Mitigation and adaptation to climate change through sustainable mangrove management on the coast of Rembang Regency

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Abstract. Climate change is very influential on the mangrove ecosystem. Adaptation and mitigation are urgent needs to minimize the impact of climate change. This study aims to analyze the sustainable management of mangroves in mitigating and adapting to climate change. This research uses a descriptive qualitative approach. The results showed that most of the community stated that the condition of the mangroves on the coast of Rembang Regency was in good condition, but in general the community had not been fully involved in Mangrove management. In mangrove ecosystems management, active community involvement is needed to maintain its sustainability. Good mangrove conditions can mitigate climate change. To adapt climate change can be done with programs that can maintain mangrove ecosystems such as using environmentally friendly fishing gear, not cutting down mangroves, developing ecotourism, and maintaining local wisdom.

1. Introduction
Indonesia is an archipelagic country that has a coastline of 99,093 km which ranks second in the length of the coast in the world [1]. In addition, Indonesia also has the most extensive mangrove ecosystem in the world and has the highest biodiversity with a mangrove area of 3,616,445.19 ha [2]. This shows that Indonesia has very potential coastal resources, both biological and non-biological resources. These biological resources are for example mangroves, fisheries, coral reefs, seagrass beds, and others, while non-biological sources such as minerals and mining materials [3]. Behind these potential resources, the length of the coastline also shows vulnerability to abrasion, ocean waves, and climate change if left without proper management. One thing that can protect coastal areas from abrasion, ocean waves, and climate change is mangroves as a green belt in coastal areas. Mangroves can withstand abrasion and tidal waves, withstand seawater intrusion, as well as a habitat for animals and coastal fisheries [2]. Nutrients supplied from the mainland through rivers, and surface flows when it rains make natural ecosystems such as mangroves, seagrass beds, coral reefs, and estuaries fertile [4]. Although mangroves are sensitive to climate change, they provide services that can help reduce damage, absorb carbon, improve shoreline stability and protect coastal areas from waves and tropical storms [5].

Mangroves provide various marine habitats such as fish, crabs, and shrimp [6]. In addition, mangroves also filter solid objects such as shrimp [7,8], and mangroves can reduce land loss due to coastal erosion [9]. The loss of mangroves can have an effect on the environment such as the loss of fish nurseries, increased pollution, and loss of coastal protection [10]. In 2004, the damage caused by the
tsunami to property and people in South India was significantly less in areas covered by mangrove vegetation [11]. 23% of the world's mangrove forests are in Indonesia. The area is equal to 3.48 million square hectares. However, the majority of mangrove forests in Indonesia, or as much as 52% (1.81 million hectares) are in damaged and critical condition. Only 48% or 1.67 million hectares of mangrove forest are still in good condition. This is in line with [4] which states that the regional forest areas on the north coast of Java, Sumatra, South Sulawesi, Bali, and East Kalimantan have been degraded due to forest destruction and conversion to other uses as settlements, ponds, agricultural land, plantation land, or industry. Meanwhile, [12] stated that the biggest contributing factors to the damage to mangrove ecosystems on the coast of Rembang Regency were aquaculture, tree felling, reclamation and sedimentation, and environmental pollution. Activities that have contributed greatly to the decline of mangroves in Indonesia are the extraction of timber for commercial purposes and the shifting of designations to ponds and agricultural areas [13].

Mangroves have an ecological function as a provider of nutrients for aquatic biota, as a place for spawning and nurturing various types of biotas. Mangrove forests also have various types of products such as construction wood, firewood, plywood, pulp, piles, fishing charts, docks, wood for furniture, and handicrafts [14]. In addition, mangroves also produce secondary metabolic products in the form of tannins to be applied to fishing nets, medicinal ingredients, carbohydrates in the form of flour derived from mangrove fruit, and dyes derived from mangrove trees waste [15]. Excessive land use of mangrove areas has negative impacts on ecological aspects and biophysical processes, such as erosion, decreased water quality, loss of habitat, and decreased biodiversity [16,17]. Indications of failure in mangrove management are the lack of community involvement and management policies that are still top-down [18]. A mangrove ecosystem is an ecosystem that grows around the coast and is influenced by the tides of seawater so that the bottom is always inundated by seawater. Mangrove ecosystems range from the highest tidal levels to levels around or above mean sea level in protected coastal areas [19], and support a wide range of ecosystem services along coastlines in the tropics [20].

Climate change damages coastal ecosystems and increases risks to communities and infrastructure [21]. Mangrove ecosystems provide benefits related to physical functions, namely mitigating the effects of natural disasters such as buffering waves and hurricanes in the hinterland, protecting the coast from abrasion, tidal waves, blocking waves, tsunamis and capturing sediments carried by surface waters, preventing seawater from the continent and can neutralize water pollution to some extent [22]. In addition, a healthy coastal mangrove ecosystem can increase the resilience of communities to climate change and reduce the impact of natural disasters such as tsunamis, hurricanes, and ocean waves (adaptive function). Mangroves also act as the lungs of the World by controlling climate change through the absorption and storage of blue carbon (mitigation function). In addition to functioning as coastal protection and blue carbon, mangroves are a nursery ground and habitat for economically valuable biota such as fish, crabs, and shrimp (benefits for livelihood). However, climate change and global developments have had an impact on the preservation of mangroves [23].

2. Materials and Methods
2.1 Community-based mangrove management
The main key to the mangrove management strategy is to implement aspects of conservation areas, law enforcement, ecotourism quality, and cooperation between all stakeholders [24]. Mangrove management is based on three stages, namely: ecological and socio-economic issues, institutional and legal means, and strategies for implementing the plan. Ecological issues include the ecological impact of human intervention on mangrove ecosystems [25]. Community participation around mangrove ecosystems is equally important for mangrove protection. This kind of participation can be done by individuals or community groups. This is in line with the provisions of Article 6 paragraph 1 of Law Number 23 of 1997 concerning Environmental Management [26], which stated that "everyone has the right and is obliged to participate in environmental management". In his explanation, it was emphasized that the rights and obligations of every person as a member of the community participate in environmental management activities include the planning, planning, and evaluation stages. The success of mangrove
management can be optimized through community-based mangrove management strategies, meaning that the community is directly involved in the management of natural resources. Managing here means that people think about, plan, monitor, and evaluate mangrove ecosystem resources and the benefits of these resources sustainably with a focus on protecting these ecosystems. Community-level management of mangroves benefits the communities surrounding the mangrove ecosystem. Community-based mangrove management can strengthen local communities, improve environmental management and livelihoods, and provide environmental, social, and cultural benefits [27,28]. It is a community and resource-driven management process based on the idea that people have an innate ability to understand and act on their problems. Community and sustainability will continue [29]. This means that community participation in mangrove management will increase if the “welfare” of the community members is ensured. Thus, the success of mangrove management will depend on the well-being of the communities surrounding the mangrove.

2.2 Mangroves as Climate Change Mitigation
Mitigation is a human intervention to reduce other sources of substances that directly or indirectly contribute to limiting climate change, including, for example, reducing very small emissions can directly change the radiation balance (for example, carbon) or actions that control emissions of carbon monoxide, nitrogen oxides, volatile organic compounds, and other pollutants may change in tropospheric ozone concentrations indirectly affect climate [30]. Mangrove ecosystems have an important role as an effective and economical way to offset carbon emissions and protect shoreline erosion [31]. Mangrove ecosystems have the same function as other forest ecosystems, namely being able to absorb carbon which is one of the mitigation actions against climate change, where mangroves can absorb higher carbon and can store carbon for up to millions of years more than the ability of tropical forests on land [32].

Every plant needs carbon dioxide (CO2) in the process of photosynthesis which is taken from the air in the atmosphere. The absorbed carbon will be stored in the form of plant biomass [33]. About 40% of the tree biomass is carbon, whereby the process of photosynthetic trees, the carbon dioxide of the atmosphere receives organic carbon (carbohydrates) and stored in body biomass as in stems, leaves, roots, tubers, fruits, and others. The way to determine the carbon storage in a plant is to calculate the biomass of the plant [34]. Biomass from carbon sequestration is a forest service as an effort to restore the environment by reducing CO2 in the air. Damage to mangrove ecosystems can result in increased carbon in the air which causes the greenhouse effect [35]. The decrease in the area of the mangrove forest ecosystem means that it will reduce the potential for carbon absorption and storage to reduce CO2 levels in the air [36]. Estimating the potential of mangrove vegetation in storing carbon is very important as global warming mitigation which is a signal for mangrove ecosystem conservation [37]. Mangrove ecosystems play a role in providing environmental services in carbon storage that have a good impact on the environment and humans. The impact of global warming due to increasing concentrations of gases in the atmosphere such as CO2 will affect the increase in the earth's temperature. This increase causes changes in the global climate such as changes in rainfall and increased intensity of storm frequencies, rising sea tides due to the expansion of seawater at higher temperatures. Global warming also has an impact on melting ice in the polar regions, decreasing salinity, and increasing sedimentation in coastal and ocean areas so that it can threaten the sustainability of coastal and marine natural resources as a support for human life [38].

2.3 Mangroves as Climate Change Adaptation
Climate change adaptation is the process of adjusting to the climate and trying to reduce, avoid hazards and take advantage of opportunities [30]. Adaptation actions to climate change by mangroves include being able to overcome the problem of abrasion and seawater intrusion, wind and tsunami barriers, mud, and sediment retention. Conservation of mangrove ecosystems can indirectly improve the economy of coastal communities [32]. Mangroves grow and develop along with the dynamics of biophysical and coastal oceanography so that mangroves become part of the unity of the coastal system. Mangrove
damage has an impact on coastal stabilization because mangroves function as sediment traps, absorption of ocean wave energy, and protection against storms [39]. Mangrove ecosystems provide services as a protector of coastal areas and contribute to the level of resilience of coastal communities so that mangroves have a very important role in mitigating natural disasters and adapting to climate change. Mangrove valuation as a greenbelt can be calculated from the value of economic loss due to the loss of mangroves or the value of artificial protective structures that must be built [40].

Naturally, mangrove ecosystems can adapt to changes in the environment, which is also known as the ability to heal itself; however, the adaptability of mangroves varies with environmental and mangrove conditions (site-specific) and factors affecting the mangroves. With the IPCC SLR (sea level rise) scenario of 0.48m (RCP6) and 0.63m (RCP8.5) in 2100, it is estimated that the area of mangroves in Indonesia will decrease [41]. In addition to rising sea levels causing permanent flooding of mangroves, the loss of mangroves is also associated with limited space for mangroves to adapt and move to the mainland due to the conversion of forest lands to human settlements. Consequently, mangroves located in residential areas (e.g., protected areas) are more likely to adapt to environmental changes than mangroves in densely populated areas. This shows that, in addition to the type and status of mangroves, environmental (ecological) and social factors also affect the sustainability of mangroves [42].

Healthy mangroves not only provide coastal protection services but also play a role in the sustainability of the availability of food sources in coastal areas. Consumption of protein from fisheries (seafood) such as fish, shrimp, and crabs is closely related to the existence of mangrove forests as spawning grounds for marine biota. It is estimated that the life cycle of 50-80% of commercial fish species depends on mangroves [43] so that a decrease in the area of mangrove forests will have an impact on fish resource stocks. The loss of mangrove forests is the main factor in the decline in stocks of natural shrimp and mud crabs which are a source of livelihood for fishermen and coastal communities.

2.4 Study Area
This research was conducted in the coastal area of Pasar Banggi Village of Rembang Regency. 120 people are living around the mangrove ecosystem who were taken as samples by accidental sampling. Data was collected employing interviews and questionnaires that had been prepared in advance related to community responses to mangrove management as mitigation and adaptation to climate change. The data analysis technique used in this research is descriptive qualitative.

![Figure 1. Study Area](image-url)
3. Results and Discussion

3.1 Profile of respondents

Based on the results of data analysis respondents in the study consisted of 75.8% male and 24.2% female as can be seen in the following table 1.

| Characteristics | Frequency | Percent |
|-----------------|-----------|---------|
| Gender          |           |         |
| - Male          | 91        | 75.8    |
| - Female        | 29        | 24.2    |
| Age (years)     |           |         |
| - ≤ 30          | 28        | 23.4    |
| - 31-40         | 24        | 20.00   |
| - 41-50         | 33        | 27.5    |
| - > 50          | 35        | 29.2    |
| Education       |           |         |
| - No school     | 4         | 3.3     |
| - Elementary    | 42        | 35      |
| - Junior High School | 29 | 24.2 |
| - Senior High school | 40 | 33.3 |
| - Bachelor degree | 5       | 4.1     |
| Jobs            |           |         |
| - Fisherman     | 49        | 40.8    |
| - Labour        | 16        | 13.3    |
| - Farmer        | 15        | 12.5    |
| - Trader        | 19        | 15.8    |
| - Businessman   | 12        | 10.0    |
| - village apparatus | 2   | 1.7     |
| - Housewife     | 7         | 5.8     |

Source: primary data processed, 2020

The age of the respondents in this study was grouped into 5 categories, most of the respondents aged between 41-50 years at 27.5% and over 50 years at 29.2%. This shows that the respondents in this study have experience and know the condition of resources in the coastal area of Rembang Regency. The education level of most of the respondents is an elementary school with 35% which indicates the level of education of the respondents is low. The low level of education is a challenge for efforts to increase the income of coastal communities as well as in increasing knowledge related to resource management in the coastal area of Rembang Regency. While the type of work Most of the respondents in this study were fishermen as much as 34%.

3.2 Community-based mangrove management

At first, efforts to manage the mangrove ecosystem in Pasar Banggi village were carried out partially by individuals. As time goes by, people realize the importance of mangrove ecosystems for their lives so that people participate in protecting and maintaining mangroves. Mangrove management in Pasar Banggi Village is considered successful, as evidenced by the relatively good mangrove ecosystem. The above conditions are considered to be quite positive conditions and can be used as good examples to be applied in other areas. The perception of the community in the study area on the condition of the mangroves can be seen in Figure 2. About 87% stated that the condition of mangroves was in good condition.
In general, people in the Coastal area of Rembang Regency are aware of the importance of the existence of mangroves as a nursery for various types of marine life where if the area with mangroves is still good, there will be good catches such as shrimp, crabs, and other fishery products. However, it is necessary to be aware of the damage to the mangrove ecosystem that can occur if there is no good coastal area management. Some of the biggest contributing factors to the destruction of mangrove ecosystems on the coast of Rembang Regency, namely: aquaculture, mangrove logging, reclamation and sedimentation, and environmental pollution [44]. Community involvement in coastal resource management in Rembang Regency from the planning aspect is still relatively low as presented in Figure 2 below:

![Figure 2. Perception of the community on mangrove condition](image)

Based on the previous figure, it can be seen that 36.7% of communities are less involved and 29.20% stated that they are not involved in coastal resource management planning. In addition, the community’s ability to convey ideas/ideas in resource management is also low. Community involvement in Mangrove
management from the implementation aspect, most of them 61.70% stated that they were sometimes involved. This shows that not all communities are fully involved in Mangrove management. Most of the community involvement in Mangrove management in Rembang Regency from the aspect of supervision stated that they would report immediately if they found out that damage had occurred. Based on the picture above, it can be seen that 70.83% of the community stated that they would report immediately if there was damage to the Mangrove. This shows that the community has begun to realize the importance of mangroves for the sustainability of community life in the coastal area of Rembang Regency. One of the efforts to preserve the mangrove ecosystem on the coast of Rembang Regency is by planting mangroves. Mangrove ecosystems can be sustainably exploited, restored, and managed if local customary rules are enforced and institutional arrangements are put in place to mediate the rate of exploitation and regeneration of mangroves [45].

3.3 Mitigation of mangrove ecosystem

The composition of mangrove species in Pasar Banggi Village, there are 3 types of mangroves namely Rhizophora stylosa, R. mucronata, and R. apiculata [46]. This is because this type of mangrove is easy to develop and cultivate and its living characteristics are by the characteristics of the coast of Central Java [47]. The density of the mangrove ecosystem in the Pasar Banggi is 62 ind/100m which is included in the very dense category [48]. While the thickness is between 129-139 m which is classified as a normal condition based on the criteria in the Minister of Environment Decree Number 201 of 2004.

3.4 Adaptation program in mangrove ecosystem management

Healthy Mangrove Ecosystem conditions in coastal areas can increase the resilience of coastal communities to climate change and minimize the impact of natural disasters, such as tsunamis, storms, and waves [23]. Climate change has far-reaching effects on coastal areas and their ecosystems. Adaptation to climate change is an urgent effort that needs to be done to minimize the negative impacts of climate change [49]. The environmental services provided by mangroves as coastal protection contribute to the resilience level of coastal communities so that mangroves have an important role in natural disaster mitigation and climate change adaptation (climate and disaster risk) [23]. The loss of mangroves can have an impact on coastal stabilization because mangroves function as sediment traps, absorption of ocean wave energy (wave energy reduction), and protection against storms (storm protection) [39]. Mangrove damage not only has an impact on increasing greenhouse gas emissions but also on the resilience and welfare of coastal communities [23]. To preserve the ecosystem. The preservation of the mangrove ecosystem in the Pasar Banggi village of Rembang Regency requires an adaptation program. Environmental sustainability can be achieved if coastal communities in Pasar Banggi Village Rembang Regency can use environmentally friendly fishing gear and the community supports government programs for mangrove reforestation and rehabilitation.

| Table 2. Adaptation Programs in Mangrove Management to Climate Change |
|---------------------------------------------------------------|
| **Aspect** | **Adaptation Program** |
| --- | --- |
| Ecology | - Not cutting down mangroves  |
| | - Using environmentally friendly fishing gear |
| Economics | - Manage ecotourism together |
| | - Looking for sea cucumbers that can be sold |
| | - Looking for fish in a certain area |
| Social | - participation in planting |
| | - participation in maintenance |
| | - participation in mangrove monitoring |
| Culture | - Maintaining local wisdom |

For the mangrove ecosystem to have high adaptability to climate change, the community adaptation program to climate change must be supported by strict regulations and sanctions in the sustainable
management of mangrove ecosystems. Regulations and sanctions must be disseminated to the entire community so that people are aware that the mangrove ecosystem is very important for people’s lives [50]. All components in the work plan are aimed at protecting the availability of biological resources and reducing the impact of damage due to global climate change [51].

Mitigation and adaptation are two things that complement each other in strategies to address climate change risks [52]. Climate change mitigation refers to “human intervention to reduce sources of greenhouse gas effects”, while adaptation refers to "the process of adjusting to the actual climate to avoid or reduce losses and take advantage of profitable opportunities" [30]. In other words, climate change risk is expressed as a combination of the likelihood of occurrence of a hazardous event or trend associated with climate change, and the impact of this event or trend occurs [30]. Mitigation will reduce the pressure on nature and humans from climate change, which will allow more time for adaptation, on the other hand, adaptation has the potential to limit the detrimental effects of climate change, but will not prevent all the damage [53]. However, Adaptation mitigation can be defined as the prevention of direct damage, while mitigation is the prevention of indirect damage [54]. Therefore, climate change mitigation can be done by managing the mangrove ecosystem properly so that the density, diversity, and density of mangroves are in a very high category. Thus, the mangrove ecosystem will have high mitigation of climate change to reduce sea waves, abrasion, sea breezes, and so on.

4. Conclusion
Most of the community stated that the condition of the mangroves on the coast of Rembang Regency was in good condition. In general, the community has not been fully involved in mangrove management. In mangrove ecosystems management, active community involvement is needed to maintain its sustainability. Good mangrove conditions will be able to mitigate climate change. In the meantime, adaptation to climate change is being carried out through the development of programs that can preserve the mangrove ecosystem, such as not cutting down mangroves, using environmentally friendly fishing gear, developing ecotourism, and maintaining local wisdom.

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