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Utilization of UAV (Unmanned Aerial Vehicle) technology for mangrove species identification in Belawan, Medan City, North Sumatera, Indonesia

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Abstract. The mangrove forests in Indonesia are starting to decrease over time because there is still a lack of knowledge among people around the coast about the importance of mangroves. Kampung Nelayan, Medan Belawaan, is a coastal community area whose life is very dependent on coastal, mangrove, and water resources. Unmanned Aerial Vehicle (UAV) technology has the potential to provide a fast, cost-effective, and efficient mangrove mapping technique. It is very useful because mangrove areas are located in remote areas, where field measurements are difficult, time-consuming, and expensive. The objective of this study is to analyze mangrove species using UAV imagery with Object-Based Image Analysis (OBIA) classification. The object-based classification result for the overall accuracy is 82.94% where there are 7 classes of mangrove species based on the classification process, including: *Avicennia alba, Avicennia officinialis, Avicennia Marina, Rhizopora apiculata, Nypah fruticans, Scyphipora hydrophylacea, Bruguiera gymnorriza*. There are also two classes for non-mangrove, consisting of the water body and non-mangrove. The largest area of mangrove species in the research site is Avicennia Marina with a percentage of 33.86% covering an area of 7.80 Ha. The second-largest mangrove species with a percentage of 21.88% is Avicennia officinalis with an area of 5.04 Ha.

1. Introduction

Indonesia is an archipelagic country with mangrove forests overgrown along its coastline. Mangrove forests in Indonesia are immensely wide. However, the mangrove forests are starting to decrease over time due to a lack of public awareness and the conversion of land into ponds [1]. Mangrove forests can be considered the only type of forest that can grow in areas experiencing high tides. This is because the mangrove plant community can tolerate salt contained on the seaside [2].

Kampung Nelayan, Medan Belawan, is a coastal community area whose life is very dependent on mangrove ecosystem [3]. Mangrove ecosystems provide various ecosystem services including food provision, providing good habitat for fauna species, regulating for climate, and protecting from diasters [4]. The extent of degradation of mangrove forests is increasing as a result of massive exploitation by people who are very dependent on the mangrove ecosystem for their lives.. Unsustainable coastal resource management can threaten ecosystems and fishermen's catches, thereby threatening their livelihoods [5]. Consequently, mangrove restoration is needed by considering the ecological and economic aspects in its implementation [6].

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Vegetation analysis is an important step taken to determine the number of mangrove vegetation found in the area since vegetation is the main element in soil and water conservation efforts. Therefore, it is necessary to carry out a vegetation analysis regarding the presence of plants to study the vegetation structure and composition of plant species. Vegetation analysis aims to determine the composition of the type (composition) of plants and the form (structure) of vegetation in the analyzed area [7].

Remote sensing provides the effective and efficient method for mapping of mangrove ecosystem. Remote sensing is very useful in measurements in mangrove ecosystems because it can overcome somes constrains such as difficult access, expensive costs and long time. Remote sensing ultimately supports the sustainable management of mangrove ecosystems [8]. The data taken from the image aims to detect changes in vegetation that are related to spatial resolution, temporal resolution and spectral resolution [9].

Unmanned Aerial Vehicle (UAV) is also widely applied in government programs such as forest stand mapping, tree volume estimation, land cover assessment, pest monitoring, and harvest planning. In addition, non-governmental organizations are also interested in using drones for work related to conservation, such as monitoring wildlife, monitoring land use changes and monitoring illegal activities [11]. The commercial availability of UAVs is increasing and the prices are more economical, making UAVs increasingly widely used as a tool for environmental and ecological analysis. The UAV function can be applied for monitoring agricultural land, forest fires impact measurement, distribution of moss in the poles and mapping mangroves ecosystem [12].

Cameras mounted on UAVs are very useful in small scale forest inventories with low cost and high flexibility. Image characteristics of UAVs that have very high spatial resolution have the potential to identify mangrove species. In recent years, object-based identification methods combined with high-resolution imagery are applied for mapping of mangrove species [14].

Generally, vegetation mapping with remote sensing imagery uses automatic classification by distinguishing various types of objects.. Objects in the form of mangrove vegetation will be distinguished based on the suitability of the image, color or wavelength reflected by the object [13]. An object-based classification is an approach that is widely used and the classification process does not only consider the spectral but also the spatial aspects of the object [15]. Therefore, the use of UAV and object-based image analysis will be indispensable in identifying species in the mangrove ecosystem so that survey work becomes faster, cheaper and easier. The objective of this study was to analyze the type of mangrove using UAV imagery with the classification of Object-Based Image Analysis.

2. Materials and Methods

2.1. Research site

This study was conducted in the mangrove forest area of Medan Belawan, North Sumatera. The data collection was conducted from March to April 2022. Aerial photo analysis was carried out in the Laboratory of Forest Resources Conservation, Faculty of Forestry, Universitas Sumatera Utara. The location of the research site is presented in Figure 1.

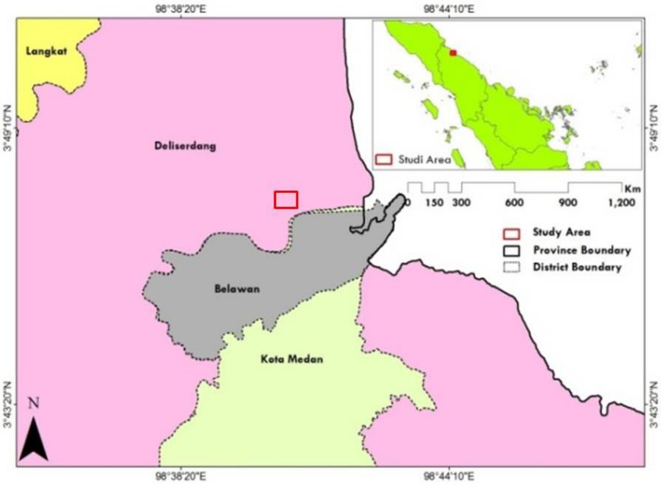

Figure 1. Research site map

2.2. Tools and materials

The hardware used in this study is personal computer (PC) and a drone type of DJI Mavic 2 Pro. The software used was ArcGIS 10.8, Agisoft Metashape, eCognition, Pix4D Capture, and Microsoft Excel, The material used in this study was high-resolution aerial photography of the Belawan mangrove forest area. The field survey tools were in the form of Avenza Maps software, maps of the Belawan mangrove forest area, stationery, digital cameras and ropes to make measuring plots for observing tree species.

2.3. Data collection

The data collection was in the form of aerial photo acquisition with flight missions and plotting for analysis of vegetation types. The acquisition of aerial photographs required several stage namely preparation, data acquisition and the data processing. In the preparation stage, identification of the area to be mapped is carried out in the form of a grid, flight path, flight height, overlap, flight speed and determination of pixel resolution or ground sample distance (GSD). Flying height in data acquisition is 80 m and 80 % of photo overlap. The UAV or Drone Type used was the DJI Mavic 2 Pro. The determination of a flight mission for the identification area of mangrove species used Pix4D Capture, an Android and IOS-based application used to estimate an area, number of paths, GSD and duration of the flight.

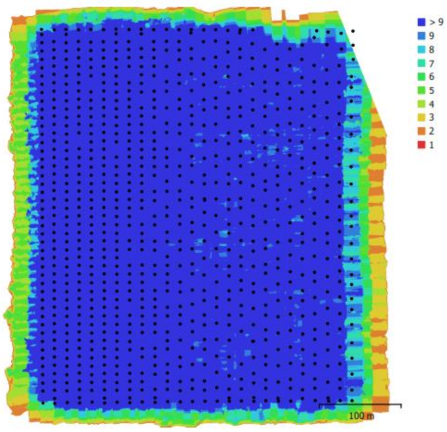

Figure 2. Display on the flight path application, camera location and image overlap

2.4. Data analysis

The processing of aerial photos into orthomosaic used Agisoft Metashape software with steps including importing photos and flight path reconstruction, Align photos, merging Dense Point Clouds, construction, texture models, DEM development, Orthophoto development and exporting orthomosaic in GeoTIFF format. The results of processing aerial photos in orthomosaic can be seen in Figure 3.

Figure 3. *Orthomosaic*

2.4.1. Object-Based Image Analysis (OBIA). The image classification that is functioned to map the mangrove composition used Object-Based Image Analysis / OBIA. The OBIA approach is considered superior to pixel-based classification because it not only considers spectral but also spatial aspects [16]. The OBIA method is a classification method developed by segmenting and analyzing objects or image classification processes based on their spatial, spectral and temporal characteristics to produce image objects or segments which are then used for classification [17].

2.4.2. Segmentation. Image segmentation is the first step of Object-Based Image Analysis and is used to produce images of objects that are more homogeneous among themselves than those with nearby regions [18]. The most widely used segmentation is multiresolution, a bottom-up region merging technique, which is used to generate image objects. In this study, the segmentation algorithm used was the multiresolution segmentation (MRS) algorithm. This algorithm is done with a single-pixel and combining neighboring segments until a heterogeneity threshold is reached. In the segmentation process using the MRS algorithm, there are three important parameters, including shape, compactness and scale. All classification object-based image processing procedures were performed using the eCognition Developer 64 software (Trimble Germany GmbH, Munich, Germany).

2.4.3. Field survey. The sampling method used in the identification of mangrove species was the stratified systematic sampling method, where the species recorded were taken in sample plots made with an area of 20 x 20 m in the form of a square. The research area was 23 ha with a sampling intensity of 1%. The distance between sampling plots was 100 m with a total of 10 sampling plots made. In the sample plots, all the names of tree species were recorded, specifically vegetation with a trunk diameter of more than 10 cm.

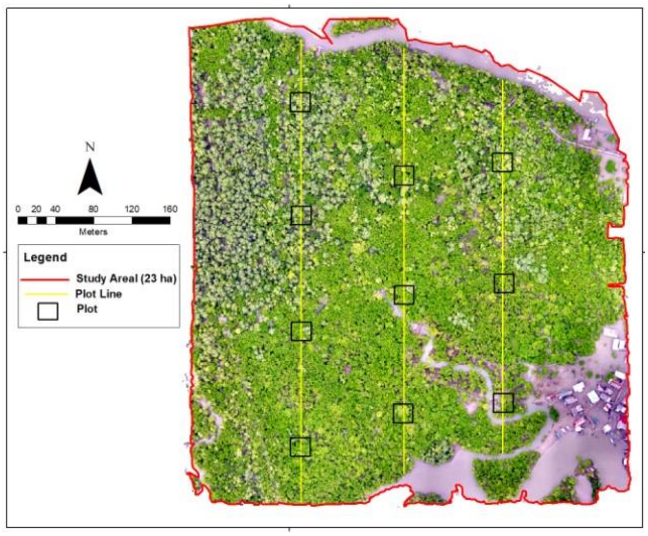

Figure 4. Map of sampling plots

2.4.4. Accuracy test. Overal accuracy is used to determine the accuracy of the calculation from the map with groundcheck data. Determination of accuracy using confusion matrix. Overall accuracy using the following formula:

$$\text{Overall Accuracy} = \frac{\sum_{i=1}^{r} xii}{n} 100\%$$

Xii : Diagonal values of the i-th row and i-th column of the contingency matrix
X+I: Number of pixels in the i-th column
Xi+: Number of pixels in the i-th row
N : Number of pixels in the sample [20]

Overall accuracy is defined as the total class classified divided by the total class. The determination of the training area is carried out by various combinations to get the best results in the accuracy test. The combinations in the training area determination can be done in small, medium or large sizes. Sampling points for accuracy test are carried out through field verification.

The calculation of accuracy in this study is based on the guidelines for processing satellite image data. In the land cover classification guidelines from satellite imagery, the accuracy value used is not less than 75% [19].

3. Results and Discussion

3.1. Aerial photo interpretation

The results of the aerial photo analysis with a total of 888 photos at an altitude of 60 produced orthomosaic with a Ground Sampling Distance (GSD) of 1.3 cm. The objects from orthomosaic visuals had clearer details and shapes. The crown of vegetation and tree shadows were clearly visible from UAV data, which could assist the visual classification process easily. Likewise, the appearance of the bottom of shallow waters could be seen clearly.

Drone mapping results show that the color and hue of the mangrove vegetation area will look greener and darker because the mangroves are usually located in wet sediments and characteristic of the water absorbs a lot of electromagnetic waves rather than reflecting them. The texture of mangrove vegetation will look rougher than other lower-level vegetation. The results of the mapping show that mangrove vegetation is scattered in all parts of the study area.

3.2. Segmentation

Multiresolution segmentation was introduced by [21] where this algorithm is a region merging technique that groups areas that have similarities and adjacent pixels into objects. In this study, the segmentation algorithm used was the multiresolution segmentation (MRS) algorithm with three parameters namely shape, compactness and scale. This algorithm was chosen because it is considered to best describe the real conditions. The formation of objects in the segmentation process was carried out with 1 level. This study was carried out on a 125 scale with a shape of 0.1 and a compactness of 0.5. The number of objects obtained from the segmentation process was 189,622 objects. The segmentation results are presented in Figure 5.

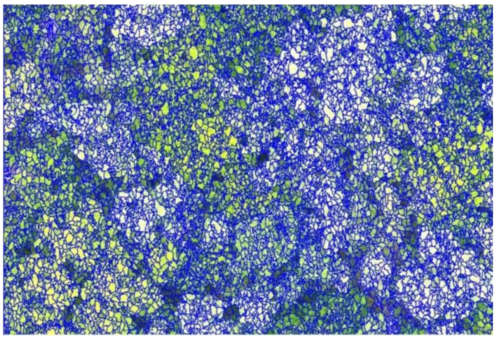

Figure 5. Segmentation results with a scale of 125

3.3. Mangrove type classification

The results of the classification using multiresolution segmentation are presented in Table 1. The determination of the training area refers to the survey results, leaf shape and different color hues from orthomosaic. At the classification stage, it is done by looking at the pixel values that correspond to the training area. Pixel values that are in the range of pixel values in the training area will be classified into a predetermined class. The distribution and area of OBIA classification results can be seen in Figure 6.

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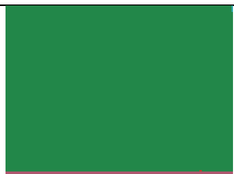
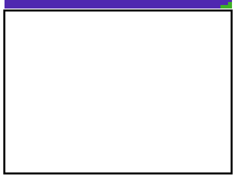
Tabel 1. The results of the classification of mangrove and non-mangrove species with multiresolution segmentation

Image Appearance	Image Classification	Field Condition	Mangrove and Non-Mangrove Classisification
			*Avicennia alba*
			*Avicennia officinalis*
			*Avicennia Marina*
			*Nypah fruticans*
			*Rhizopora apiculata*
			*Bruguiera gymnorriza*
			*Scyphipora hydrophylacea*
			Non-Mangrove (Settlement)
			Water Body

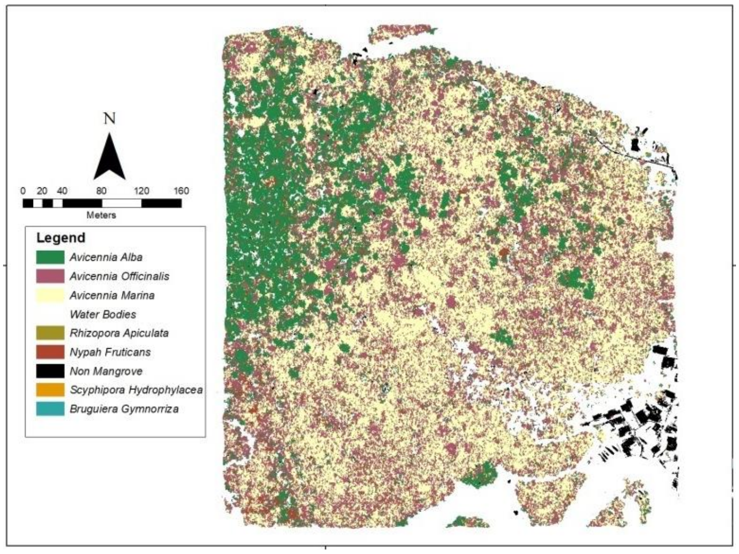


Figure 6. Mangrove species classification map of Medan Belawan

Table 2. Results of land cover identification using the object-based image analysis method

Class	Area (ha)	Percentage (%)
Avicennia alba	3.40	14.77
Avicennia officinalis	5.04	21.89
Avicennia Marina	7.80	33.87
Water body	4.91	21.31
Rhizopora apiculata	0.29	1.27
Nypah fruticans	1.07	4.65
Non-Mangrove	0.29	1.28
Scyphipora hydrophylacea	0.02	0.09
Bruguiera gymnorriza	0.19	0.87
Total Area	23.00	100

The results of class identification using OBIA with the multiresolution segmentation (MRS) algorithm (Table 2) showed the largest area of mangrove species in the research site, specifically *Avicennia Marina* with a percentage of 33.86% covering an area of 7.80 Ha. The second-largest mangrove species with a percentage of 21.88% is *Avicennia officinalis* with an area of 5.04 Ha.

3.4. Accuracy test (confusion matrix)

After the classification process is complete, it is necessary to conduct the accuracy test. Based on Table 3, it can be seen that in class 1 there are 17 points that are classified correctly, and 1 point is in another class. Furthermore, in class 2 there are 16 entry points in the correct class and 6 points outside the supposed class. Finally, in class 3 there are 26 points that are classified correctly and 1 point is not in the correct class and so on.

The segmentation result is validated by the species identification from field survey with the sample unit in a plot size of 20 x 20 m. We identify the dominant canopy mangrove species seen from above (UAV) in the sample plot. In one plot we found more than 1 mangrove species.

Table 3. Confusion matrix of mangrove species classification

Class	1	2	3	4	5	6	7	8	9	*Grand Total*	*Producer Accuracy*	*User Accuracy*
1	17		1							18	94.44	77.27
2	2	16	4							22	72.72	80.00
3		1	26							27	96.29	70.27
4				13						13	100.00	86.66
5	2		3	1	12	1				19	63.15	100.00
6						10				10	100.00	90.90
7							4			4	100.00	100.00
8		1						2		3	66.66	100.00
9	1	2	2	1					7	13	53.84	100.00
Grand Total	22	20	36	15	12	11	4	2	7	129		
Overall Accuracy	82.94											
Kappa Accuracy	84.51											

Class Description: (1) *Avicennia alba, (2) Avicennia officinalis, (3) Avicennia Marina, (4) Water Body, (5) Rhizopora apiculate, (6) Nypah fruticans, (7) Non-Mangrove, (8) Scyphipora hydrophylacea, (9) Bruguiera gymnorriza*

Errors of classification can occur because the classes have similar color and hue of other classes. For example, The classification error is caused because certain classes have a color and hue that is close to the same as the color and hue of other classes. In Table 4, errors in classification occur in class 1 where there are 17 correct points and 1 point is incorrectly classified and enters class 3. Class 1 and Class 3 are located on adjacent pixels so that they have almost the same color and hue. Visually there are similarities in shape and color between *Avicennia alba, Avicennia officinalis* and *Avicennia Marina*. Even in the *Rhizopora apiculata* class, apart from being included in other types, it is also included in the water body class.

The study area is a secondary forest area that has been planted in the past. The results of field observations still found formations according to the natural zoning of mangroves. It is evident that the results of segmentation method found that most of the *Avicenia spp* were closest to the sea. Generally, the identified species distribute randomly within the study area.

The canopy of *Avicennia,* which height dominated in almost every research site, becomes an obstacle in the process of making the training area. The results showed that the *Avicennia* species dominate. This is because this type of wood has a low selling price, making this plant not hunted by local residents, in contrast to *Rhizopora* and *Bruguiera* whose wood has a fairly high selling price.

The study finding related to the previous studies which found that the aerial photo interpretation using object-based image analysis can produce very accurate classification. Identification of species in mangrove vegetation adjusts to the image based on the color or wavelength reflected by the object. [13,23]. In this case show that data from UAV systems is reliable to identify mangrove species. A study by [14] and [24] found that drone mapping of mangrove species in recent years using UAV obtained the reliable accuracy.

Mapping using UAV technology is very reliable in mangrove ecosystem, especially in analyzing ecological aspects of mangrove ecosystem. This study found that it can be seen in detail the dominant mangrove species and other types that can be used as sources of seeds, food and habitat for animals and aquatic animals. The high quality data of mangrove ecosystem is very helpful in protecting, monitoring and restoring of mangrove ecosystems. The identified mangrove tree species can be used as value data for various programs for the community and other stakeholders.

The overall accuracy of the results of the OBIA classification method with the multiresolution segmentation (MRS) algorithm is 82.94% from the groundcheck points of 129 points. This value is more than the minimum threshold of the good accuracy value. The level of measuremnet of the accuracy of the classification used must more than 75.00%.

Very high spatial resolution images can increase overall accuracy in assessing image classification. This is evidenced by a study conducted by [22] which found that the maximum likelihood classification method on remote sensing images with a spatial resolution of 30 m only obtained an overall accuracy of 63.1%. Based on study by [24] found the overall accuaracy of 92 % for mangrove ecosystem using UAV technology mapping The overall accuracy value is 75% or more, show that the classification results are eligible to be used as the final results of the study. According to the National Institute of Aeronautics and Space [19], the level of classification accuracy assessment must be not less than 75%.

4. Conclusion

There are seven types of mangroves identified based on the UAV aerial photography map using the OBIA method, including: *Avicennia alba, Avicennia officinialis, Avicennia Marina, Rhizopora apiculata, Nypahfruticans, Scyphipora hydrophylacea, Bruguiera gymnorriza. Avicennia Marina* dominates the research site with a percentage of 33.86% or an area of 7.80 Ha. The second dominant species is *Avicennia officinalis* with an area of 5.04 ha or 21.88% of the research site. Based on the accuracy was obtained at 82.94%. The accuracy test value can indicate that the use of UAV images is better in terms of accuracy and classification accuracy. We suggest to develop deep learning method for identifying vegetation type in the next study.

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