Geographic Object Based Image Analysis (GEOBIA) for Mangrove Canopy Delineation Using Aerial Photography

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Abstract. Mangrove canopy cover is one of the important indicators for monitoring mangrove ecosystem’s health. Measuring and monitoring mangrove canopy cover using direct field measurement is tedious and inefficient work. This study implements the advanced geographic object-based image analysis (GEOBIA) approach to a very high-spatial resolution aerial photograph taken from unmanned aerial vehicle (UAV). This new technology has ability to capture mangrove canopy information in the field rapidly and present it in a spatially explicit manner. The aims of this study are to (1) establish a rule set to discriminate mangrove canopy to other coastal objects from UAV images; and (2) map mangrove canopy and calculate its accuracy. The image data used in this study was acquired on 27 April 2018, covering part of dwarf Avicennia marina and Ceriops tagal stands in Karimunjawa Island, Jepara, Central Java. Based on this image the rule set was then developed to delineate mangrove canopy borders by considering the color and shape properties of the object of interest on the image. An iterative classification process was conducted to find the most operational rule set to map the targeted object. Once the map produced, the area-based accuracy assessment was then applied to assess the quality of the canopy delineation. The results of this study show that UAV image – although handicapped with limited spectral information – is a valuable input for GEOBIA to delineate and map mangrove canopy borders with high level of accuracy. This study contributes to the development of canopy delineation methods using the emerging remote sensing technology and mapping approach.

Keywords: GEOBIA, mangrove canopy, UAV, orthophoto

1. Introduction

Mangrove canopy is one of the important information in mangrove ecosystem conservation. From canopy information, biophysical parameters such as health and vegetation growth can be derived and identified [1]. Information of mangrove canopy can be used to support various activities, such as estimating Leaf Area Index (LAI), carbon stock counting, and maintaining biodiversity in the mangrove ecosystem [2]. Measuring and monitoring mangrove canopy cover using direct field measurement is tedious and inefficient work. Remote sensing data are capable of producing information of mangrove canopy quickly and present the information spatially explicit.
Remote sensing data with very high spatial resolution result in high accuracy delineation of vegetation canopy [3]. However, there are limited studies undertaken to delineate the mangrove canopy from remote sensing data, especially with aerial photographs. Heenkenda et al. [1] delineated the mangrove tree crown through WorldView-2 imagery and GEOBIA in the mangrove forest of Rapid Creek, Darwin, Australia. They used region growing algorithm based on near infrared and normalized difference vegetation index (NDVI) to delineate the mangrove tree crown and result in 77% of delineation accuracy. Kamal et al. [4] also applied similar approach to map the mangrove tree crown in Whyte Islands, part of the Moreton Bay Marine Park, Brisbane, Australia using WorldView-2 image. The mapping result showed an overall accuracy of 68%.

According to Wang et al. [5], the use of aerial photography for canopy delineation would be much more efficient if it conducted by automated methods. This study implements the advanced geographic object-based image analysis (GEOBIA) approach to a very high-spatial resolution aerial photograph taken from unmanned aerial vehicle (UAV). This new technology has ability to capture mangrove canopy information in the field rapidly and present it in a spatially explicit manner. GEOBIA approach also offer some advantages (1) ability to handle a very high-spatial resolution, such as aerial photograph (2) this approach better to translate human perceptions and (3) can integrated of some important attribute (tone, shape, size, texture) [6]. Therefore, the aims of this study are to (1) establish a rule set to discriminate mangrove canopy to other coastal objects from UAV images; and (2) map mangrove canopy and calculate its accuracy.

2. Methods
2.1. Data and Study Site
Aerial photographs part of Karimunjawa Island was used as an input for this research. Orthophoto image that form a mosaic from 57 aerial photos is presented in Figure 1. This orthophoto image was produced from red green and blue (RGB) bands of commercial photograph with digital value from 0-255. Therefore, this image has very limited spectral information. However, this image has a very high spatial resolution with pixel size of 7.5cm. The aerial photographs were acquired from DJI Phantom 4 on 27 April 2018 at about 4.00 pm. The study site for this research was mangrove in part of Karimunjawa Island, Jepara, Central Java (110°27'50"E - 110°28'00"E and 54°09'45"S - 54°09'55"S). This specific study area was covering part of dwarf *Avicennia marina* and *Ceriops tagal* stands. In this area, *Avicennia marina* and *Ceriops tagal* dominant mangrove species, but distribution of both is very heterogenic.

![Figure 1. Study area in part of Karimunjawa Island.](image-url)
2.2. Orthophoto Image Preparation
Orthophoto was created with build up a model formed by 57 overlapping aerial photos from UAV. There are several steps in process of model building, first is aligning all aerial photo to enhance camera position for each photos. Second is building point cloud. Third, result of point cloud was then converted into a solid cloud in polygon form. Polygon produced in the third process still not describing the condition of object in the field yet. So, it needs to perform texture conversion to obtain an appropriate orthophoto image. Figure 2 below describes step by step procedure of preparing orthophoto starting with creating point clouds, dense clouds and building texture (c).

![Figure 2](image1.png)

**Figure 2.** Processing steps to result ortophoto image (a) building point cloud, (b) building dense cloud, and (c) building texture.

2.3. Mangrove Canopy Delineation Using GEOBIA Approach
Mangrove canopy delineation was performed using eCognition Developer 8.7 by creating rule sets. The process of rule set development for mangrove canopy delineation started by segmenting the orthophoto to separate objects that have different shape and compactness. We used multiresolution segmentation algorithm to segment the image into several meaningful object primitives. This segmentation process was conducted iteratively to obtain the most appropriate delineation of mangrove canopy (i.e. segment borders following the edge of canopy). Once the segmentation process has been completed, we then developed a rule set to separate the object primitives into mangrove canopies and non-mangrove classes. The non-mangrove category consists of water body (or substrate under mangroves in study area) and asphalt road. Separation of mangrove canopy to other objects was done using some features combinations such as brightness, texture of objects and band ratio by combining red and green band of the image. Figure 3 the conceptual hierarchy of mangrove canopy and other objects discrimination used in this study.

![Figure 3](image2.png)

**Figure 3.** Conceptual hierarchy of the classification process.

2.4. Mapping Mangrove Canopy and Calculating Accuracy
The mapping process implementing GEOBIA approach in this study was intended to discriminate and map mangrove canopy and non-mangrove canopy objects from orthophoto image. Each of the segments generated were then labelled to one of these classes in the classification process. To assess the accuracy of the produced map, we used area-based accuracy assessment developed by Kamal and Johansen [7]. This type accuracy assessment was designed to be used within GEOBIA context. The objectives of this
accuracy assessment are to calculate geometric accuracy of the segment delineation and assess the thematic accuracy of the class [8]. The process of accuracy assessment requires set of sample from both the resultant map and the reference. For the accuracy assessment reference we visually delineate the mangrove canopy from orthophoto, and assume the canopy borders are correct. To assess the map accuracy we used ten random 5m buffered points spread across the map and used them as the basis of both geometric and thematic accuracy assessment. Any coincidence in border or class between map and reference was identified as correct, and vice versa. The final result of mangrove canopy accuracy assessment was overall accuracy (OA, Eq. 1). From equation 1, C is any object on the resultant map and R in any object on the reference. The equation describes that the overall accuracy is a comparison between intersection of C and R and union of C and R.

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OA = \frac{|C \cap R|}{|C \cup R|}
\]

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However, the rule set used to discriminate mangrove canopy and water body (or substrate background) has limitations. That rule set was sensitive to the shadow created from different mangrove tree height. Most of the darker parts of the shadows were miss-classified as water body and marked blue in Figure 5b. This issue was also evidence in the lower part of the canopy clumps in the dense mangrove stands. This limitation was due to the lack of available spectral bands in the orthophoto image so that the spectral identification features was limited to three RGB bands. From other perspective, the time of acquisition was at 04.00 pm when the shadow of objects was optimum.

![Figure 5](image_url)

**Figure 5.** Issue with shadow in mangrove canopy classification; (a) original orthophoto and (b) miss-classification (red box).

### 3.2. Mangrove Canopy Map and Accuracy Assessment Result

Karimunjawa Island has a large area of mangrove canopy. The canopy density of dwarf species of *Avicennia marina* and *Ceriops tagal* in the study site is moderately high. Figure 6a shows the final map of mangrove canopy produced from GEOBIA approach in this study. From this figure we can observe that there are many openings or gaps between the mangrove canopies. This evidence is true because this area was waterlogged most of the time during a year. This water inundated *Avicennia marina* and *Ceriops tagal* most of the time and might cause the development of dwarf mangroves in this specific site. On the other hand, the high number of canopy gaps was also a result of the over-classification of water body object due to the limitation of the rule set above. Nevertheless, this study shows the potential of orthophoto acquired from UAV to discriminate mangrove and non-mangrove objects in coastal environment.

In terms of accuracy assessment of the map, Figure 6b shows the distribution of ten randomly selected buffers of 5 meters used as a reference for area-based accuracy assessment calculation. This polygon buffers were used to calculate the geometrical and thematic accuracy of the map against the reference. Any positional agreement between classes was marked as correct, and vice versa (Figure 6c). Table 1 summarises the results of area-based accuracy assessment for mangrove canopy classification in this study. Overall quality shows class related area accuracy, for instance, area of correctly classified as mangrove canopy was 72% out of the total area mangrove in orthophoto image. Thus, the image and rule set were failed to identify 24% of mangrove canopy class area from study site. The user’s accuracy or commission error indicates the probability that an object classified on the map actually represents that category on the ground, and producer’s accuracy describes the omission error or the probability of a reference object being correctly classified. In this case 66% of mangrove canopy were correctly...
classified as a mangrove canopy, and 98% area called mangrove canopy in map were actually mangrove canopy in the ground. Overall accuracy calculated the percentage of all correctly classified classes of mangrove canopy and water bodies in comparison to the total class domain area, which in this case is 73%. In general, from the accuracy value shows that GEOBIA approach can represent the actual condition mangrove canopy delineation.

Figure 6. Results of the GEOBIA approach: (a) map of mangrove canopy, (b) accuracy assessment sample distribution, and (c) area-based accuracy assessment example.

Tabel 1. Accuracy measures of mangrove delineation.

|                | Overall Quality | User Accuracy | Product Accuracy | Overall Accuracy |
|----------------|-----------------|---------------|------------------|-----------------|
| Mangrove canopy| 72%             | 66%           | 98%              | 73%             |
| Water bodies   | 62%             | 96%           | 39%              |                 |

4. Conclusion

Mangrove canopy information can be delineated from UAV aerial photography using the GEOBIA approach at medium-high level of accuracy. Aerial photograph from drone has an advantage in providing a very high-spatial resolution image data for mangrove canopy delineation. The red/green band ratio provided the most optimum feature to discriminate between mangrove canopy and non-mangrove objects from this image. However, it has limited spectral bands due to the commercial camera usage, i.e. it was only limited to the visible bands. This limitation affected the GEOBIA rule set development for this purpose. Mangroves located in the shadowed areas of the image were miss-classified as water bodies. The final result of mangrove canopy map in this study site has an Overall Accuracy of 73%. This study shows the potentials of drone-derived image to delineate mangrove canopy and non-mangrove objects. Further research needs to be undertaken to improve the rule set for this purpose and test its applicability at other mangrove sites with different stand characteristics.

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