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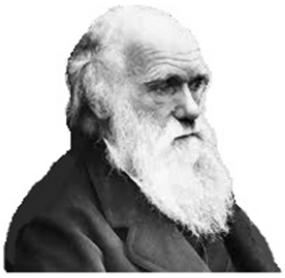

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Planning of potential mangrowe planting and tourism areas in Pangandaran Regency, West Java, Indonesia

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ABSTRACT

This study aims to identify and plan potential areas for mangrove ecosystem planting (rehabilitation/restoration) as well as to identify and design potential areas for the development of sustainable mangrove ecotourism in Pangandaran Regency, West Java. This study focuses on six main locations—Karang Tirta, Bojong Salawe, Majingklak, Batu Karas, Babakan (Bulaksetra), and Nusawiru—to restore coastal ecological functions and generate positive economic impacts for local communities. This research employs a descriptive-evaluative method with a qualitative approach. Data collection was conducted through field observations and in-depth interviews with various stakeholders. Secondary data—including ecosystem conditions and supporting documents—were integrated with spatial mapping using a Geographic Information System (GIS). The ecosystem area planning (site plan) phase applied the Integrated and Sustainable Tourism Development Planning approach. Identification of potential mangrove planting areas revealed that Karang Tirta has 5 ha of suitable land dominated by *Rhizophora mucronata*. Bojong Salawe has a 12-ha mangrove area with two potential sites for new plantings. In Majingklak, a 3-hectare reforestation area is recommended on degraded land that was formerly a disposal site for a stalled project, using the *Sonneratia alba* species. Batu Karas has 2.72 hectares of potential land along the river channel, with *Rhizophora mucronata* and *Avicennia* as the primary vegetation. Babakan (Bulaksetra) has 5.54 hectares of potential land in a post-2006 tsunami succession area with a sandy-mud substrate dominated by *Rhizophora apiculata* and *Sonneratia spp*. Nusawiru is a river estuary area with potential for recreational expansion and mangrove vegetation

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restoration. This study produced a site plan that divides the area into conservation and utilization zones, as well as planned eco-friendly facilities including a wooden jogging track/boardwalk, a boat/canoe dock, an educational pavilion/gazebo, a floating market, an information center, and a camping ground. Mangrove restoration strengthens natural coastal protection against erosion and tsunami disasters while enhancing aquatic habitats. The development of ecotourism managed by the Pangandaran Regency Tourism Office ( )—based on local communities (Pokdarwis) and in collaboration with small and medium enterprises (SMEs)—has proven capable of creating jobs and sustainable alternative sources of income.

***Keywords*:** Ecotourism, Geographic Information System (GIS), Mangroves, Pangandaran Regency, Rehabilitation, Site Plan

1. INTRODUCTION

Mangroves are woody plants tolerant of salinity, and this ecosystem is found in tropical and subtropical tidal environments, the ocean, and brackish water. [1-5]. Mangrove forests are key coastal ecosystems found in coastal areas; they serve as life-support systems and ecosystem regulators, boasting an abundance of biological resources, providing various ecosystem services, and performing important ecological functions [6-8]. Indonesia is an ideal location for mangrove growth due to its climate, geology, and oceanography. However, under current conditions, human land use has led to a decline in the extent, structure, and function of coastal ecosystems, particularly mangrove ecosystems [9-13].

One of the efforts undertaken to ensure the sustainability of mangrove ecosystems is mangrove rehabilitation. Mangrove ecosystem rehabilitation is an effort to restore degraded mangrove land to a functional mangrove ecosystem, regardless of the original condition of the degraded land [14]. Mangrove ecosystem rehabilitation poses significant challenges because mangroves are highly dynamic natural ecosystems influenced by natural factors such as ocean currents and tides, as well as disturbances resulting from human activities [15]. Therefore, rehabilitation efforts must take into account several environmental factors that can influence the success of rehabilitation, including substrate type, salinity, temperature, soil elevation, pH, season, waterways, and the substrate type suitable for the mangrove species to be planted.

Mangrove forests have great potential to be developed as tourist destinations [16]. Mangrove forests can serve as nature-based tourism destinations, and such activities make a significant contribution to mangrove conservation [17]. A form of tourism known as ecotourism emphasizes ethical travel that benefits local communities and minimizes negative impacts on the environment [18].

Mangrove conservation, tourism education, and generating economic benefits for local residents are highly valued aspects of ecotourism in mangrove environments [19].

Mangrove ecotourism can also provide socioeconomic benefits to local communities through the indirect value of natural resources [20]. Careful consideration is needed to ensure that mangrove ecosystems are well-maintained and protected through ecotourism activities [21]. The three main aspects of ecotourism are (i) ecology, which encompasses the presence of components that support mangrove ecosystems and conservation efforts [22], (ii) financial revenue from sustainable mangrove ecotourism activities, a portion of which is used to conserve the ecosystem [23], and (iii) the empowerment and involvement of local communities in the

ecotourism industry [20].

Pangandaran Regency is one of the regions on the southern coast of West Java, covering an area of approximately 1,010 km^2 and boasting natural resources including a 91 km-long coastline and a marine area spanning 67,340 hectares (Central Statistics Agency, 2019). Pangandaran also features a greenbelt that plays a crucial role in supporting coastal ecosystems. Pangandaran Regency possesses significant economic potential, particularly in the tourism sector, with a variety of attractive areas, one of which is the mangrove ecotourism area. There are three main locations for mangrove ecotourism, one of which is the Bojong Salawe Mangrove Ecotourism Area, located approximately 20 km west of the center of Pangandaran Regency.

Mapping of mangrove ecosystems can be conducted using GIS technology. Aerial imagery data generated from mangrove mapping at seven locations in Pangandaran Regency constitutes primary data that needs to be processed and integrated into a Geographic Information System (GIS)—a system capable of managing, analyzing, and presenting spatial information [24]. The use of satellite imagery and aerial photographs combined with GIS enables the analysis of changes in mangrove forest area.

Mapping potential areas for mangrove planting and mangrove ecotourism in Pangandaran has significant socioeconomic impacts. Mangrove ecosystem restoration can enhance coastal resilience to natural disasters, while the development of mangrove ecotourism can provide an alternative source of income for the community and serve as an effort to support the sustainable management of marine and coastal resources in Pangandaran Regency. This study was conducted to identify and plan potential areas for mangrove planting and the development of mangrove ecotourism in Pangandaran Regency, West Java. The study covered six main locations: Karang Tirta, Bojong Salawe, Majingklak, Batu Karas, Babakan, and Nusawiru.

2. METHOD

Location of astronomical Pangandaran between longitude 108°40' E and latitude 07°43' S. The methods used in this study were field observations and interviews. Field observations were conducted to collect direct data regarding the physical conditions of the areas, tourism potential, and interactions between humans and the mangrove environment. This research employs a descriptive-evaluative approach with a qualitative methodology. Descriptive research can be interpreted as a problem-solving process that analyzes the current state of the research object based on observable facts or existing conditions [25]. Interviews were conducted to gather information regarding the needs, expectations, and potential for mangrove ecotourism development from various perspectives. Interviews were conducted with various stakeholders, such as local government officials, ecotourism managers, local communities, and business operators.

Research locations were determined by identifying seven mangrove areas in Pangandaran Regency: Karang Tirta, Bojong Salawe, Majingklak, Batu Karas, Babakan, and Nusawiru. Field observations were conducted to collect physical and ecological data for each area. Both primary (field observations, interviews) and secondary data were collected. Primary data included vegetation conditions, substrate and accessibility, socioeconomic conditions, mangrove management, and tourism potential. Secondary data included the condition of the mangrove ecosystem and tourism potential in Pangandaran.

Mapping potential areas for mangrove rehabilitation and tourism development using a geographic information system (GIS) and analyzing the potential socioeconomic impacts of mangrove planting and ecotourism development. This study will also design site plans for mangrove ecotourism development at potential locations, taking into account environmental aspects, infrastructure, and community empowerment. The research methodology for tourism area planning consists of several stages: inventory, analysis, and tourism planning. The planning study was conducted using the tourism development component planning approach [26, 27].

The integrated and sustainable tourism development planning approach developed by Edward Inskeep (1991) combines environmental conservation (mangrove planting/restoration) with spatial planning aspects, which include (defining area boundaries both ecologically and socioeconomically, collecting biophysical data (mangrove species, substrate characteristics, water quality, the use of satellite imagery to identify critical areas with potential for mangrove replanting, socio-tourism data (accessibility, tourist profiles, coastal communities (pokdarwis), and the presence of key infrastructure), analysis, implementation, and monitoring.

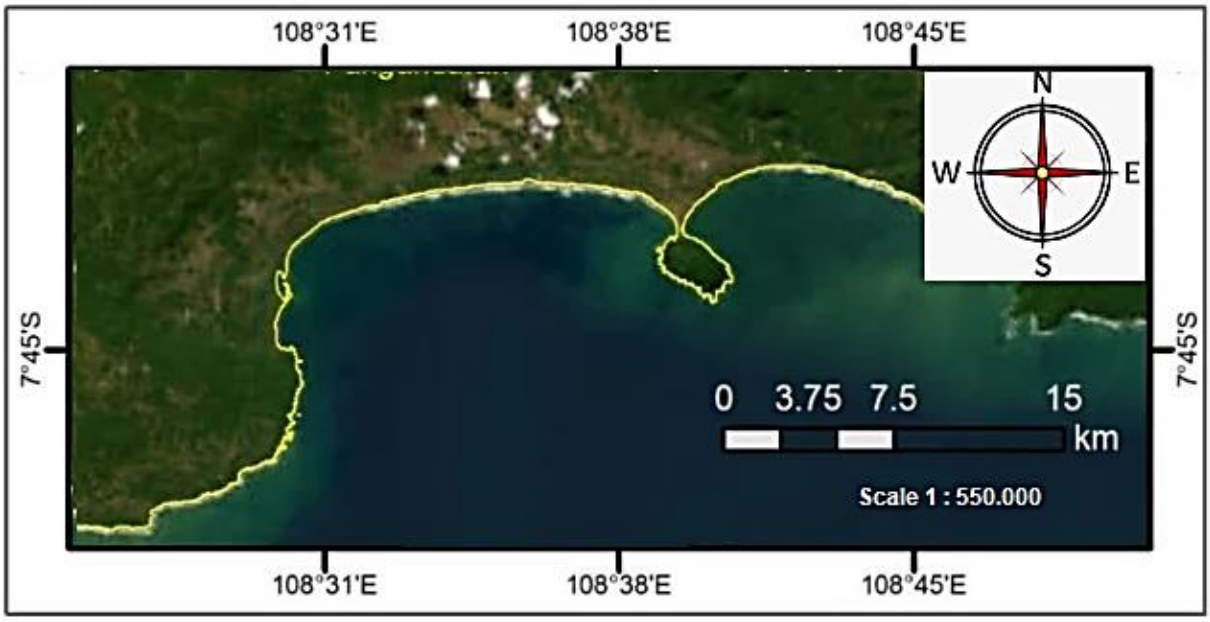

Figure 1. Study Area, Pangandaran Regency, West Java, Indonesia.

3. RESULTS

3. 1. Potential Areas for Mangrove Planting in Pangandaran Regency

3. 1. 1. Karang Tirta

The potential area for mangrove planting in Karang Tirta, Pangandaran Regency, is shown in Figure 2. The area marked in blue is assessed to have environmental conditions that support the development of a mangrove ecosystem, such as suitable soil structure, optimal water levels, and protection from waves, which can accelerate mangrove growth.

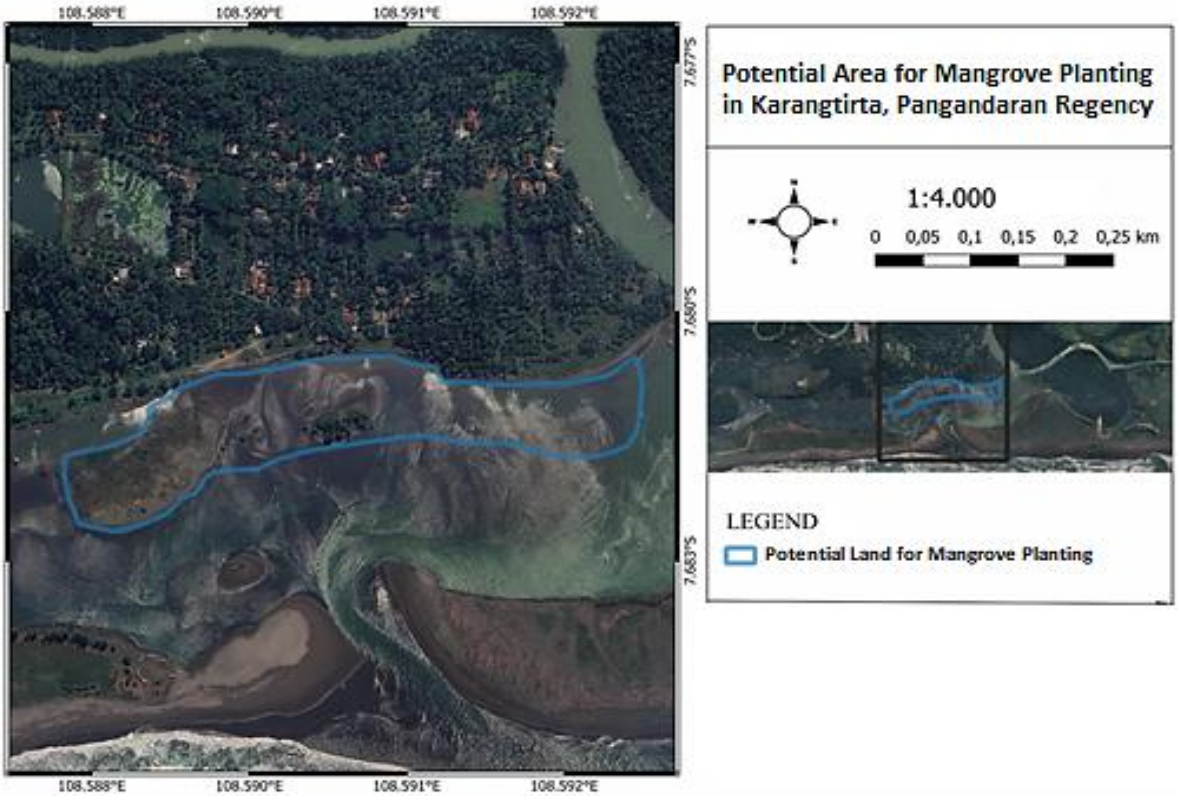

Figure 2. Potential Area for Mangrove Planting in Karang Tirta, Pangandaran.

The potential area that can be developed for mangrove planting and rehabilitation in Karang Tirta covers 5 hectares. These locations were selected to maximize the success of mangrove rehabilitation and planting, which play a crucial role in coastal environmental conservation efforts. The substrate in this area consists of mud and sand, which are suitable for the growth of various mangrove species. Muddy substrate retains water and maintains moisture around the mangrove roots. Meanwhile, the sandy substrate serves as an effective drainage area, facilitating the exchange of water and nutrients. The mangrove species growing in this area include *Rhizophora mucronata*, *Avicennia marina*, *Sonneratia alba*, and *Nypa fruticans*. The dominant species is *Rhizophora mucronata*.

Karang Tirta Beach is a transition zone that connects terrestrial and marine ecosystems. Planting mangroves in this area is expected to provide ecological benefits such as erosion prevention, improved habitat quality for marine fauna, and carbon sequestration. Identifying these potential areas is crucial to ensure that mangrove planting activities are carried out in the right locations to support conservation efforts and mitigate the impacts of climate change. Surveillance and monitoring of potential mangrove planting areas in Karang Tirta are crucial steps to ensure the success of the rehabilitation of the mangrove ecosystem, which spans several hectares.

Monitoring of mangrove growth is conducted by measuring vegetation density using drone technology, as well as through direct observation of mangrove health. Key species such as *Rhizophora mucronata*, *Avicennia marina*, and *Sonneratia alba* are the focus of monitoring due to their vital roles in the mangrove ecosystem.

The application of mangrove area monitoring methods can provide new insights into the biophysical characteristics and growth dynamics of mangrove forests and can serve as input for future monitoring [28]. Mangrove planting methods can influence density levels, particularly the spaced clump method. The spaced clump method is used to adapt to the strong tidal currents in the island's coastal areas. These strong currents can cause young mangrove seedlings to be washed away, making the spaced clump method a solution to the problem of mangrove drift.

3. 1. 2. Bojongsalawe

The Bojongsalawe mangrove forest covers an area of 12 hectares and is in fairly good condition. The dominant mangrove species are Rhizophora sp. and Nypa fruticans, though Avicennia alba has also been found in some areas. The mangrove vegetation in Bojong Salawe is quite dense, growing on a muddy-sand substrate.

There are two potential planting sites in Bojong Salawe: Site 1, adjacent to the fish ponds, and Site 2, located near the restaurant. Site 1 is suitable for mangrove planting due to its proximity to water bodies with salinity levels that support mangrove growth. In this area, the space available for mangrove planting is limited, and a bridge cannot be built due to the extremely dense mangrove stand and the fact that part of the land is already used as a boat parking area for fishermen. This area is also adjacent to a shrimp farm. The existing shrimp farm has a well-managed wastewater treatment system (IPAL), which supports healthy mangrove growth.

Potential Area 2 has several vacant and fairly large plots suitable for mangrove planting and has the potential for building a trail. However, constructing a wider trail in this second area remains somewhat challenging, as some plots are currently occupied as parking areas for local fishermen. Developing facilities by expanding the nature trails and improving road access to the mangrove forest, requires regular management and monitoring, which will ultimately impact the sustainability of the mangrove forest ecotourism initiative itself. From a social and economic perspective, mangrove planting can provide direct benefits to the local community.

This area has the potential to be developed into an educational ecotourism destination, where visitors can learn about the importance of mangrove ecosystems. Additionally, healthy mangroves will support sustainable fisheries, providing additional economic benefits for local residents.

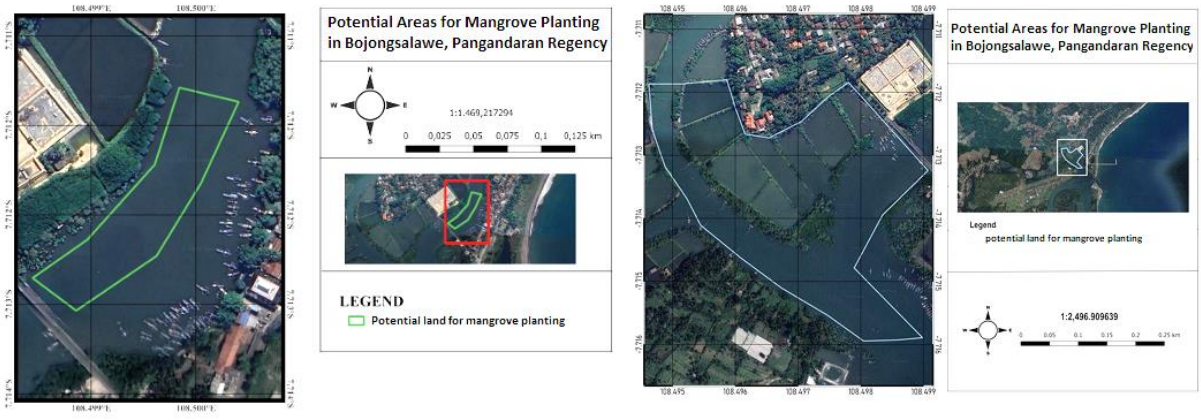

Figure 3. Potential Area for Mangrove Planting in Bojong Salawe, Pangandaran.

However, challenges such as nearby human activities, including boat mooring, must be properly managed to prevent them from hindering mangrove growth. For the mangrove planting program to succeed, a rehabilitation project involving various stakeholders including the government, the community, and academics is essential. Continuous monitoring is also necessary to assess the effectiveness and sustainability of this project. This map serves as a vital tool for mangrove management planning in Bojong Salawe, with the aim of supporting coastal environmental conservation in the area.

3. 1. 3. Majingklak

The Majingklak mangrove forest area is located at the mouth of the Citanduy River, in Kalipucang Subdistrict, Pangandaran Regency, which lies on the border between West Java and Central Java provinces. The brackish water area around the Majingklak River estuary is also highly suitable for mangrove planting. The muddy soil and periodic inundation by seawater create an ideal environment for mangrove growth. The Majingklak mangrove forest originally covered an area of 12 hectares with fairly dense mangrove canopy cover. However, over time, the area of the Majingklak mangrove forest has continued to decline due to logging and land-use conversion by the local community, as well as plans for a landfilling project. Currently, only 9 hectares of the Majingklak mangrove area remain with mangrove trees; the remaining 3 hectares were logged for land-use conversion to serve as a disposal site, but this project stalled and was not continued.

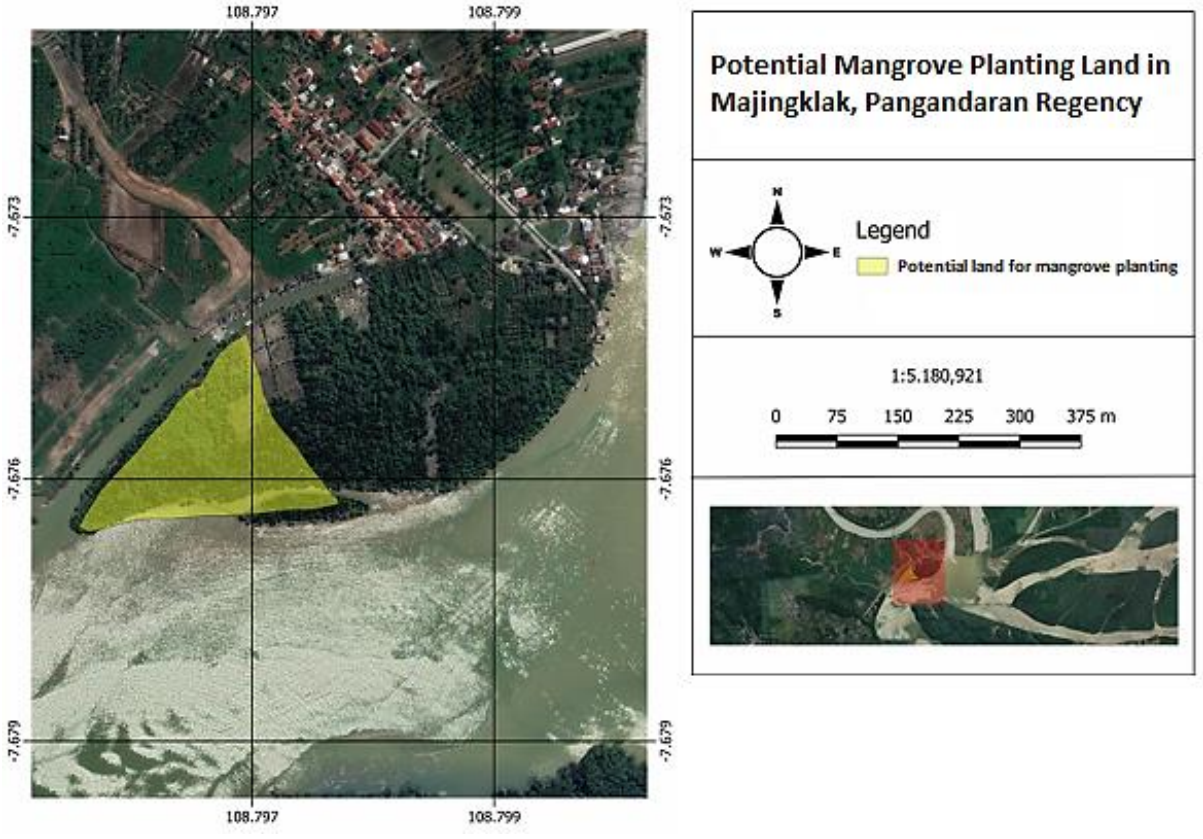

Figure 4. Potential Area for Mangrove Planting in Majingklak, Pangandaran.

The substrate in the Majingklak mangrove area is mud. The mangrove species found at this location include *Sonneratia alba*, *Nypa fruticans*, and *Acanthus ilicifolius*. Damaged land often experiences a decline in productivity due to changes in water and soil quality. By planting mangroves, the land's function as a balancer of the coastal ecosystem can be restored, and the soil structure damaged by environmentally unfriendly management practices can be improved. Planting mangroves around the estuary can improve habitat quality for various species of fish, crabs, and birds living in the ecosystem, while also enhancing water fertility.

The Majingklak mangrove area is currently neglected and poorly managed. For potential mangrove planting areas in the Majingklak region, it is recommended to carry out reforestation on a 3-hectare disposal site to restore the function of the degraded land. The recommended mangrove species for this area is *Sonneratia alba*, planted using propagules (mangrove fruits) that either fall directly onto the ground or are collected beforehand for sowing, selected from healthy parent trees that are sufficiently mature. Seeds or propagules are sown in a nursery of ideal size, with seedlings reaching a height of approximately 30–50 cm before being transplanted into the field. The ideal planting spacing for *Sonneratia alba* is 1–1.5 meters between seedlings to ensure sufficient space for growth. Long-term monitoring is required after the first 6 months, conducted periodically every 2–3 years, until the seedlings are strong enough to survive independently. Monitoring helps identify potential issues such as erosion or environmental changes that affect seedling growth.

3. 1. 4. Batu Karas

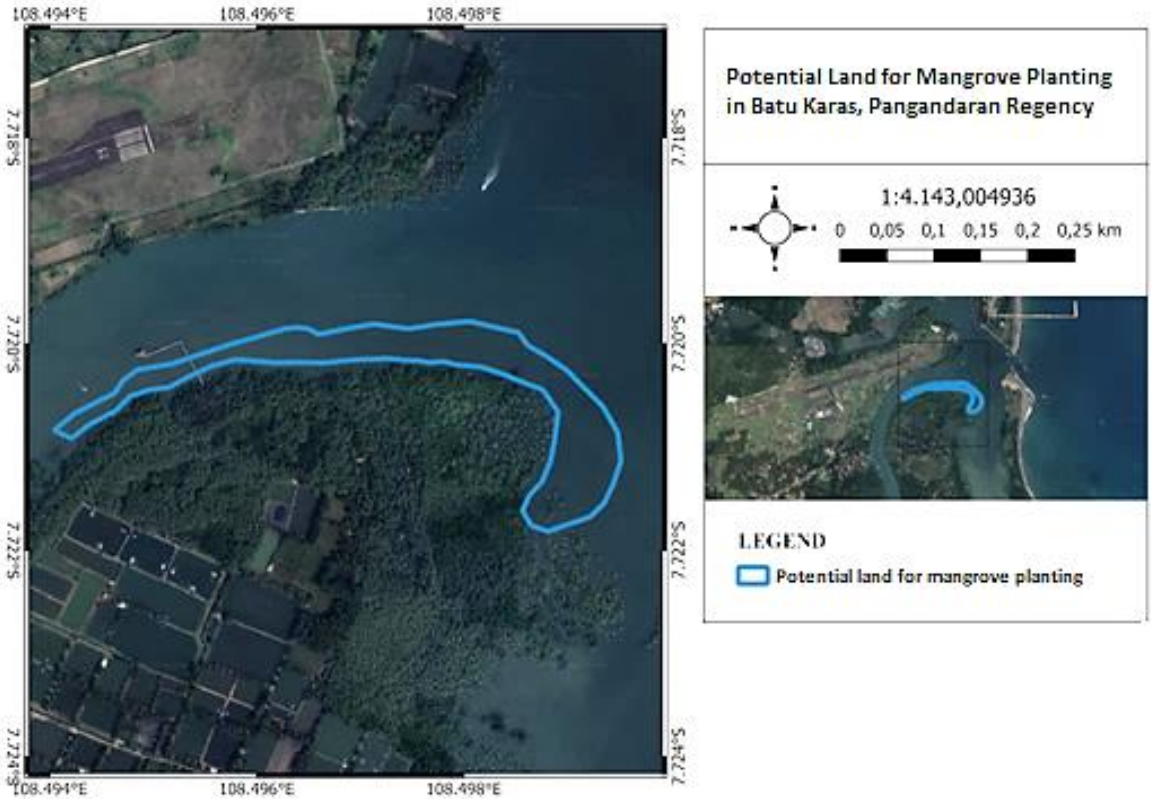

Figure 5. Potential Area for Mangrove Planting in Batu Karas, Pangandaran.

The Batu Karas mangrove area is located along a river channel and is populated by *Rhizophora mucronata* mangroves. This mangrove species serves to prevent erosion and filter water entering aquaculture ponds and rice fields. This area has the potential to be developed into a mangrove forest and an ecotourism site. The most dominant mangrove species are *Rhizophora mucronata* and *Avicennia*. Inadequate accessibility is a factor to be evaluated for the development of this area. The soil conditions around this potential area are muddy, with *Rhizophora mucronata* forming the outermost layer of vegetation. The potential area (marked with a blue line in Figure 5) for planting new vegetation spans 2.72 hectares and consists of *Rhizophora mucronata*. The location of this mangrove area in Batu Karas is adjacent to the Lagoon tourist site, fish ponds, the mainland, and the Bojongsalawe estuary—the main entry and exit point for fishermen in Nusawiru. This ecotourism area has the potential to support the local economy and is also expected to provide ecological benefits such as preventing coastal erosion, improving habitat quality for marine fauna, and sequestering carbon.

3. 1. 5. Babakan

The Bulaksetra Mangrove Area is located in Babakan Village, Pangandaran District. According to the Indonesian Tsunami Catalog published by the BMKG, the tsunami that struck the southern coast of Java Island affected the Babakan area. The Bulaksetra Mangrove Area is currently still in the growth stage as a result of the succession process following the 2006 tsunami. The Bulaksetra Mangrove Area is a mangrove initiative launched by the community of Babakan Village, Pangandaran Regency, to replant residents' settlements and plantations—which were damaged by the tsunami—with mangrove vegetation. This planting was carried out as a form of natural coastal protection to mitigate damage should another tsunami occur in the future, given that Pangandaran Regency is a coastal area prone to earthquakes (Sumaryana et al. 2018). Over the past seven years, efforts have been made to rehabilitate the Bulaksetra coastal area by planting mangrove seedlings, predominantly of the *Rhizophora apiculata* species. Meanwhile, the native mangrove species in the area is Sonneratia spp., which originally formed the dominant mangrove stand ( ) in the area but was destroyed by the tsunami; the remaining *Sonneratia* spp. stands that survived are unable to grow to their full potential. Bulaksetra showcases a diverse array of natural phenomena, ranging from the variety of mangrove species to the fauna found within this ecosystem. In addition to mangroves, the area is home to a diverse array of fauna, such as birds, mollusks (snails and conches), fish, various crustaceans (crabs), and other animals.

Here, visitors can also enjoy canoeing and participate in mangrove seedling planting activities. The area spans 1.65 hectares, with low-density vegetation covering 4,075 m^2 (NDVI 0.2–0.2), sparse vegetation covering 5,489 m^2 (NDVI 0.2–0.4), and moderate-density vegetation covering 6,906 m^2 (NDVI 0.4–0.6). The total potential area is 5.54 hectares. The Bulaksetra mangrove area extends parallel to the coastline, with an average width ranging from 8 to 25 meters. This area has a sandy-mud substrate. This supports biodiversity; the sandy-mud substrate also provides a good balance between soil retention and water drainage. Furthermore, this substrate tends to be more stable than pure mud, allowing mangrove roots to grow well and grip the soil more firmly. It is imperative that the Bulaksetra area be restored to its original condition.

This mangrove area has undergone land-use conversion since 2017, including the construction of the Pangandaran Maritime Polytechnic (PKPP) campus, the Pangandaran Integrated Aquarium and Marine Research Institute (PIAMARI) building, the Independent

Feed Production Unit building, the development of fish ponds, and the construction of a seawall. The area is managed by the local community. The mangrove rehabilitation initiative, launched by the community with support from the local government and funding from Corporate Social Responsibility (CSR) programs, has been successful, transforming the area into the Bulaksetra Mangrove Area. The establishment of the Pangandaran Marine and Fisheries Polytechnic and PIAMARI near the Bulaksetra mangrove area—construction of which began in 2017, has further solidified the area's potential to become the Bulaksetra Mangrove Ecotourism Area. It is hoped that the mangrove ecotourism initiative in the Bulaksetra Mangrove Area will serve as an educational tool for the community to learn about and appreciate mangroves in an enjoyable way, while also providing additional income for residents living near the area. By planting mangroves, the land can regain its function as a balancer of the coastal ecosystem and help restore soil structure damaged by environmentally unsustainable management practices. Planting mangroves around the estuary can improve habitat quality for various species of fish, crabs, and birds living in the ecosystem, while also enhancing the fertility of the waters.

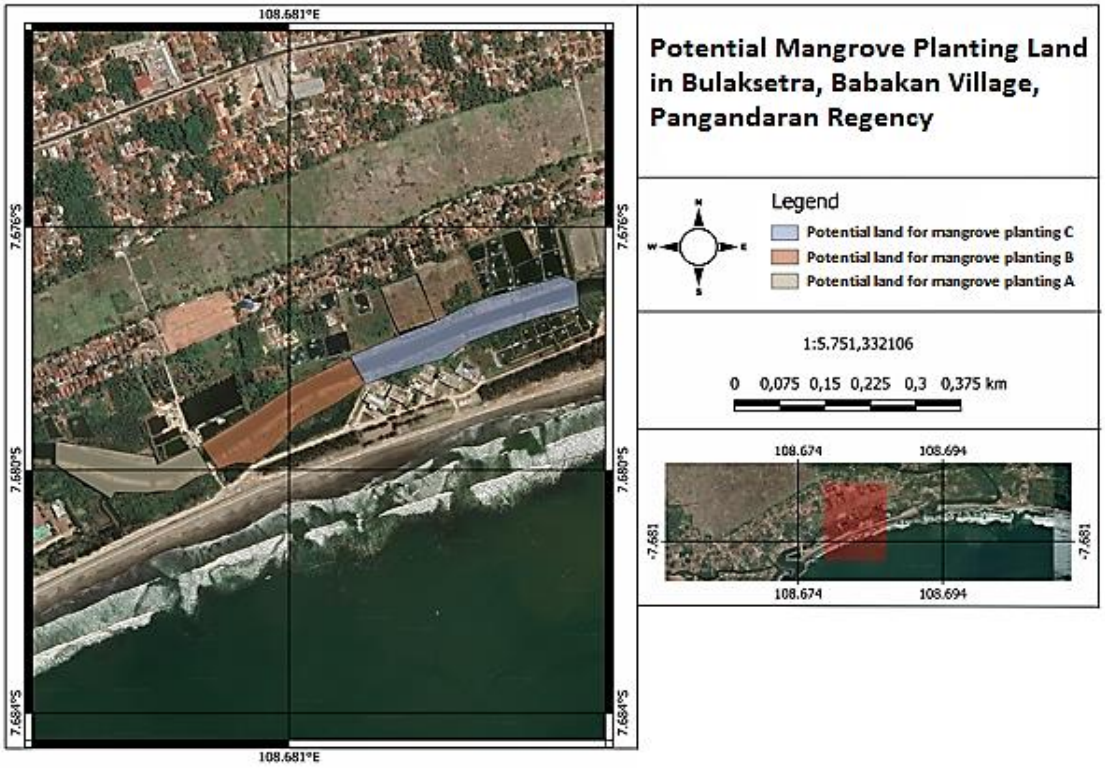

Figure 6. Potential Area for Mangrove Planting in Babakan, Pangandaran.

3. 1. 6. Nusawiru

The Nusawiru mangrove area is located in Cijulang Subdistrict, Pangandaran Regency. It has an ecosystem area of approximately 5 ha with mangrove vegetation cover exceeding 10 ha. The vegetation structure in Nusawiru varies in trunk diameter (1–32 cm) and height (1–25 m) because the area is in the recovery phase and undergoing phased replanting following the 2006 tsunami. There are still potential areas along the estuary that have been set aside for the

expansion of mangrove vegetation rehabilitation (restocking) and will also serve as an observation area and an environmental education center. A local community group manages the area independently and actively. This mangrove area is managed by an organized local community group, namely the Nusawiru Mangrove Ecotourism Group or the Nusawiru Mangrove Activists Group. In addition to the ecotourism group, monitoring and planting activities in the field also involve the Community Monitoring Group (Pokmawas), the Nusawiru Hamlet Administration, the Fishermen's Group, the Joint Business Group (KUB), and officials from Cijulang Village. The management group provides mangrove seedlings and assists tourists who wish to plant seedlings directly in the designated planting areas. Community groups independently establish partnerships with various parties, such as the Pangandaran Regency Department of Marine Affairs, Fisheries, and Food Security, as well as with academics from various universities, to collaborate on community service activities. These efforts support initiatives ranging from mangrove seedling restocking and shrimp seed release to training on the utilization of processed mangrove products and digital marketing.

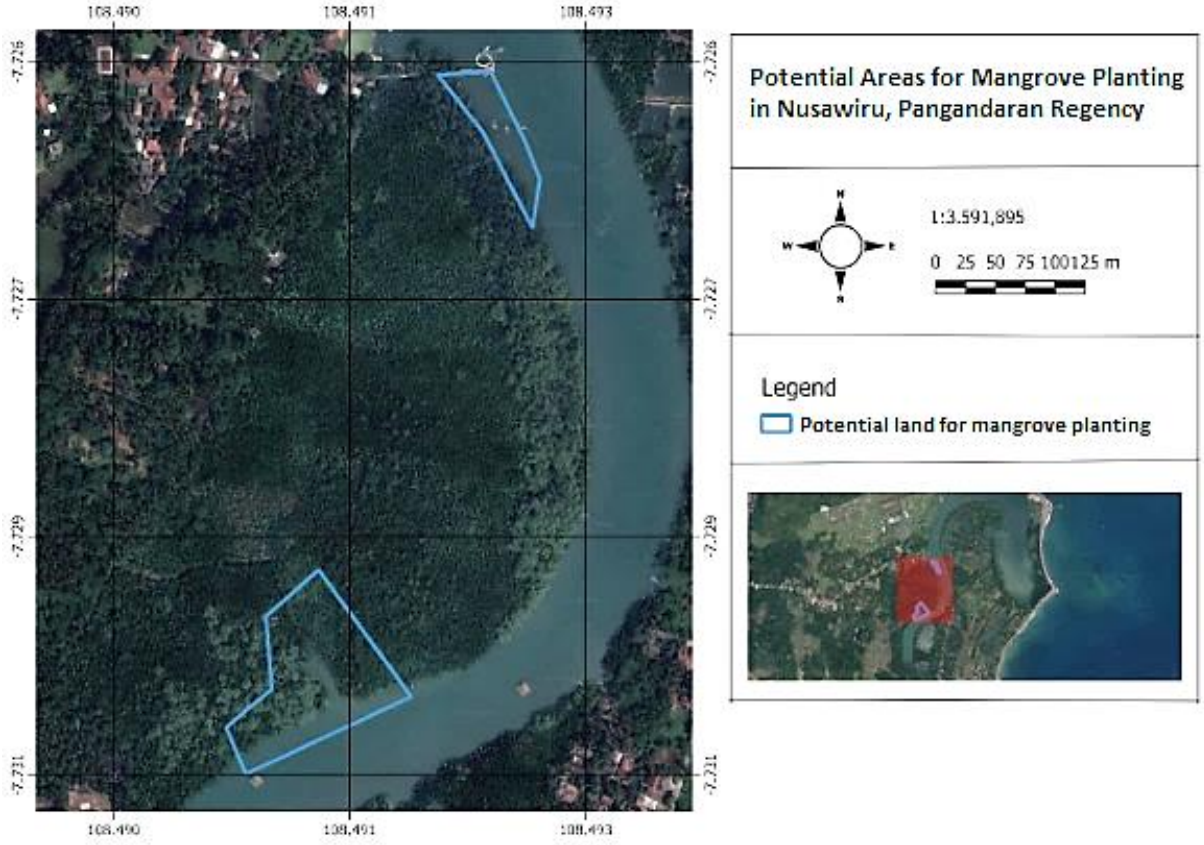

Figure 7. Potential Area for Mangrove Planting in Nusawiru, Pangandaran.

3. 2. Site Plan of Potential Mangrove Tourism Area

3. 2. 1. Karang Tirta

The following is a map of the potential area for the Karang Tirta Mangrove Tourism Site

in Pangandaran Regency as of October 2024.

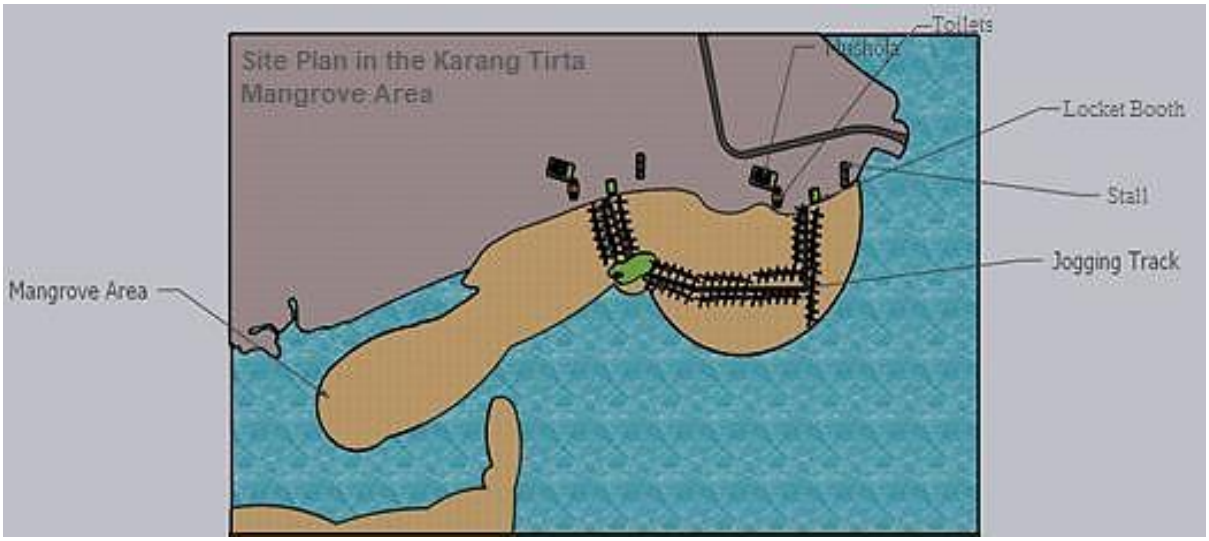

Figure 8. Karang Tirta Site Plan (Source: SketchUp, 2024).

The Karang Tirta Mangrove Area is managed by the Tirta Mandiri Klewer Group, which consists of 17 members. Karang Tirta is often chosen as a mangrove planting site by various stakeholders during major celebrations, as this area has great potential to be developed as a sustainable mangrove tourism destination.

The image above shows the site plan for mangrove ecotourism at Karang Tirta. The tourism development plan for the Karang Tirta area will focus on sustainable mangrove ecotourism, with the primary goal of conserving the mangrove ecosystem while improving the well-being of local communities by collaborating directly with existing community groups to transform this area into a sustainable mangrove ecotourism destination. The initial phase of development will include the construction of infrastructure such as a *jogging track* bridge that allows visitors to walk over the mangrove area without damaging the soil or mangrove roots. This path will be equipped with educational information boards explaining the benefits of mangroves as well as the types of mangroves growing in Karang Tirta. Additionally, infrastructure such as an entrance booth, an information center, a prayer room, rest areas, and a parking lot will be constructed.

To boost the area's appeal, plans include providing several tourist facilities for visitors to enjoy, such as boat and canoe tours that allow them to explore the mangrove forest and appreciate the natural beauty. Furthermore, a mangrove planting program has been established so that tourists can participate directly in planting mangroves. The program includes educational sessions on mangroves, seedling planting, and mangrove tree planting, allowing tourists to experience firsthand how they are contributing to environmental conservation.

As part of community empowerment efforts, small and medium-sized enterprises (SMEs) based on local potential will be developed, such as the sale of eco-friendly souvenirs and food products made from mangrove fruits. Community involvement will also be expanded by training local residents to become tour guides, conservation officers, and workers involved in tourism activities.

3. 2. 2. Bojong Salawe

The following is a map of the potential mangrove tourism area in Bojong Salawe, Pangandaran Regency, as of October 2024.

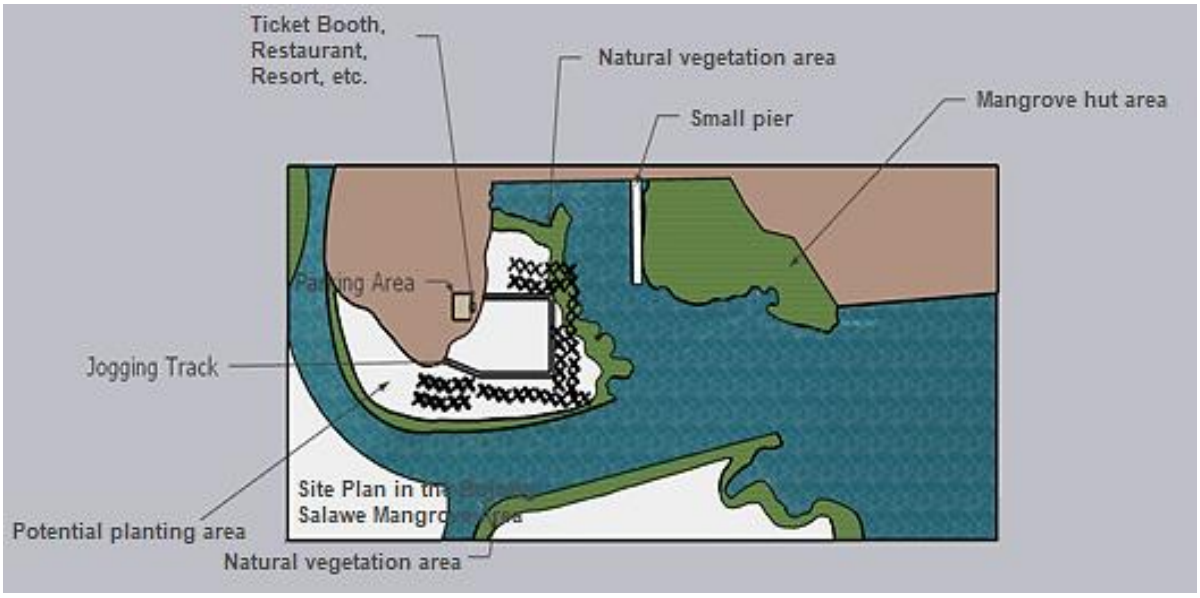

Figure 9. Bojong Salawe Site Plan (Source: SketchUp, 2024).

The area development plan shown in this site plan emphasizes a combination of nature conservation and tourism facilities to create sustainable ecotourism. The area is dominated by natural vegetation, underscoring the importance of preserving local biodiversity while utilizing the space for recreational activities. Mangrove huts are provided as resting spots, also aimed at raising visitors' awareness of the critical role mangroves play in maintaining coastal ecosystems. Additionally, there is a small pier to support water-based tourism activities or serve as an access point for visitors arriving by boat.

Other planned facilities include a jogging track, allowing visitors to enjoy the natural beauty while exercising. In the center of the area, there is a restaurant and a "saung balong," which serves as both a dining area and a resting spot after exploring. The parking area is strategically located near the main facilities to ensure visitor convenience. Potential planting areas have also been identified as part of plans for further vegetation development, demonstrating a commitment to environmental restoration efforts. Overall, this site plan illustrates a balance between conservation, environmental education, and recreation, with a focus on ecological sustainability in this area.

3. 2. 3. Majingklak

The following is a map of the potential Majingklak Mangrove Tourism Area in Pangandaran Regency as of October 2024.

The Majingklak mangrove area has the potential for the development of a 9-hectare mangrove ecotourism site. In the plan, the Majingklak mangrove site will be divided into two

zones: an ecotourism zone covering 9 hectares and a conservation zone covering 3 hectares, which is the disposal area for a stalled project. The conservation zone will be accessible only for planting and research activities. Meanwhile, the ecotourism zone—as outlined in the site plan shown in Figure 10—is designated for the development of mangrove ecotourism in Majingklak.

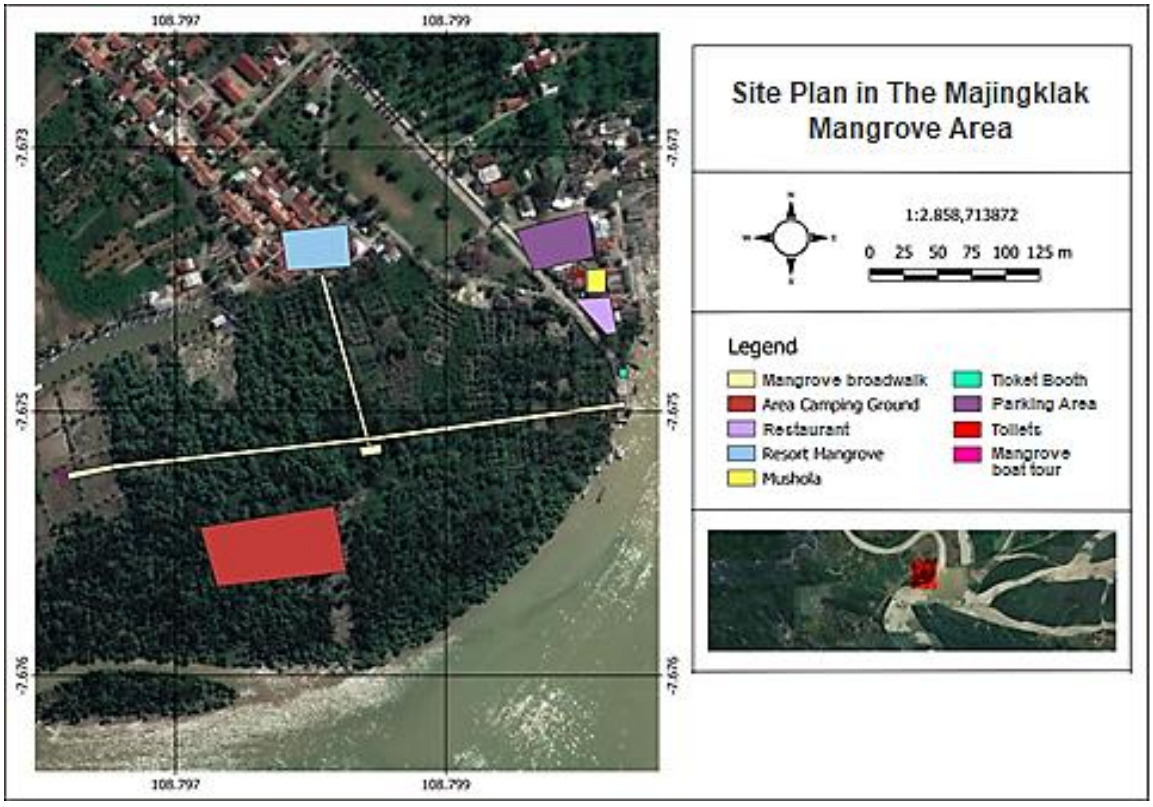

Figure 10. Majingklak Site Plan (Source: Google Earth, 2024).

The Majingklak mangrove tourism plan features an educational theme, with tour guides available to introduce visitors to mangroves. This ecotourism site includes supporting infrastructure such as a mangrove trail in the form of a bridge spanning the mangrove area, a tourist information center, an observation tower, and a small dock for tour boats. In addition, there is a camping ground, which is one of the facilities offered in the Majingklak ecotourism area. The mangrove trail is a wooden walkway built in the middle of the mangrove forest to make it easier for visitors to enjoy the natural beauty, such as the flora and fauna living in the mangrove area.

The infrastructure built in the Majingklak mangrove area must adhere to environmentally friendly principles. The construction of the wooden trail, the observation tower made from local materials, and the information center facilities are designed to be energy-efficient. Furthermore, the area's accessibility is carefully considered, such as by providing an eco-friendly dock for small boats as part of the mangrove tour facilities.

The development and management of this ecotourism area actively involve the local community. This is achieved by providing training for them to become tour guides, facility

managers, or business operators in tourism-supporting sectors such as resorts, restaurants, souvenir shops selling processed mangrove fruit products, and craft shops. Through this community involvement, local residents can directly benefit economically from ecotourism while simultaneously increasing their awareness and sense of responsibility in preserving the mangrove area for environmental sustainability. Our mangrove educational tourism plan draws inspiration from the Pangkalan Jambi Mangrove Ecotourism project.

3. 2. 4. Batu Karas

The following is a map of the potential mangrove tourism area in Batu Karas, Pangandaran Regency, for October 2024.

Figure 11. Batu Karas Site Plan (Source: Google Earth, 2024).

The image above shows the site plan for the mangrove ecotourism area in Batu Karas. This area was previously operational but experienced a decline due to infrastructure damage—such as to bridges—and the impact of the COVID-19 pandemic, which halted its operations. Therefore, this development plan will focus on restoring and revitalizing the existing ecotourism site while also enhancing it by constructing new facilities that support visitor comfort and ecosystem conservation. This area is managed by a group that also manages the mangrove area in Bojong Salawe; consequently, the management system for the Batu Karas mangrove area will collaborate with that group.

The initial planning phase will include the repair of a bridge that previously served as the main pathway for visitors to walk through the mangrove area and enjoy the natural scenery without damaging the environment. This bridge will also be preserved as part of a jogging trail, equipped with educational information boards explaining the benefits of the mangrove ecosystem and the biodiversity in Batu Karas. In addition to restoring existing infrastructure, additional facilities will be built, such as a ticket booth, an information center, a prayer room, restrooms, a parking lot, and a strategically located café area, allowing visitors to relax while enjoying the beautiful scenery—especially during sunset in the evening. This café will serve as an additional attraction, providing a comfortable atmosphere for tourists to enjoy the natural beauty of the Batu Karas coastline. To revitalize the area's appeal, boat and canoe tours will be offered, allowing visitors to explore the mangrove forest while taking in the beauty of the surrounding natural landscape.

As part of community empowerment efforts, small and medium-sized enterprises (SMEs)

will be revitalized, particularly through the sale of eco-friendly souvenirs and processed mangrove fruit products. Local residents will also be retrained to serve as tour guides, conservation officers, and workers in the tourism sector, ensuring their active involvement in the management of this ecotourism area.

With this redevelopment plan, it is hoped that Batu Karas will once again become a popular tourist destination while also serving as a model for sustainable ecotourism that provides economic benefits to the local community and preserves the natural environment.

3. 2. 5. Babakan

The following is a map of the potential Babakan Mangrove Tourism Area in Pangandaran Regency as of October 2024.

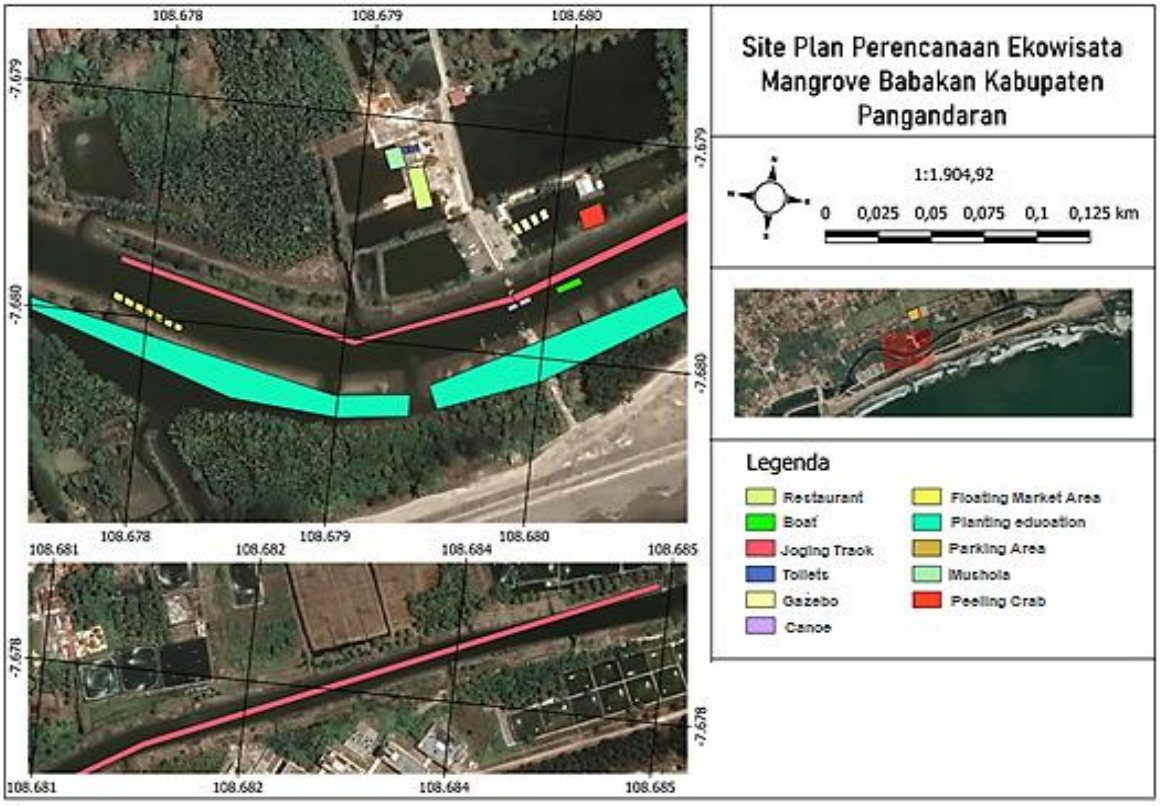

Figure 12. Babakan Site Plan (Source: Google Earth, 2024).

The image above shows the site plan for the mangrove ecotourism area in Babakan. This area was previously operational but sustained damage during the 2006 tsunami. Previously, the Bulaksetra area was operational as a mangrove site managed by the local community, who referred to it as “ilalang,” but all activities ceased when the tsunami struck. Currently, restoration efforts are gradually underway, ranging from facility improvements to reforestation. Today, the Bulaksetra mangrove area is managed by the Coastal Area Development and Management Group.

A restaurant is currently under construction to serve as a facility where visitors can enjoy meals featuring local cuisine or seafood-based dishes that support ecotourism. There are also boats available for touring the mangrove area and visiting the floating market. A jogging track is provided for tourists who wish to enjoy nature while exercising, offering a relaxing walk through the mangroves with fresh air and scenic views. The floating market area showcases the concept of a floating market, which is often a major attraction for tourists. This floating market can sell various local products, such as seafood, handicrafts, or regional specialties. The crab-peeling area serves as a venue for activities related to crab fishing or the processing of crab products, which can be part of both tourism attractions and educational programs.

The site plan in Figure 12 illustrates how the mangrove area in Babakan, Pangandaran, can be developed into an integrated ecotourism center featuring various facilities such as restaurants, a jogging track, canoeing, planting education, a floating market, and other public amenities. The focus of this area is to provide a nature-based tourism experience that simultaneously supports mangrove ecosystem conservation.

This plan is inspired by the mangrove ecotourism management in Kulonprogo, which is known for its community-based mangrove management that involves local residents in preserving the ecosystem and developing ecotourism. The mangrove ecotourism management in Kulonprogo has successfully attracted tourists by providing photo spots, wooden bridges, boats, and scenic viewpoints.

3. 2. 6. Nusawiru

The following is a map of the potential Nusawiru Mangrove Tourism Area in Pangandaran Regency for October 2024.

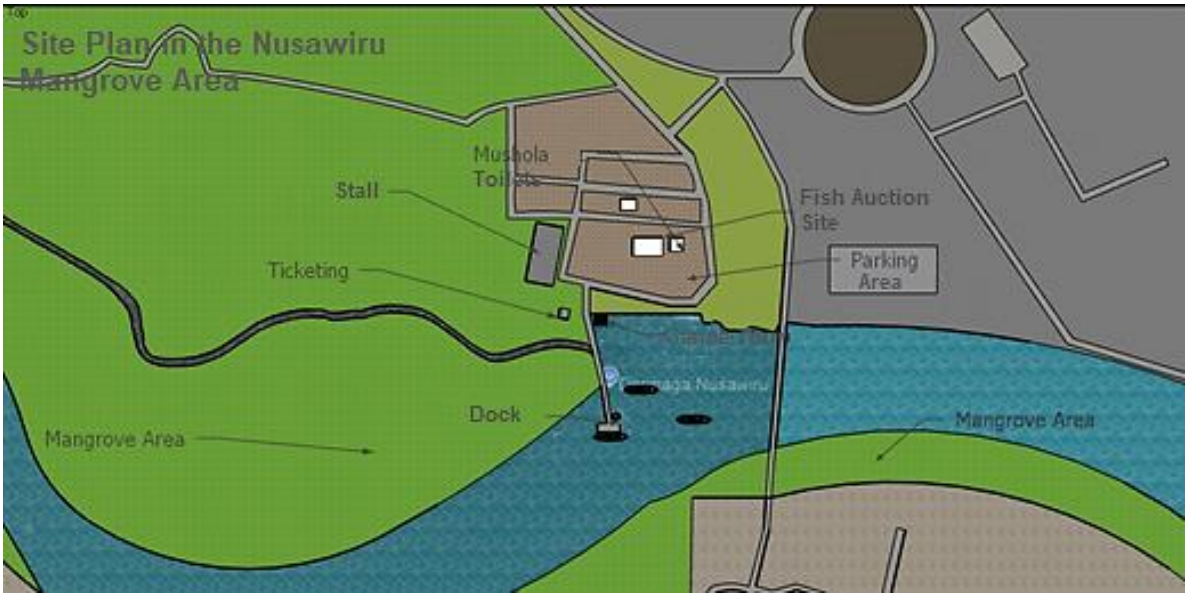

Figure 13. Nusawiru Site Plan (Source: SketchUp, 2024).

After assessing the physical condition of the Nusawiru mangrove forest, there is tourism potential that can be developed into an ecotourism area. Therefore, the Nusawiru mangrove

forest needs to be developed as an ecotourism area so that existing natural resources can be utilized to the fullest extent possible for the well-being of the local community itself. The local community can benefit from these opportunities in many ways, including as managers, tour guides, food or restaurant providers, accommodation facilities, transportation providers, and sellers of handmade crafts. As shown in Figure 16, the available potential land will be developed into a larger recreational area, an observation area, and an environmental education center. This area focuses on empowering the local community through participation in ecotourism activities, such as providing tour guide services. To support ecotourism, a bridge spans the mangrove forest area, extending from the estuary's edge to its midpoint; at the bridge's end—in the middle of the estuary—there is a small dock. The bridge was originally used solely as a landing spot for fishermen's boats returning from the sea. However, because the mangrove bridge is often used as a photo spot by visitors and also as a training ground, the bridge has gradually become well-known to the general public, both locals and outsiders.

3. 3. Karang Tirta

Three main mangrove species are found in Karang Tirta: *Sonneratia alba, Rhizophora* sp., and *Nypa fruticans,* with *Sonneratia alba* and *Rhizophora* sp. being the most dominant. In addition to mangroves, other vegetation found in this area includes sea pandanus, grasses, coconut palms, ketapang, and boro gondolo. The presence of mangroves has a positive impact on the surrounding community, particularly as a new habitat for birds and various catches for fishermen, such as peci shrimp, bubui shrimp, galah shrimp, mangrove crabs, and various types of fish. Currently, there is a mangrove management community in Karang Tirta, established in 2021, that plays an active role in protecting and maintaining the mangrove area in this region.

The substrate conditions in the waters around Karang Tirta tend to be sandy and muddy, requiring specialized mangrove planting techniques. A common technique involves digging the soil to create more stable planting holes and using stakes (such as bamboo or wood) to support the mangrove plants, preventing them from being easily toppled by water currents or waves. These conditions are often found in coastal areas subject to tidal fluctuations. Sand and mud tend to erode easily due to water currents, making it difficult for mangrove roots to anchor firmly. Tilling is performed to create deeper, denser planting holes, providing mangrove roots with a better environment to grow and anchor the plants. Selecting the appropriate planting

technique is crucial for successful mangrove growth in less-than-ideal substrate conditions. If not done correctly, mangrove plants may die or fail to grow optimally. Additionally, it is important to consider other factors such as the type of mangrove suited to local conditions, water depth, and salinity levels.

3. 4. Bojong Salawe

The mangrove forest in Bojong Salawe covers an area of approximately 12 ha. Currently, there is a mangrove management group in Bojong Salawe that plays an active role in mangrove conservation efforts. These efforts are primarily focused on replanting and restoration to ensure the sustainability of the mangrove ecosystem. The existence of this forest is vital for coastal communities, particularly fishermen. Mangroves help provide a safe habitat for fish and other marine life, thereby positively impacting fishermen's catches. Additionally, there are direct economic benefits from the sale of mangrove seedlings. The primary benefit lies in the role of mangroves in carbon sequestration, which helps maintain environmental balance.

The Climate-Smart Agriculture (CSA) program has also made a significant contribution to mangrove conservation efforts in Bojongsalawe. Through this program, funds raised at are used to purchase mangrove seedlings for replanting in the mangrove forest area. These efforts not only help maintain the area's size but also restore mangrove areas and increase community participation in protecting the coastal environment. With this program, it is hoped that the Bojongsalawe mangrove forest can continue to provide ecological and economic benefits to the local community, as well as play a role in climate change mitigation.

3. 5. Majingklak

Originally, the mangrove forest in Majingklak covered an area of approximately 12 ha; 3 ha of the land was cleared for landfilling, leaving only 9 ha remaining, and there are currently no optimal management efforts in place. To address this, mangrove planting efforts were once undertaken, but without monitoring or follow-up on the planting activities, which ultimately led to the loss of many mangroves. This situation is exacerbated by ongoing land-use conversion that continues to this day. Local residents hope that in the future there will be assistance or support—whether from the government or relevant parties—to replant the mangroves. This is important not only for the ecosystem but also to help increase the income of local fishermen.

3. 6. Batu Karas

The mangrove species growing in Batu Karas are Avicennia sp. and Rhizophora sp. The mangrove forest in this area covers approximately 3 hectares. This area contains land suitable for mangrove planting, which has the potential to enhance the sustainability of the coastal ecosystem. Additionally, plans are in place to develop mangrove ecotourism at three locations: Bojong Salawe, Batu Karas, and the surrounding areas. The access road to Batu Karas is passable by small vehicles and motorcycles, making it easy for visitors to reach the location. Most local residents work as fishermen, and they hope that the establishment of ecotourism activities in Batu Karas will boost the local economy and increase the income of the Batu Karas community through sustainable and environmentally friendly tourism.

3. 7. Babakan

The mangrove forest in Bulak Setra covers an area of approximately 1.6 hectares, with some sections still exhibiting low, sparse, and moderate vegetation density. The mangrove species growing there are Rhizophora and Sonneratia. Currently, the Bulak Setra mangrove area in Babakan Village is managed by a group called the Coastal Area Activists and Managers, which is currently conducting rehabilitation efforts by planting new mangroves. The area has also been designated as an educational tourist site that can be enjoyed by both local residents and visitors from outside the area.

Access to the Bulaksetra mangrove area is currently limited to small vehicles such as minibuses and motorcycles, but there are future plans to construct a road from the direction of the Polytechnic. In the surrounding area, the mangrove ecosystem provides many benefits to the local community; for example, many residents harvest oysters or barnacles there to sell or consume. Additionally, catches such as shrimp, small fish, crabs, and barnacles help supplement the income of local residents.

3. 8. Nusawiru

Based on interviews conducted in Nusawiru, the Nusawiru mangrove forest has become an ecotourism destination for tourists and visitors. Tourists learn about the Nusawiru mangrove forest through social media and from relatives or family members. The Nusawiru mangrove forest area has its own unique appeal because the natural scenery in the area is particularly beautiful and refreshing, and it also offers stunning views of the sunset. Visitors can enjoy these views, which are often used as photo subjects. Based on interviews, the natural scenery in the Nusawiru mangrove forest has the potential to be developed as an ecotourism destination.

The Nusawiru mangrove forest offers activities for visitors, such as planting mangrove seedlings, taking photos, and exploring the bridge area. Visitors can plant mangrove seedlings provided by the management. Planting takes place in designated areas set aside for visitors who wish to participate. With the management's assistance, visitors can plant the seedlings in these designated spots. Visitors also often take photos using the river estuary as a backdrop while strolling along the mangrove bridge area. They then upload their photos to social media, which has made the Nusawiru mangrove area famous and well-known to many people, both local residents and visitors from outside the region.

4. DISCUSSION

Successful mangrove ecosystem restoration requires a deep understanding of hydro-oceanographic dynamics, substrate types, and vegetation species zonation [14, 15]. The findings of this study reveal substrate diversity across six sites in Pangandaran Regency (Karang Tirta, Bojong Salawe, Majingklak, Batu Karas, Babakan/Bulaksetra, and Nusawiru), which dictates the selection of mangrove species and specific planting methods.

At Karang Tirta, Batu Karas, and Majingklak, the predominance of muddy to sandy-muddy substrates exposed to tidal waves requires a specialized technical approach. Planting *Rhizophora mucronata* and *Rhizophora apiculata* in these areas is ecologically appropriate, given that the Rhizophora genus possesses a stilt/prop root system that is well-adapted to soft substrates and effectively anchors the soil against wave erosion [5, 6]. In Karang Tirta, the use of spaced clump planting and staking techniques is a key factor in minimizing the risk of seedlings being washed away by strong tidal currents. Meanwhile, in areas experiencing severe degradation due to abandoned projects, such as in Majingklak (3 ha in area), pioneer species like *Sonneratia alba* are recommended for reforestation.

Sonneratia alba possesses pneumatophore roots (breathing roots) capable of penetrating compacted or degraded soil and is tolerant of extreme salinity fluctuations in the estuary or at the mouth of the Citanduy River [2, 8]. Planting pioneer species is considered crucial for improving soil physical structure, stabilizing sediment, and restoring water quality prior to the introduction of other mangrove species. In Babakan (Bulaksetra), the post-2006 tsunami succession and the vegetation transition from *Sonneratia spp*. to *Rhizophora apiculata* reflect the dynamics of natural ecosystem recovery accelerated by human intervention. The sandy-mud substrate in Bulaksetra not only facilitates optimal root aeration and drainage but also provides an ecological niche for macrozoobenthos diversity, such as mangrove crabs and mollusks, as well as avifauna [7].

Ecologically, the restoration of mangrove areas along the Pangandaran coast plays a vital role as a natural defense barrier (*greenbelt*). Mangrove forests have been scientifically proven

to effectively dampen the energy of extreme waves, prevent erosion, and mitigate the destructive impacts of tsunami waves [4]. The historical experience of the 2006 tsunami in Pangandaran confirms that areas with dense and healthy mangrove stands have a significantly lower level of physical vulnerability compared to open coastal areas. In addition to their role in physical disaster mitigation, the successful expansion of mangrove vegetation in Pangandaran contributes significantly to global climate change mitigation through carbon sequestration (blue carbon) [9, 12, 13]. Mangrove ecosystems have a carbon storage capacity per hectare that is 3–5 times greater than that of terrestrial tropical forests, with most of this carbon stored stably within anaerobic soil substrates [12]. The integration of spatial monitoring using Geographic Information Systems (GIS) and drones, as applied in this study, enables the periodic and precise evaluation of vegetation density (NDVI) and estimation of coastal carbon stocks [7, 24].

The spatial planning (site plan) for the Pangandaran mangrove area adopts the Integrated and Sustainable Tourism Development Planning approach [26]. This approach successfully reconciles two often-conflicting interests: ecological conservation and economic utilization [18, 19]. The division of the area into conservation zones (restricted to research and reforestation activities only) and ecotourism zones (Majingklak, Bojong Salawe, and Babakan) ensures that human activities do not damage the vulnerable core zones [22]. Planned ecotourism infrastructure—such as jogging trails, wooden boardwalks, eco-friendly piers, educational pavilions, and a floating market—is designed according to the principles of low-impact development. Wooden boardwalks allow tourists to explore the beauty of the mangrove ecosystem without compacting the soil substrate or damaging the vegetation's root systems.

The community-based ecotourism development model—which involves tourism awareness groups (Pokdarwis) and local community groups (such as the Tirta Mandiri Klewer group in Karang Tirta and the Penggerak Pesisir group in Babakan)—serves as the main pillar of the project's sustainability. The involvement of local communities as managers, educational tour guides, and operators of mangrove-based small and medium enterprises (SMEs) can shift the community's paradigm from destructive practices (such as illegal logging and land conversion) to protective ones (viewing biodiversity as an economic asset) [17, 23]. This diversification of livelihoods creates a financial feedback loop, in which a portion of ecotourism revenue is reinvested in the maintenance and independent, sustainable mangrove conservation and restoration activities [21, 23].

5. CONCLUSIONS

Based on an analysis of six potential areas for mangrove ecosystem planting (rehabilitation / restoration) in Pangandaran Regency, the following conclusions can be drawn: The Majingklak and Babakan areas are top priorities for mangrove rehabilitation and expansion due to their hydrological conditions that support dense vegetation growth. Meanwhile, the tourism sectors in Karangtirta and Batukaras can be optimized through a community-empowerment-based ecotourism concept, which integrates the beauty of mangrove forests with culinary and water sports activities. The planning of the Nusawiru tourism area provides unique added value as a gateway for tourists; if managed properly, it can position Pangandaran as a sustainable, low-carbon tourism destination. The success of this planning heavily depends on collaboration between the local government, the local community in maintaining the saplings, and the private sector in promoting tourism.

Overall, the planning for the rehabilitation and development of mangrove ecotourism in Pangandaran Regency demonstrates that a spatial-ecological approach integrated with community empowerment can create synergy between the restoration of environmental functions and the improvement of local economic well-being. The future success of this plan depends heavily on a long-term collaborative commitment among local governments, academics, the private sector (through CSR schemes and CSA programs), and local communities in overseeing and monitoring the area.

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