Local scale climate change mitigation through mangrove revegetation on the south coast of Lombok island

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Abstract. The mangrove vegetation in the coastal environment has a vital role, especially as a regulation for CO₂ and O₂ gas exchange. Mangrove revegetation has significant relevance for local-scale climate change mitigation. This study aims to assess and describe the success of mangrove revegetation in mitigating climate change at a local scale. Ecological data research methods are through surveys, observations and transect methods. Furthermore, the collection of social data through surveys, interviews, questionnaires, and Focus Group Discussions (FGD). Meanwhile, the research data were analyzed using descriptive statistical analysis, and analysis of the mangrove vegetation structure through frequency, density, cover, and essential value index analyses. The study results found seven types of mangroves, namely Sonneratia alba, Rhizophora stylosa, Rhizophora apiculata, Avicennia marina, Bruguiera gymnoryzha, Lumnitzara racemosa, and Ceriops tagal. Sonneratia alba and Rhizophora stylosa are species with the highest importance value of 194.04 where S. alba found Poton Bako and R. Stylosa found in Tanjung Luar. As for social data and knowledge, people in areas with a distance of 0-50 meters from mangrove forest have a better understanding than people living in areas with an average percentage value perspective of 52 %. Then, most respondents agreed that mangroves could prevent abrasion and reduce heat temperatures, with the percentage of respondents responding more than 41 % and 61 %, respectively in all locations. Based on the essential value index and respondents' perceptions, it can be concluded that the Sonneratia alba and Rhizophora stylosa are species that have the highest ecological function because they have good adaptability in the coastal areas of South Lombok making them suitable as species for revegetation programs in South Lombok, and for the next revegetation program should be involving people who are close to mangrove forests because they are the ones who know and feel the benefits of mangrove forests.

1. Introduction
Climate change caused by global warming due to carbon emissions has resulted in many disasters, such as severe economic, social and political dislocations worldwide [1]. Among the impacts that are felt are climate change accompanied by an increase in carbon gas accumulation and sea level, which causes abrasion [2,3]. Global warming is a condition in the earth's climate that is warmer than it should be due to the accumulation of greenhouse gases, such as CO₂ (about 50%), chlorofluorocarbons (CFCs, 25%), methane gas (10%), and other gases [4]. The triggers of climate change and global warming are associated with human anthropogenic activities and natural processes [2]. However, climate change impacts can be reduced through organic carbon absorbed from photosynthesis and stored in woody biomass, such as mangrove tree stands [5]. Physically, mangroves withstand impacts. From global warming to land on the coast.

Mangroves are one of the wealthiest carbon-rich ecosystems globally [6]. It knows that mangroves can store more carbon than terrestrial forests [7]. That makes mangroves reduce greenhouse emissions by providing carbon stocks for the coastal carbon cycle and biofilters of water pollution from heavy metal poisoning [8]. Furthermore, strong mangrove roots can reduce the influence of waves to protect the coast.
from abrasion, withstand surges and hurricanes [9]. Therefore, mangrove revegetation is a way to implement sustainable environmental management in coastal areas. Although mangrove forests have an essential role in mitigating climate change, the existing management and utilization do not reflect efforts to preserve the sustainability of mangrove forests. Globally, deforestation and conversion of mangrove forests have contributed 0.08–0.48 Pg CO2e per year, or 10% of total global emissions from tropical deforestation. However, mangroves only account for about 0.7% of the world's tropical forests. Loss of C from mangrove conversion can be high because of C losses above ground and below ground carbon of mangrove stand. For example, the potential loss of C from mangroves converted to shrimp ponds in the Dominican Republic is 661–1,135 MgC ha-1 [10]. In 1980, there were 4.2 Mha of mangrove forest along 95,000 km of Indonesia's coastline. In just 20 years, mangrove cover has decreased by about 26%, to around 3.1 Mha [11]. In 2005, mangrove forest cover fell to 2.9 Mha [12]. Based on FAO data, cumulatively, Indonesia has lost 30% of its mangrove forests between 1980 and 2005; this is equivalent to an annual deforestation rate of 1.24%. Recent estimates of Indonesia's mangrove cover show a total loss of 40% in the last three decades. Aquaculture development is the main cause, having expanded rapidly in 1997–2005 and resulted in an officially recorded active pond area of around 0.65 Mha. It reported that revenue from shrimp exports was close to US$ 1.5 billion in 2013; almost 40% of total income comes from the Indonesian fisheries sector. The existence of mangroves on the southern coast of Lombok Island is the result of revegetation, especially from the *Rhizophora stylosa* and *Rhizophora apiculata* species in the 1990s [13]. The indicator of the success of mangrove revegetation is the richness of fauna associated with mangroves [9,13]. The coastal environment in the study location, especially the presence of mangrove ecosystems, has a significant contribution to fauna richness, such as the richness of fish species associated with seagrass [14,15,16]. Another indicator is the potential of the carbon content of the revegetated mangroves as an important instrument for mangrove conservation at the study site. The indicators of revegetation success have relevance to the resilience of mangrove vegetation from the effects of global climate change, such as at the study site. Furthermore, the resilience capacity of mangroves is the main parameter in mitigating climate change at a local scale. However, research on local scale climate change mitigation issues, such as at the study site has not been carried out. Therefore, this study aims to assess and describe the success of mangrove revegetation in mitigating climate change at a local scale. The results of this study have an essential meaning as an ecological parameter for mangrove conservation management, such as at the study site and other relevant locations.

2. **Methods**

2.1. **Time and location of research**

This study was carried out in east Lombok. Data collecting from May to August 2021. Teluk Jor and Poton Bako have an area of 61.53 ha with a planting area of 4 ha. Furthermore, the geographical location of the three sites stretches 116°27′0″ - 116°30′0″ South Latitude and 8°48′0″ - 8°51′0″ East Longitude on the South Coast of East Lombok (Tanjung Luar, Poton Bako, and Teluk Jor). The coastal environment in the study location, especially the presence of mangrove ecosystems, has a significant contribution to fauna richness, such as the richness of fish species associated with seagrass [14], crustaceans, echinoderms and bivalves [15,16].
2.2. Data collection

Sources of research data are mangrove ecological data and data on perceptions (local community knowledge about the function of mangroves as an instrument for mitigating climate change on a regional scale). Mangrove ecology variables were mangrove species, and stem diameter and environmental parameters measured were pHs, substrate type, substrate depth, salinity, and temperature—mangrove vegetation data retrieval using transect and quadratic methods. Furthermore, ecological data collection: salinity using a refractometer, temperature with a mercury thermometer, pH meter, substrate type, and depth carry directly. Meanwhile, social data use a purposive sampling method through surveys, observations, and interviews with local communities. Determination of the sample as respondents with the following criteria: respondent’s age, residence distance from mangrove forest, and length of stay at the research site. The selection of respondents at each location was 100 people, so the total respondents were 300 people for the three research locations.

2.3. Data analysis

The process of analyzing mangrove vegetation data uses analysis of frequency, density, coverage area (dominance), and essential value index.

2.3.1. Frequency

Frequency is the intensity of the discovery of a species of organism in observing the existence of organisms in a community or ecosystem. Plant communities analyze based on the Frequency of species (F), the Frequency of the i-th species (F-i), and the relative Frequency (FR-i) can be calculated by the following formula [17]:

$$FR\cdot i = \frac{Frequency\ of\ a\ species\ i}{Frequency\ of\ whole\ species} \times 100\%$$

2.3.2. Density

Specific Density is the number of individuals per unit area or unit volume. In other words, Density is the number of individual organisms per unit space. The i-th species' Density can be calculated as K-i, and the relative Density of each i-th species to the total Density can be calculated as KR-i. The formula for calculating Density as stated [17]:

$$K\cdot i = \frac{Density\ of\ a\ species\ i}{Density\ of\ all\ species} \times 100\%$$

Figure 1. Map showing research locations
KR-i= \frac{\text{Species density}_i}{\text{Density of all species}} \times 100\% \quad (2)

2.3.3. Coverage Area
Coverage area is the proportion between the area covered by plant species and the total area of the habitat. The relative cover of species is the ratio between the closure area of type I and the whole surface area for all species. Some experts use the term dominance to express the area of coverage of a plant species. If based on the basal area, the formula is as follows [17].

CR-i= \frac{\text{Species closure}_i}{\text{Cover of all species}} \times 100\% \quad (3)

2.3.4. Essential Value Index
The critical value index is used to determine the species that have the most vital role. Essential value index was gathered by adding up relative density (KR), relative dominance (DR), and relative frequency (FR). Essential value index (INP) explains the significance of a species ranging from 0-300. Plant species that have a high INR indicate that this species is more dominant than other species. This substantial value provides an overview of the influence or role of a species in the community. This critical value can also indicate the level of a species' ability to maintain its life in a specific area. The formula is as follows (17):

INP = KR + DR + FR \quad (4)

3. Results and Discussion
3.1. Composition of Mangrove Vegetation
Mangroves in the study site identified as many as seven species. Composition of mangrove species that can be found at all research sites are Sonneratia alba and Rhizophora apiculata. Meanwhile, the lowest mangrove species composition were Bruguiera gymnoryzha and Lumnitzera racemosa. The number of mangrove species in the study site was more than on Maitara Island, North Maluku which consisted of four species (Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, and Sonneratia alba) [18]. There is an increase in the number of mangrove species in the study area compared to 2017, this indicates the success of mangrove revegetation at the study area [19].

Table 1. Mangrove composition (trees, saplings and seedlings) on each transect.

| Species          | Tanjung Luar | Poton Bako | Teluk Jor |
|------------------|--------------|------------|-----------|
|                  | Tree | Sapling | Seedling | Tree | Sapling | Seedling | Tree | Sapling | Seedling |
| Avicennia marina | 1    | 1       | 9        | -     | -       | -        | -     | -       | -        |
| Bruguira gymnoryzha | 3   | 3       | -        | -     | -       | -        | -     | -       | -        |
| Ceriops tagal    | -    | -       | 6        | 50    | 4       | 4        | -     | -       | -        |
| Rhizophora stylosa | 3  | 3       | 2        | 15    | 60      | 4        | -     | -       | -        |
| Rhizophora apiculata | 12 | 12      | 10       | 38    | 78      | 16       | 24    | 20      | 20       |
| Sonneratia alba  | 12   | 12      | 10       | 38    | 78      | 16       | 24    | 20      | 20       |
| Lumnitzera racemosa | -  | -       | -        | -     | -       | -        | -     | -       | -        |
| Total Number     | 25   | 25      | 25       | 25    | 44      | 128      | 24    | 35      | 33       |

3.2. Mangrove community structure
The vegetation structure in the South Coast of Lombok Island mangrove ecosystem is majority composed of Rhizophora stylosa and Sonneratia alba. The existence of these species indicates that they...
naturally grow optimally in the area. That suggests that the species is very suitable to live with the environmental conditions of the South Coast of Lombok Island. The value of relative Frequency, relative Density, and relative dominance of mangrove tree categories varies.

The analyzed data showed that the highest relative frequency value of tree category is *Rhizophora stylosa* 64.29% found in Poton Bako, and the lowest is *Avicennia marina* 9.09% found in Tanjung Luar. Furthermore, the highest relative density value of the tree category is *Sonneratia alba* at 60.00% found in Poton Bako, and the lowest is *Avicennia marina* at 2.94% found in Tanjung Luar. Meanwhile, the highest relative dominance value of the tree category is *Sonneratia alba* at 69.75% and the lowest is *Avicennia marina* at 2.13%. The high value of Frequency, Density, and relative dominance in *Sonneratia alba* was due to the number of individuals, the number of plots found for this species, and the higher basal area value.

The highest value for the Relative Frequency of the sapling category was *Sonneratia alba* at 75.00% found in Poton Bako, and the lowest was *Bruguiera gymnorrhiza*, *Ceriops tagal*, and *Rhizophora stylosa* at 9.09% in Tanjung Luar. The Relative Frequency of *Rhizophora apiculata* is high because this species is typically found in the research point. Furthermore, the highest relative density values of sapling category belonged to *Sonneratia alba* species at 34.88% found in Poton Bako, and the lowest species to *Bruguiera gymnorrhiza* and *Ceriops tagal* at 4.65% found in Tanjung Luar. The high value of the Relative Density of *Sonneratia alba* was due to the highest number of individual species found. Meanwhile, the highest relative dominance value was *Sonneratia alba* at 69.75%, and the lowest was *Bruguiera gymnorrhiza* and *Ceriops tagal* at 3.16%. The high value of the relative dominance of this species is because the total basal area value is the highest compared to other species.

| Table 2. Mangrove community structure. |
|---------------------------------------|
| No | Species   | Category | Tree | Sapling | Seedling | |
|    |           |          | FR   | KR     | DR       | FR   | KR | DR | FR | KR |
| Tanjung Luar |
| 1   | *Avicennia marina* | 9.09 | 2.94 | 2.13 | 18.18 | 34.88 | 24.25 | - | - |
| 2   | *Bruguiera gymnorrhiza* | 13.64 | 8.82 | 15.85 | 9.09 | 4.65 | 3.16 | - | - |
| 3   | *Ceriops tagal* | - | - | - | 9.09 | 4.65 | 3.16 | - | - |
| 4   | *Rhizophora stylosa* | 27.27 | 20.59 | 14.91 | 9.09 | 9.30 | 13.49 | - | - |
| 5   | *Rhizophora apiculata* | 31.82 | 44.12 | 42.30 | 31.82 | 27.91 | 36.70 | 60.00 | 56.45 |
| 6   | *Sonneratia alba* | 18.18 | 23.53 | 24.81 | 22.73 | 19.77 | 40.00 | 43.55 |
| Total Number | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Poton Bako |
| 1   | *Rhizophora stylosa* | 64.29 | 40.00 | 30.25 | 25.00 | 13.64 | 30.25 | 60.00 | 60.94 |
| 2   | *Sonneratia alba* | 35.71 | 60.00 | 69.75 | 75.00 | 86.36 | 69.75 | 40.00 | 39.06 |
| Total Number | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Teluk Jor |
| 1   | *Ceriops tagal* | - | - | - | 26.47 | 14.29 | 9.45 | - | - |
| 2   | *Lumnitzera racemosa* | - | - | - | 11.76 | 11.43 | 7.28 | - | - |
| 3   | *Rhizophora apiculata* | 18.18 | 16.67 | 16.19 | 29.41 | 17.14 | 13.56 | 60.00 | 39.39 |
| 4   | *Rhizophora stylosa* | 27.27 | 16.67 | 14.15 | - | - | - | - | - |
| 5   | *Sonneratia alba* | 54.55 | 66.67 | 69.66 | 47.06 | 57.14 | 69.70 | 40.00 | 60.61 |
| Total Number | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Notes: Relative Frequency (FR), Relative Density (KR), and Relative Dominance (DR).
The highest relative frequency value of the seedling category is *Rhizophora stylosa* at 60.00% found in Poton Bako, and the lowest was *Sonneratia alba* at 40.00% at all locations. Meanwhile, the highest density value is *Rhizophora stylosa* with 60.94% found in Poton Bako, and the lowest was *Rhizophora apiculata* at 39.39% found in Telok Jor. The high value of the Frequency and Density of *Sonneratia alba* species is because this species is found most often at the study site with an increased number of individuals. In addition, environmental conditions favor the growth of seedlings of *Sonneratia alba*.

The essential value index results from the sum of the relative values of the three parameters (density, frequency, and dominance) so that the values vary. The highest essential value index for the tree category is *Rhizophora stylosa* at 194.04 found in Tanjung Luar, and the lowest is *Rhizophora apiculata* at 51.04 found in Teluk Jor (Figure 2). Furthermore, for the sapling category, the highest essential value index also for *Rhizophora stylosa* was 248.49 found in Poton Bako, and the lowest was *Ceriops tagal* at 16.38 found in Tanjung Luar (Figure 2). The magnitude of the essential value index indicates the role of mangrove species in the community or at the research site. The same thing is stated by [20] that the significance value index shows how vital a plant species is to its ecosystem. The type of *Rhizophora stylosa* was found in large numbers and spread evenly in almost all south coast of Lombok Island forest areas. That shows that this species is the most adaptive to the south coast of Lombok Island mangrove forest environment.

![Figure 2](image-url) Important value index of all mangrove categories.

### 3.3. Local Community Knowledge on Mangrove Mitigation Functions on climate change at local scale

Three parameters used to select respondents in this study namely respondents age, length of stay at study area, and distance of residence from the mangrove forest. The results of the assessment of respondents' characteristics, in Tanjung Luar and Poton Bako with a distance of 0-50 m from mangrove forest have the highest and lowest percentages at a distance of 76-100 and 100 m from mangrove forest. In contrast to the location of Teluk Jor at a distance of 51-75 m from mangrove forest which has the highest percentage and the lowest distance is 100 from mangrove forest. The next parameter is the respondent's
age, in Tanjung Luar 41-50 years, the highest and lowest percentage is 50 years. Furthermore, in Poton Bako and Teluk Jor respondents aged 31-40 years had the highest and lowest percentage of 50 years. The third parameter is the length of stay of respondents in Tanjung Luar and Poton Bako 41-50 years which has the highest and lowest percentage value of 50 years. Meanwhile, in Teluk Jor, the longest respondent's length of stay was 31-40 years and the lowest was 50 years. Further explanation of the data in Table 3.

Table 3. Distribution of respondents based on results from characteristic assessment

| No  | Respondent Characteristics | Location          | Tanjung Luar | Poton Bako | Teluk Jor |
|-----|----------------------------|-------------------|--------------|------------|-----------|
|     |                            |                   |              |            |           |
| 1   | Distance of residence      |                   |              |            |           |
|     | 0-50                       |                   | 26.21%       | 28.16%     | 29.13%    |
|     | 51-75                      |                   | 25.24%       | 26.21%     | 36.89%    |
|     | 76-100                     |                   | 24.27%       | 24.27%     | 28.16%    |
|     | ≥ 100                      |                   | 24.27%       | 21.36%     | 5.83%     |
| 2   | Age (year)                 |                   |              |            |           |
|     | 20-30                      |                   | 25.24%       | 27.18%     | 31.07%    |
|     | 31-40                      |                   | 32.04%       | 35.92%     | 33.98%    |
|     | 41-50                      |                   | 35.92%       | 31.07%     | 26.21%    |
|     | ≥ 50                       |                   | 6.80%        | 5.83%      | 8.74%     |
| 3   | Period of stay (year)      |                   |              |            |           |
|     | 20-30                      |                   | 31.07%       | 26.21%     | 28.16%    |
|     | 31-40                      |                   | 29.13%       | 33.01%     | 34.95%    |
|     | 41-50                      |                   | 35.92%       | 33.98%     | 31.07%    |
|     | ≥ 50                       |                   | 3.88%        | 6.80%      | 5.83%     |
|     | Average                    |                   | 52.02%       | 26.94%     | 21.04%    |

Respondents who live closest to mangroves forest (category 0-50 meters from mangrove forest) have higher knowledge of mangrove revegetation than respondents with other categories. The regulation on mangrove revegetation is more increased due to the intensity of community interaction with mangroves being higher than other communities [21]. Almost all respondents in this category are fishermen or fishermen's wives. In addition, the close distance allows this community group to observe mangrove debt more intensely and directly feel the changes in mangroves. For example, the presence of mangroves on the coast will determine the number of impacts caused by abrasion [22].

Table 4. Respondents perceptions of mangrove in climate change mitigation

| Question Items                                      | Number of Respondents |
|-----------------------------------------------------|------------------------|
|                                                     | Know       | Less Know  | Doesnt know |
| **Tanjung Luar**                                    |            |            |             |
| Ecological function (habitat/animal habitation)      | 48.54%     | 24.27%     | 27.18%      |
| Economic function (Location of livelihood)           | 46.60%     | 33.01%     | 20.39%      |
| Physical mitigation function (Resistance for abrasion)| 61.17%     | 27.18%     | 11.65%      |
| Indirect mitigation function (Reducing environmental heat) | 46.60%     | 25.24%     | 28.16%      |
| **Teluk Jor**                                       |            |            |             |
| Ecological function (habitat/animal habitation)      | 52.43%     | 24.27%     | 23.30%      |
| Economic function (Location of livelihood)           | 43.69%     | 34.95%     | 21.36%      |
| Physical mitigation function (Resistance for abrasion)| 67.96%     | 23.30%     | 8.74%       |
| Indirect mitigation function (Reducing environmental heat) | 56.31%     | 19.42%     | 24.27%      |
The majority of respondents know or are aware that mangroves can prevent abrasion, one of the impacts of climate change. Mangroves can prevent aberrations through physical mechanisms by binding the soil to avoid. The community can observe this situation through differences in the volume of land on the coast that has mangroves and those that do not. The importance of soil in the part that has mangrove vegetation will survive and even increase [23]. This fact can be used as capital to make mangrove revegetation efforts in coastal areas successful. People who are aware of the importance of mangroves in preventing aberrations will spontaneously help with mangrove revegetation efforts.

In addition, most respondents also agree that mangrove revegetation can reduce other impacts of climate change, namely the increase in environmental temperature. Mangroves can prevent overheating the environment through oxygen production and absorb carbon emissions through biochemical cycle mechanisms. So, apart from physically, mangroves also minimize the impact of climate change biochemically. Communities can feel the benefits of mangroves in reducing temperature levels through temperature differences in areas that have mangroves and those that do not. Regions that have mangroves will be more relaxed than those without [24]. However, only 48% of respondents considered the addition of mangrove revegetation after planting or relegation. This result shows that more extraordinary efforts need to be made to increase mangrove revegetation, given its significant benefits.

### Table 4

| Question Items                                      | Number of Respondents |
|-----------------------------------------------------|-----------------------|
|                                                     | Know | Less Know | Doest know |
| Ecological function (habitat/animal habitation)     | 49.51% | 23.30% | 27.18% |
| Economic function (Location of livelihood)          | 39.81% | 34.95% | 25.24% |
| Physical mitigation function (Resistance for abrasion) | 61.17% | 26.21% | 12.62% |
| Indirect mitigation function (Reducing environmental heat) | 50.49% | 27.18% | 22.33% |

3.4. **The role of mangroves in mitigating climate change**

The role of mangroves in mitigating the impacts of climate change can be seen through two mechanisms, namely biochemically and physically. Biochemically, mangroves are able to absorb carbon gas emissions through photosynthetic reactions. This is in line with the response from respondents who stated that the presence of mangroves made the environment cooler (Table 4). The existence of a cool atmosphere is the result of a photosynthesis reaction that absorbs carbon and releases oxygen. Physically, mangrove roots are able to bind the volume of the soil that makes it not washed away by the ocean waves. This is in line with the respondent's perception (Table 4) that the presence of mangroves is able to maintain soil which is different from areas without mangroves.

The significance of mangroves through biochemical mechanisms can be seen through the ability of mangroves per hectare to store four times more carbon than other tropical forests around the world. Mangrove vegetation in Teluk Jor can absorb carbon dioxide of 2559.63 CO2/ha, equivalent to the carbon dioxide emission produced by transporting 241.46 tons of CO2/ha. Mangrove forests can mitigate climate change by absorbing CO2 from the atmosphere and oceans at higher rates than terrestrial forests. Therefore, mangrove forests are one of the natural resources that must be conserved to reduce the impact of climate change [8].

Mangroves have been considered an essential protector against climate change. It protects coastal areas from tidal waves and cyclones and is one of the most carbon-rich forests in the tropics. In the face of rising sea levels and climate change, coastal buffering against the negative impacts of wave action is critical and will play an essential role in climate change adaptation. Reviewed the state of knowledge of mangrove vulnerabilities and responses to predicted climate change and considered adaptation options [25]. Based on the available evidence from all climate change outcomes, it is concerned that relative sea-level rise is perhaps the greatest threat to mangroves. Pacific Island mangroves are at high risk of substantial reduction due to hazards caused by climate change [26]. Protecting and replanting mangroves will help protect communities from the impacts of climate change. Nevertheless, further research on the
risks posed by climate change to mangroves is needed to develop assessment methods and standard indicators of change in response to the effects of climate change. In contrast, regional monitoring networks require observing these responses to enable well-informed adaptation, including planting mangroves for carbon sequestration [26].

4. Conclusion
Based on the highest essential value index at 194.04 and respondents' perceptions, it can be concluded that the Sonneratia alba and Rizopora stylosa are species that have the highest ecological function because they have good adaptability in the coastal areas of South Lombok making them suitable as species for revegetation programs in South Lombok, and for the next revegetation program should be involving people who are close to mangrove forests because they are the ones who know and feel the benefits of mangrove forests. Because mangrove parameters are recognized by people who are close to mangrove forest in mitigating climate change. Which are preventing coastal abrasion, producing oxygen that provides coolness during the dry season, and the gathering place for diversity of fauna. Therefore, to avoid deforestation and inefficient resources, the government and society must protect the mangrove ecosystem.

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Author's Contributions
Agil Al Idrus, Abdul Syukur, Zulhalifah, Lalu Hasan Nasiruddin Zohri, Jamiatul Aulia. Conducted all experiments, observation, analysis, and paper manuscript preparation.

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