



Mapping The Potential of Mangrove Planting in The Rehabilitation of Coastal Ecosystems Using Drone Technology

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Abstract. Mangroves, as one of the vegetation types that is a natural stronghold from coastal disasters, also function as a shelter and find food for various biota in coastal ecosystems. Therefore, protecting the mangrove ecosystem from degradation is very important. One effort that needs is ecosystem rehabilitation through mangrove planting in coastal environments. To support it, a design was devised using drones and remote-sensing vehicles to assist in making mangrove planting designs. This research was conducted in Jenggalu Estuary, Gading Cempaka District, Bengkulu City. This research aims to study the use of drones in mapping potential mangrove planting areas and designing a mangrove planting plan to rehabilitate coastal ecosystems. In mapping using drones, the height used was 80 meters with 80% overlap, and 2.87 hectares of potential mangrove planting area was obtained. Based on the research results, drones in mapping are very useful in calculating the area of potential mangrove planting areas and designing effective planting plans. There are four scenarios for planting mangroves with a spacing of 0.5 m, 1 m, 2 m, and 3 m, respectively. For a planting area of 2.87 ha, the number of seeds needed is 114,800 planting points for a distance of 0.5 m, 28,700 planting points for a distance of 1 m, 7,175 planting points for a distance of 2 m, and 3,189 planting points for a distance of 3 m.

Keywords: Coastal Ecosystems, Drones, Jenggalu Estuary Area, Mangroves, Rehabilitation

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1 Introduction

The mangrove ecosystem is one of the typical tropical coastal vegetation ecosystems, dominated by several types of mangroves that grow around the coast and river mouths that can survive in muddy coastal tidal areas and the plant community is salt tolerant [1]-[2]. Mangrove ecosystems have many functions in terms of ecological, economic, physical, and socio-cultural [3]-[4]. The ecological functions of the mangrove ecosystem include spawning ground, nursery ground, and feeding ground for associated biota, besides that the mangrove ecosystem is capable of being a good carbon sink [5]. The economic function of the mangrove ecosystem is as a place of livelihood for the surrounding community in the form of wood, medicines, and food sources, and has the potential as a place for ecotourism education [6]-[7]. One of the physical functions of the mangrove ecosystem is being able to accelerate the expansion of land around the area using sedimentation carried by currents, protecting the coastline from erosion and abrasion, and being able to protect the area around the coast from waves, strong winds and tsunami hazards, while the socio-cultural function of this mangrove ecosystem can be an area for cultural development, education, and conservation [5]-[8].

The sustainability of the mangrove ecosystem greatly affects the survival of living things and protects the mangrove ecosystem from widespread damage. Therefore, it is necessary to plan rehabilitation efforts to protect the mangrove ecosystem from various negative impacts caused by natural and anthropogenic disturbances [9]. Efforts to rehabilitate mangrove ecosystems are land restoration activities that have the potential to plant mangroves so that can build structural or functional characteristics of a mangrove ecosystem area [10].

The development of a systematic rehabilitation plan suggests several things to focus on land selection and preparation, species selection, propagule and seed sources, and level of maintenance [10]. Neglect of ecological principles in the rehabilitation planning stage is one of the factors causing the failure of rehabilitation efforts [9]. In carrying out mangrove rehabilitation efforts, it is necessary to make a design to support rehabilitation activities. Obtaining information is not easy to do because the area is very wide and requires terrestrial measurements which will take a lot of time and cost [11]. One of the rapid and efficient alternative ways to find potential areas for mangrove planting is to use remote sensing data [12]. With the support of drone technology, making mangrove planting designs will be easier. Drone or Unmanned Aerial Vehicle (UAV) is a tool used for remote sensing-based remote sensing mapping for the study of mangrove ecosystems [13]. UAVs can fly much lower than mapping planes to obtain high-resolution spatial data supported by special software to assist survey activities. The application of UAV technology integrated with GIS in mapping mangrove ecosystems is expected to be an alternative in database collection.

The area that has the potential for mangrove ecosystems is the Jenggalu estuary area, Gading Cempaka District, Bengkulu City (approximately 214.62 ha). Mangrove ecosystems that grow in Jenggalu estuary area generally have several species, with less than ten types of dominant vegetation [14]. According to the results of research using Sentinel 2 imagery data with processing using supervised classification with mangrove ecosystem area of 242.35 Ha, which includes the Ratu Agung, Gading Cempaka, and Kampung Melayu areas [11]. The types of substrates found along the mangrove habitat are sand, silt, and sand mixed with silt. Most of the mangrove ecosystems on the coast of Bengkulu City are included in the middle mangrove zone, some are in the form of primary and secondary mangrove ecosystems, and some are areas with the potential for mangrove planting [15]. This research aims to examine the use of drones in mapping potential areas for mangrove planting and to plan a design for mangrove planting to rehabilitate coastal ecosystems.

2 Research Method

2.1 Research Area

This research was conducted in the Jenggalu estuary area, Gading Cempaka district, Bengkulu city. The selection of land areas that have the potential to be planted with mangrove seedlings and at the same time can carry out efforts to rehabilitate mangrove ecosystems was carried out in December 2021-January 2022 with a research area of 5.35 hectares. The observation area was chosen since this area is influenced by tides, has a muddy sand substrate, and is protected. Thus, it has the potential to be a location for planting mangroves. The map of the research location is in Figure 1.

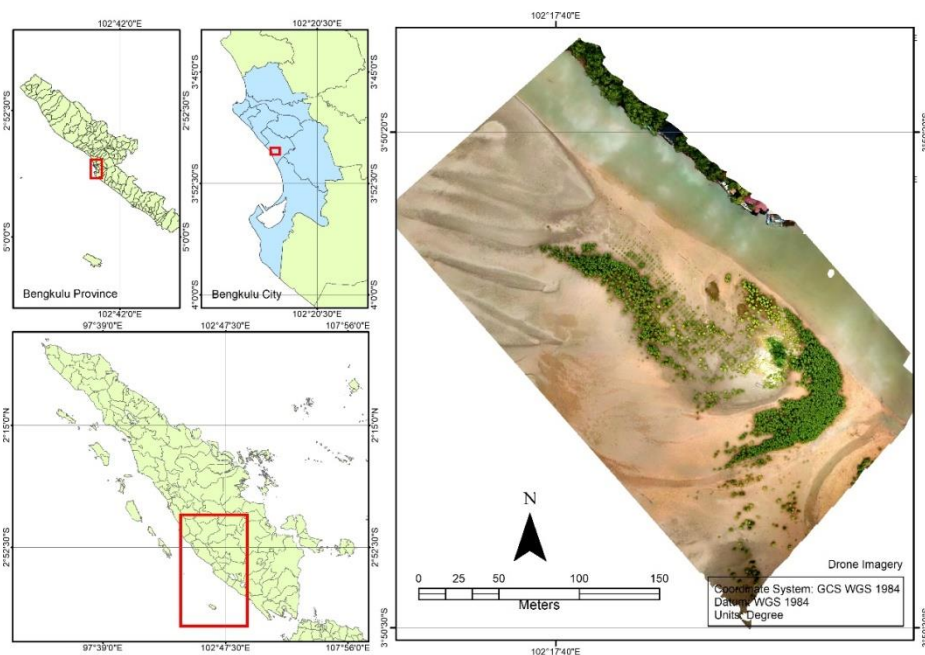


Figure 1 Research Site Map of Jenggalu Estuary Area, Gading Cempaka District, Bengkulu City

2.2 Tools and Materials

The following is a list of equipment and materials used for research.

Table 1 Tool and Materials Research

No	Tool	Description
1	Drone DJI P Movic Pro	Aerial photography
2	GPS Garmin 78s	Coordinate data's collection
3	Dry Bag	GPS protection during survey
4	Camera	Ground photo shoot
5	Laptop/Computer	Processing and data analysis
6	Pencil and paper newton	For writing in underwater
7	Ruler	Measure the height of the mangroves

2.3 Research Plan

The research design includes drone camera and compass settings, drone flight planning for mapping and field data collection. Drone flight planning includes camera, compass calibration settings, and the GPS lock. The research flow chart is in Figure 2.

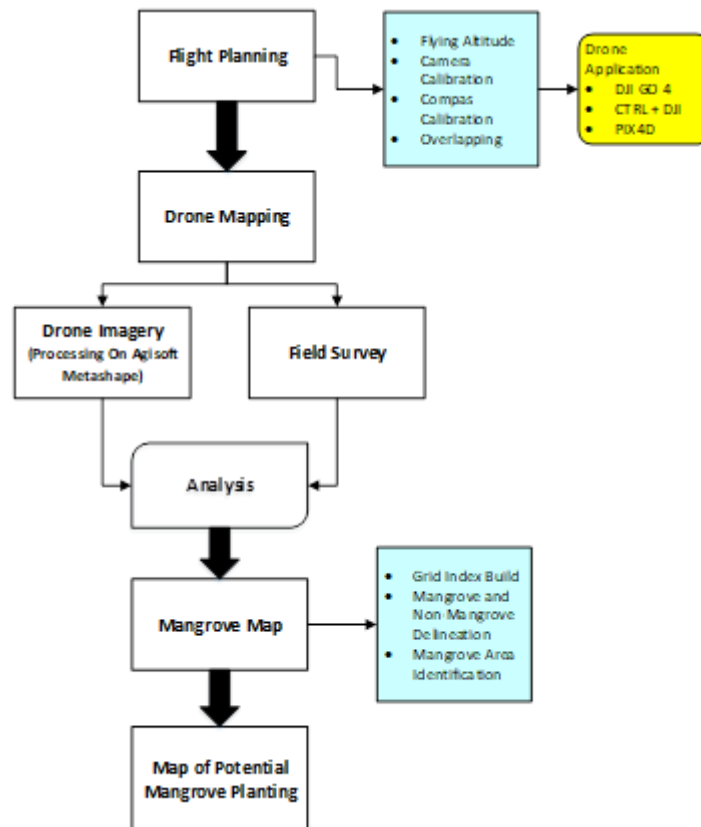


Figure 2 Research flow chart

2.4 Mapping Using Drones

A. Data collection using drones

Data collection using the DJI Mavic Pro type drone is divided into 3 stages, the first stage is the stage in setting up the camera and compass using the DJI GO 4 application. The second stage is setting up the GPS device with the aim of increasing the accuracy of coordinate points. The third stage of mapping using drones. At this stage using the CTRL+DJI and PIX4D applications on Android, this application can set flight plans such as flight altitude and overlapping when mapping the research location. The Android-based DJI GO 4, CTRL+DJI and PIX4D applications can be downloaded from the Play Store.



Figure 3 Process of aerial photo data collection process

B. Drone data processing

Drone data processing using the Agisoft Metashape Professional application. In this application, the processing is divided into several stages, namely inputting drone photos from mapping and adding photos, after which the alignment between each photo is carried out (aligning process). After aligning it, build a dense cloud based on the provisions of the sparse cloud point by estimating the camera position in looking for pixel similarity based on the previous cloud point. The next stage is to build a solid cloud point surface model that has been generated (mesh) and DEM (Digital Elevation Model). The final process in aerial photo image processing is making orthophoto drone images. The results of this orthophoto are then analyzed to become a map.

2.5 Field Data Collection

The field survey aims to identify existing mangroves planted by the Jenggalu community who are members of the Jenggalu Kito Village and Non-Government Organization Lestari Alam Laut Untuk Negeri “Marine Natural Conservation for the Nation” (LATUN) as well as partners from government and non-government institutions. In addition, field surveys were carried out to take area markings using Garmin 78s GPS at mangrove planting locations at

different periods. GPS is used to gain coordinates in the field in survey activities to determine positions in the geographic coordinate system (longitudinal latitude) and the Universal Transverse Mercator (UTM) [16]. This is intended to study spatially each different mangrove planting period. Accessibility to the research location area is using a boat with a capacity of 6 people at a distance of 500 meters from community settlements. Ground photos area are taken using a camera.

2.6 Area criteria for planting mangroves

Areas that are affected by tides have a muddy sand substrate and are protected so that they have the potential for planting mangroves. In this area, some mangroves live and grow naturally without being directly planted by humans. Aerial photography using drones is a supporting tool in supporting area spatial information and planning in management in the future development of mangrove ecosystem sustainability.

3 Result and Discussion

3.1 Mapping Using Drones

Mapping using drones obtains a classification of the spatial distribution of the mangrove ecosystem. Sugara et al. (2021) said that drone technology in mangrove mapping can produce good mangrove spatial information [13]. The results of image acquisition using drones are aerial photos with an image footprint of 307 m x 157 m. Aerial photos processed by orthorectification amounted to 144 photos using Agisoft Metashape Professional software. Mapping using a drone with a flying height of 80 meters and 80% overlapping produces a spatial resolution of 2.36 cm/pixel. Based on the results of drone image processing, obtained information regarding the visualization of the existing mangrove planting area is in Figure 4.

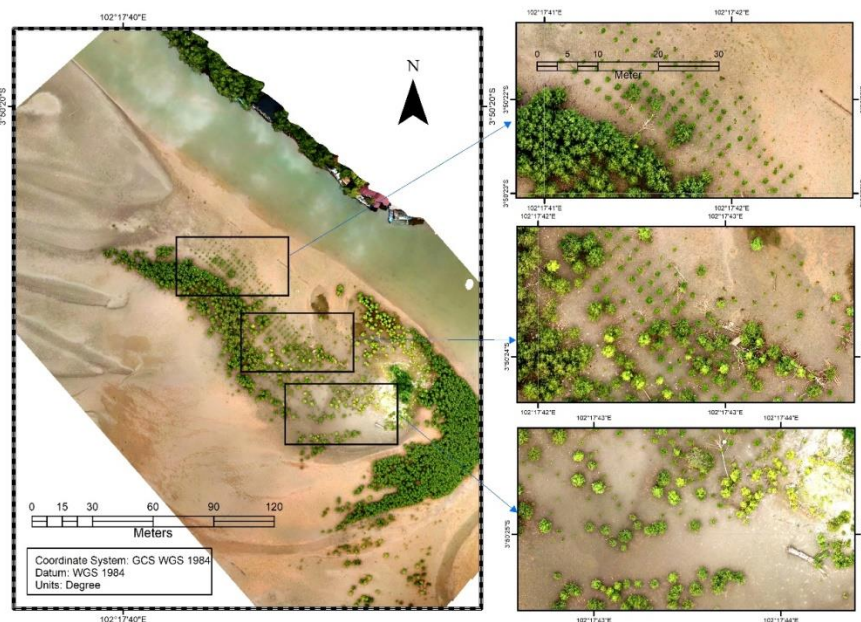


Figure 4 Visualization of the existing mangrove planting area

The results of the existing mangrove planting area can be identified on a scale of 1: 500 to 1: 150. It is the characteristics of the distribution pattern of mangroves planted at different periods (Figure 4). There is a difference in planting year. Different spacing is obtained when the plants are one to five years old. Height growth was faster for plants planted more closely than planted with sparse spacing. Mangroves are not planted together at the same time. On the contrary, it is planted using the patchwork method. Thus, during the monitoring process, the mangroves that are carried away will be replanted. The period of mangrove plants can be monitored by the difference in color and pattern. The planting mangroves will display darker colors and have a more regular distribution pattern. Natural mangroves display colors that appear not only to have one dominant color, but the distribution pattern looks irregular [1]. In this result, mangroves that grow naturally tend to have irregular growth patterns and spacing. Meanwhile, the mangroves resulting from the rehabilitation are located and grow at regular intervals.

Mapping using drone imagery with a height of 80 m overlapping 80% produces a spatial resolution of 2.36 cm/pixel that can be interpreted to the level of the mangrove canopy which is still 15 months old (Figure 5). According to the 4–5-month-old mangrove on *Rhizophora mucronata* has a height of 55 cm and 4 strands or 2 pairs of leaves [17]. In this research (Pranata et al., 2020) the use of a drone with a height of 100 m resulted in a spatial resolution of 2.79 cm/pixel capable of interpreting the land cover area of the Mandiingin forest area [18]. The results of the aerial photo analysis are categorized as having a good resolution seen from the height of the flight when operating the drone, where the higher the spatial resolution of the resulting image, the more detailed object in resulting image [19].

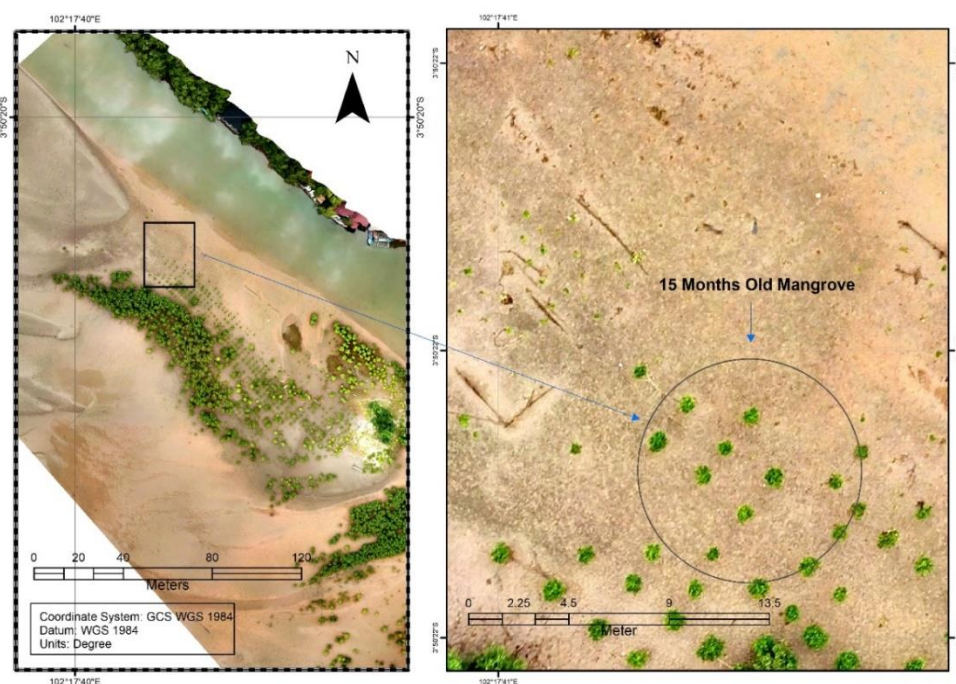


Figure 5 Details of mangrove planting area objects

3.2 Identification of Mangrove Planting Results

Identification of the results of mangrove planting serves to see the results of the appearance of drone images at different planting periods. The type of mangrove planted at the research site is *Rhizophora apiculata*. According to Mustika et al. (2014), the mangrove species *Rhizophora apiculata* is one of the most important species in the mangrove ecosystem [20]. The growth process of *Rhizophora apiculata* is rapid and has very strong wood, breath roots, opposite leaf types, and can reach 15 meters in height. *Rhizophora apiculata* has a seed-type form of vivivar that is on the lower surface of the leaves and is yellowish green. It is known that the type of mangrove *Rhizophora apiculata* is easy to grow on muddy, smooth substrates, and likes tidal waters [21]. Stated that the average proportion of *Rhizophora apiculata* mangrove survival was around 60 to 78% [22].

Mangrove planting is carried out by utilizing 3-4 month-old mangrove seedlings with 4-5 leaves. Mangrove seedlings are placed 3-4 in one planting hole with the help of ajir (stakes) made of bamboo. The reason is to minimize drifting seeds and increase mangrove protection. If the seeds drift away, there is still a reserve available in the planting hole. Meanwhile, air (stakes) serves to help support mangrove seedlings from currents and waves during high tides.



Figure 6 Mangrove seedlings planted with ajir supports (A) and 15-month-old mangroves of planting (B)

Measurement of height in mangroves using a ruler. Mangrove seedlings aged 15 months after planting have an average 62 cm height with an average number of leaves of 20-25 strands. In a field survey of mangroves planted with 3-4 stems in one planting hole, on average, two mangroves survive.



Figure 7 Visualization of mapping area

This data processing stage determines the distance per point at an angle according to the mangrove rehabilitation area. Thus, that visualization is obtained according to conditions in the field. The Jenggalu River estuary has a mapping area of 5.35 ha and has the potential to be planted with mangroves. It can be seen in the visualization image above that shows the condition of the observation area has muddy soil conditions. In general, mangroves grow in coastal areas that have wide river mouths and water flows that contain a lot of mud [23]. Mangrove ecosystems grow in intertidal areas where the soil type is muddy, sandy, and periodically inundated with water [24].

3.3 Mapping of Potential Mangrove Planting Areas

The development of the mapping results in the research area is to determine the potential areas for further mangrove planting. Drone images can be used as guideline data to see the spatial distribution of areas with the potential for mangrove planting based on the availability of existing land. The potential areas for mangrove planting are obtained from segmentation results using ArcGIS software. The result of the digitized map is in Figure 8. The observation area is affected by tides, has a muddy sand substrate, and is protected so that it has the potential to become a location for planting mangroves.

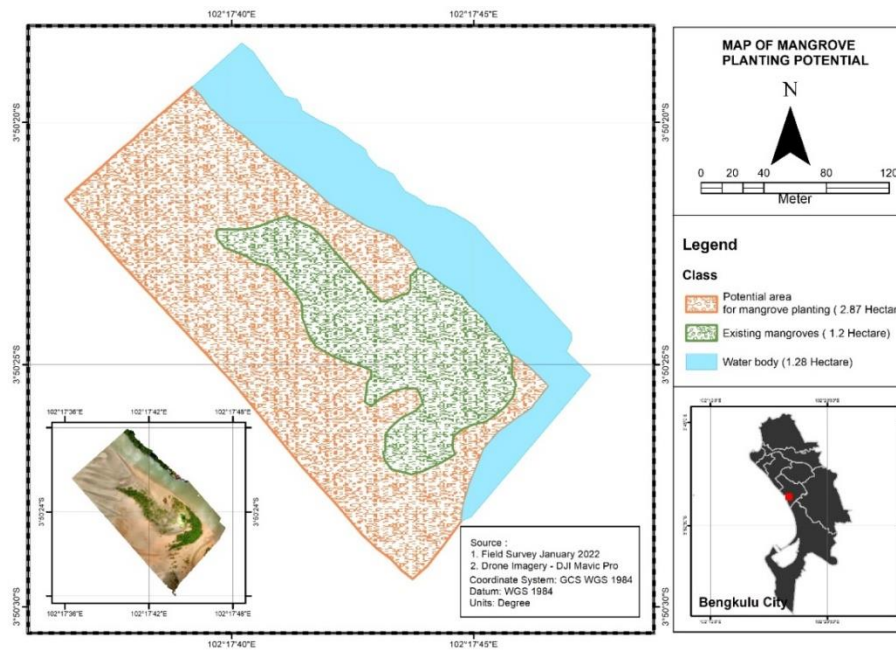


Figure 8 Map of Potential Mangrove Planting Area

After the digitization process using the ArcGIS Software, it was found that an area of 1.2 hectares of the existing mangrove plant is designated with a green. Meanwhile, the potential for planting mangroves (orange) covers an area of 2.87 hectares. Given the importance of the function and role of the mangrove ecosystem. It must be managed immediately according to the function and land use through rehabilitation efforts for mangrove ecosystems that have experienced a decline in environmental quality or damaged [25].

The rehabilitation of mangrove ecosystems needs to be done for several reasons. First, the ecological importance and environmental values of mangrove forests have long been neglected. Second, the high subsistence dependence on natural resources of mangrove forests. Third, large-scale damage to mangrove ecosystems occurs worldwide leading to coastal erosion, decline in fishery resources, and other environmental consequences [26]. One of the factors supporting the success of mangrove planting is the geomorphological structure of the mangrove planting area. A cross-section of the potential area for mangrove planting (Figure 8) was obtained from the Digital Elevation Model (DEM) data. DEM data is obtained from the National DEM, namely on the website <https://tanahair.indonesia.go.id/demnas/>. National DEM data is built from several data sources such as IFSAR data (5m resolution), TERRASAR-X (5m resolution), and ALOS PALSAR (11.25m resolution), by adding the masspoint data result in stereo-plotting. The spatial resolution of the National DEM is 0.27-arcsecond, using the EGM2008 vertical datum.

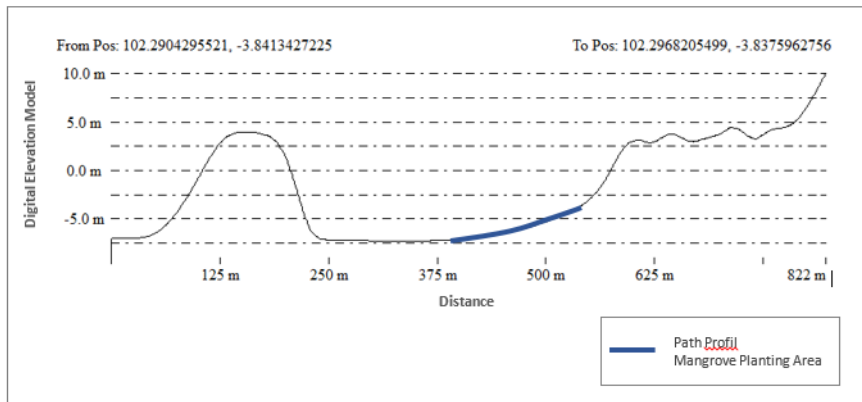


Figure 9 Path profile of mangrove planting area

The cross-section (Figure 9) provides information that the potential area for mangrove planting has a sloping zone with a height of -5 to -3 meters. It is known that the potential area for mangrove planting is an area that is affected by tides. Therefore, it concluded that mangrove seedlings aged 15 months have an average height of 62 cm and will sink during high tide.

Based on the results of modeling identified potential land, a design of land has the potential to be planted with mangrove seedlings covering an area of 2.87 hectares. Several models that are designed at once equipped with the density distance and the number of mangrove seedlings needed can be seen in Figure 10. The results of potential land segmentation for the rehabilitation of mangrove ecosystems are obtained from the overlay between mangrove-planted land and potential land (Figure 10).

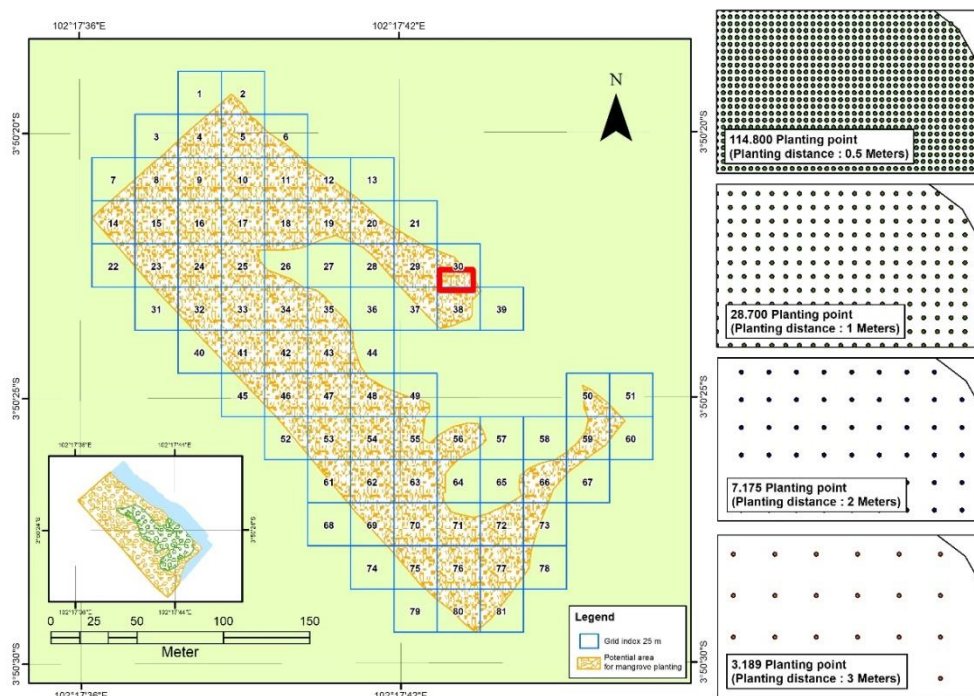


Figure 10 Mangrove planting design

In this potential land map, there are four designed models. In the first land model, there are 114,800 planting points with 0.5 m of density spacing where the number of mangrove seedlings has the planted potential of 344,400 seedlings (3 seeds planted in each hole). In the second land model, there are 28,700 planting points with a density distance of 1 m where the number of mangrove seedlings that have the planted potential is 86,100 seeds (each hole planted is three seeds). The third model has 7,175 planting points with a density spacing of two m where the number of mangrove seedlings that have the potential to be planted is 21,525 seedlings (3 plant seeds are in each hole). In the last model, there are 3,189 planting points with a density spacing of 3 m where the number of mangrove seedlings that have the potential to be planted is 9,567 seedlings (3 seeds are planted in each hole). One of the important factors for the growth of mangrove seedlings is the density distance because it can provide optimal growth space can affect light absorption, and can affect nutrient, water, and air factors.

The research (Wardhani, 2014) said that station 3 has a high level of mangrove density, which is as many as 81 trees with a land area of 100 m² [25]. Mangrove density affects leaf litter production. The higher the tree density, the higher the leaf litter production [27]. Mangrove litter production is one of the primary things used to create a food chain for aquatic biota, one of which is as a supplier of nutrients for plankton growth [28].

4 Conclusions

Mapping using drone imagery in the Jenggalu estuary area with a height of 80 m overlapping 80% resulting in a spatial resolution of 2.36 cm/pixel can interpret the mangrove ecosystem to the level of the mangrove canopy of 15 months old. The potential area for mangrove planting is obtained from the results of segmentation using ArcGIS software that covers an area of 2.87 hectares. It has four models designed to rehabilitate mangrove ecosystems. The first land model has the potential of 114,800 planting points at a distance of 0.5 m. In the second model, the land has the potential of 28,700 planting points of 1 m distance. In the third model, the land has 7,175 potential planting points at a 2 m distance, and the last model has 3,189 planting points at a 3 m distance.

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