawning ground for fish, crabs, and shrimp is correct, but this idea has led to the misconception that people can use the mangrove forest as a spawning ground for aquatic animals.

According to Ng & Ong (2022), exploiting mangrove forests is a tragedy of the commons, in which each community seeks maximum benefit from a natural resource. However, in the end, these resources' availability dwindles and negatively affects the exploiting community and other communities. Changing the area's status to make it more stable, establishing regional regulations, counseling and community empowerment, and managing mangroves by local community groups in partnership with other parties are all viable options. The employment of government regulations, norms, incentives, educational initiatives, community-based management, moral, religious, and social appeals were found to follow Gardner & Stern's (1996) perspective on preventing the tragedy of the ethics of the common. However, the tragedy of the commons along the coast of Batu Bara Regency could not be avoided because these measures were not incorporated. In contrast, if these solutions are implemented as part of a variety of programs, including coastal rehabilitation programs and regional development programs, the Batu Bara Regency's coastal resources will, in addition to benefiting the community economically, also remain in good ecological condition.

The rate of development of the national economy in the fisheries sector, particularly the development of aquaculture, which is accompanied by the low growth rate of mangrove forests, has a significant and sustainable effect on environmental quality in general (Islam & Wahab 2005). Indirectly, the actual consequence is the fishermen's income rate. The diminishing mangrove forest and expanding pond area reduce the number of fish that nest in the mangrove forest. Mangrove forests are powerless because they aim to shield little fish, shrimp, and crabs from their predators and because they are home to various creatures. In addition, mangrove forest land provides breeding habitats for certain species of fish, shrimp, and crabs that can no longer reproduce after laying eggs in mangrove forest land. It will result in a decline in the income of coastal fishermen.

Natural resources can only be protected and managed effectively with knowledge of people's thoughts and attitudes toward the environment (Lee & Zhang 2008). A favorable public view indicates that mangrove forests provide an ecological function, which includes preserving the potential for biodiversity, buffering the environment, reducing abrasion, and regulating the quantities of oxygen and carbon dioxide in the atmosphere. It aligns with what the community has said, as demonstrated by the 'Good' ratings (4.12).

A mangrove forest ecosystem can serve as a breakwater and defend the coast by reducing abrasion, preserving coastal stability, and deflecting or absorbing strong winds coming from the sea to the land. In addition, mangrove plant roots serve a role in sustaining the existence of groundwater, so serving as a buffer zone against the incursion or seepage of seawater onto land. However, according to the questionnaire results, the community needed to have more support to support this. The community did not notice

when numerous mangrove forest habitats were harmed, and seawater intrusion caused the coastal groundwater of Batu Bara Regency to become salty. The community needs to be aware that the beach, which lacks a mangrove habitat, would be progressively covered by sand transported by the waves. This hot sand layer causes the trees near the beach to wilt and perish. It is what causes changes in the area dynamics of mangrove forests.

The participation of coastal people is crucial to the successful management of mangrove forests. Participation in the community can be done alone or in groups. It follows article 6, paragraph 1 of Law Number 23 of 1997, which states, "Every person has the right and duty to engage in environmental management." The community endorsed the community's review of the mangrove forest ecosystem management. The evaluation conducted by the community is an example of the direct and indirect engagement of numerous parties in managing mangrove forest ecosystems. Although the examination was not usually conducted. It is consistent with Mursyid et al (2021) that the active participation of parties in the participation of coastal communities plays a vital role in the sustainable management of mangrove forests.

Conclusions. The communities in three districts, namely Talawi, Tanjung Tiram, and Lima Puluh Pesisir Districts at Batu Bara Regency, have a favorable opinion of mangroves (Good category). Based on the perception category, public perceptions of mangroves are positive. It is evident from the community's responses to the questionnaire, which reveal a consensus regarding the mangrove ecology. Nonetheless, data on the area of mangrove ecosystems in the study area indicates a 31.3% decline from 2013 to 2022. This is contrary to the community's perception of mangroves. According to an analysis of public perceptions and field observations, one of the reasons for the decline in mangrove forest area is the use of mangrove forest land for shrimp aquaculture. Therefore, support is needed so that people may better understand to manage land and continue to protect mangrove. Public perception must be addressed to prevent a decline in mangrove areas over the next few decades. In addition, there must be increased public participation along the coast, as these people directly interact with the mangrove ecosystem.

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Conflict of interest. The authors declare that there is no conflict of interest.

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