GEOGRAPHIC OBJECT BASED IMAGE ANALYSIS (GEOBIA) FOR MANGROVE TREE CROWN DELINEATION USING WORLDVIEW-2 IMAGE DATA

Muhammad Kamal1,2, Stuart Phinn1 and Kasper Johansen1
1 Remote Sensing Research Centre, School of Geography, Planning and Environmental Management, The University of Queensland, Brisbane, QLD 4072, Australia,
Email: m.kamal@uq.edu.au, s.phinn@uq.edu.au, k.johansen@uq.edu.au
2 Cartography and Remote Sensing Study Program, Faculty of Geography, Universitas Gadjah Mada, Bulaksumur, Yogyakarta 55281, Indonesia,
Email: m.kamal@ugm.ac.id

KEY WORDS: GEOBIA, mangroves, tree crown, WorldView-2

ABSTRACT: Providing spatially explicit information of mangrove tree crown is essential to support management and monitoring of mangrove environment. This study developed a method to delineate individual Avicennia marina mangrove tree crown in Whyte Island (Brisbane, Australia) using the newly emerged GEOBIA approach and pan-sharpened WorldView-2 (WV-2, 0.5m pixel size) data. We used region growing technique modified from Culvenor (2002) to isolate the tree crowns based on the tree crown radiometric topography concept. A rule set was specifically developed to (1) enhance the differentiation between trees and canopy gaps, and (2) find the tree crown seed (i.e. tree top), (3) grow the seed towards the tree crown border within the tree class, and (4) refine the tree delineation. The results show that the principal component (PC) 1 and 2 of the image enhanced the differentiation of trees and canopy gaps. The near-infrared1 (NIR1) band of WV-2 found to be best suited for identifying tree seeds and growing the tree boundaries. We compared the GEOBIA delineation result with the manual tree crown delineation based on a very high-spatial resolution aerial photograph (0.75m pixel size) and found a realistic tree crown polygon boundaries with an overall accuracy of 68%. Some delineation errors were attributed to a single tree with multi-canopy crowns (i.e. it was identified as more than a tree) and small mangrove shrubs which were unable to be delineated. The results demonstrate the potential of GEOBIA approach to delineate mangrove tree crowns, but need some improvements in the future. The use of high-spatial resolution image data with pixels significantly smaller than the tree canopy size is an essential requirement for tree crown delineation.

1. INTRODUCTION

Forest inventories are essential to support conservation and sustainable management of mangrove environment. The results of the mangrove forest inventory can be used effectively as a tool for decision-making in this environment, such as maintaining biodiversity, preserving wildlife and environmental protection (Wang et al., 2004, Jing et al., 2012a). One of the most important structural information is individual trees within the forest stand, as a fundamental structural elements in the forest (Culvenor, 2003, Wang et al., 2004). Therefore, efficient forest management requires detailed, accurate, repeatable, and spatially explicit information of the individual tree crown. Remote sensing data provide a useful tool for mapping and analysing forest tree crowns (Culvenor, 2003, Bunting and Lucas, 2006). As high spatial resolution remotely sensed imagery becomes more available, the potential for this data be used as a source of forest inventory at a single tree level become more apparent.

Numerous algorithms for automatic individual tree-crown detection and delineation have been developed to provide tree-based forest inventory measurements. However, these methods need to be tested under a variety of forest conditions. Previous studies have demonstrated the effectiveness of tree crown delineation techniques from high-spatial resolution remotely-sensed data in the conifer or deciduous forest, tropical or sub-tropical savannah and plantation (Culvenor, 2003, Jing et al., 2012b). However, there are limited studies that aimed to delineate tree crown of mangroves from remote sensing data (Heenkenda et al., 2014). Although mangroves share the common properties of terrestrial vegetation, the detection of individual mangrove tree is remain a challenge. The spectral characteristics of mangrove is greatly influenced by the tidal fluctuations of the background soil (Blasco et al., 1998), and the fact that commonly it has uniform structure with less apparent height variation and tree clumping compare to the terrestrial vegetation (Heenkenda et al., 2014). To deal with these challenges GEOBIA offers several advantages; (1) ability to handle high resolution image data, (2) ability to incorporate multiple scale of analysis, (3) better mimics of human perception of objects and (4) numerous attributes can be obtained from image objects (Morgan et al., 2010). This study implements and evaluates the potential use of high spatial resolution WV-2 data and GEOBIA approach for delineating mangrove tree crowns in a test site at Whyte Island, Brisbane, Australia.
2. DATA AND STUDY AREA

This study used WV-2 multispectral image of the mouth of the Brisbane River acquired on 11 April 2011. This image was obtained in an ortho-rectified format (corrected at Level 3X), and were assigned to a UTM zone 56J map projection. It has eight multispectral bands at a pixel size of 2 m (Coastal blue (400-450nm), blue (450-510nm), green (510-580nm), yellow (585-625nm), red (630-690nm), red edge (705-745nm), NIR1 (770-895nm), NIR2 (860-1040nm)), and one panchromatic band at a pixel size of 0.5 m (450-800nm). A very high-spatial resolution aerial photograph (7.5 cm pixel size) with the true colour layers captured on 14 January, 2011 (www.nearmap.com) was also used (1) to delineate the mangrove tree crowns and (2) as a reference to analyse the classification accuracy of the produced GEOBIA tree crown delineation map.

The study area for this project was mangroves at Whyte Islands, part of the Moreton Bay Marine Park, Brisbane Australia (Fig. 1). *Avicennia marina* is the dominant mangrove species found in the study sites. Distinct structural zonations are noticeable in this area; from the saltmarsh area, through the mangroves to the water, the progression is open scrub formation, followed by low-closed forest and finally closed forest, according to Specht et al. (1995) forest structure classification. The test site was selected to represent the variation of mangrove zonation and test the applicability of the selected approach to map tree crowns at different mangrove vegetation structure.

3. METHODS

3.1 Image Preparation

The image pixel values (in digital numbers) of WorldView-2 were converted to top-of-atmosphere (TOA) spectral radiance (W/cm²sr nm) using the ENVI 4.8 software (ITT Systems, ITT Exelis, Herndon, VA, USA). This process was carried out following the procedures and correction coefficients described in Updike & Comp (2010). Further atmospheric correction was then performed to convert TOA spectral radiance to at-surface reflectance using the Fast Line-of-sight Atmospheric Analysis of Hypercubes (FLAASH) atmospheric correction model for the WV-2 image, with the atmospheric visibility parameter estimated from the moderate-resolution imaging spectroradiometer (MODIS) aerosol product (LAADS, 2012). The Gram-Schmidt spectral sharpening image fusion technique (Laben and Brower, 2000) was applied to produce a pan-sharpened WV-2 image with a 0.5 m pixel size. This pan-sharpening technique was selected because it delivers the closest pixel values to the original 2m multispectral bands of the image, and could be simultaneously applied to multispectral bands.
3.2 Tree Crown Delineation Approach

To delineate individual mangrove tree crowns and gaps the individual tree crown (ITC) “valley following” (Gougeon, 1995) and “region growing” (Culvenor, 2002) approaches were modified and applied in the eCognition Developer 8.7 software. The basic principle of ITC can be using three dimensional “radiometric topography” analogy of tree crowns (Culvenor, 2002). Given any tree objects on the image, lower spectral reflectance (i.e. in the NIR or panchromatic band) represent the boundary of tree crowns and recognized as the valleys or local minima. On the other hand, the centre points with maximum local spectral reflectance (or local maxima) are assumed to be the peak of the tree crown. These peaks are treated as seeds and will be grown towards the boundary of the valleys. The polygons created from this region-growing approach are the tree crowns. There are two implicit assumptions in these approaches; (1) the tree crown should be visually recognizable as a discrete object on the image (i.e. the pixel size of the image must be smaller than the average size of the tree), and (2) the tree crown is brighter (or has a higher pixel value) than the edge of the crown (Culvenor, 2003). Based on the image visual checking and field observation, the pan-sharpened WV-2 image with a pixel size of 0.5 m was sufficient to map the spatial dimension of mangrove trees in this area, and therefore used to delineate the tree crowns in this study.

Prior to the implementation of tree crown delineation approach, the conceptual object hierarchy was setup to facilitate delineation of object of interests (Fig. 2a). This hierarchy imitates human perception on object recognition from an image. It starts with the broader category of objects at the larger area of observation and then the object of interest is successively broken apart into smaller objects at smaller observation window, until the targeted object is achieved. This multi-stage/scale approach helps the image analyst to define the targeted object using series of reasoning processes and to focus on the tree object for further tree crown delineation processing. This approach was translated through the rule-set developed in the eCognition Developer 8.7 software (Fig. 2b).

![Figure 2](image.png)

**Figure 2.** (a) conceptual object hierarchy and (b) classification rule set applied to GEOBIA for mangrove tree crown delineation.

3.2.1 Tree objects delineation

The first two steps performed in this study were to separate between vegetation and non-vegetation class, and between mangroves and non-mangroves class within vegetation class boundary. Multi-scale segmentation and image classification based on spectral homogeneity of segments were applied to obtain these classes. A detailed description for these procedures are published in Kamal et al. (2015). The next step was to discriminate tree canopy gaps from the trees as the boundary of the tree crowns in mangrove class. It is common in mangrove forest to have irregular tree stands and canopies with groups of trees often clumped into a single wider canopy, making the delineation of canopy gaps through shadow (valleys) difficult. Exploratory analysis of WV-2 image dataset was performed to find the best band or bands combination to enhance the difference between tree objects and canopy gaps or shadows. We found that PC1 and PC2 of the image, which accounted for 99.84% of the image variance, were able to emphasise the difference in appearance between soil backgrounds or canopy gaps and mangrove tree canopies (Fig. 3b). Using the spectral threshold based on the PC1 and 2 bands, the tree objects and canopy gaps were mapped (Fig. 3.c). The tree objects were then used as basis for applying tree crown delineation algorithm.
3.2.2 Finding and growing local maxima

A chessboard segmentation was first applied to all of the tree objects in order to preserve the image pixel information. A median filter was then applied to the NIR1 band to minimise the image noise due to the high variation of spectral response of the vegetation. The tree tops or local maxima within tree objects boundary were identified from the original NIR1 band and were treated as crown seeds (Fig. 4a). The identified local maxima have one or more pixels depending on the size and configuration of the tree crown. Starting from the seeds, we grew the tree crown boundary toward the canopy gaps border (Fig. 4b) using ratio of neighbouring pixels algorithm. A ratio of NIR1 spectral reflectance values of the adjacent pixels to the crown seed was used to grow the crown boundary in a looped iteration until the crown seed polygons reached the canopy gaps border. This rule set was developed to adapt the test sites’ mangrove pattern, where there were noticeable canopy gaps between tree canopies. Modifications might be needed to apply this rule set to mangrove forests with very dense canopy cover and limited canopy gaps. Finally, the delineated tree crowns were refined using a pixel-based morphological opening operation to smooth the edge of the tree crown polygons and removing some of the isolated polygons (Fig. 4c).

4. RESULTS AND DISCUSSION

4.1 Tree Crown Mapping Results

The results demonstrate the potential of GEOBIA approach to delineate mangrove tree crowns. The conceptual object hierarchy provides effective demarcation process of object of interests, from large objects at a wider context to the smaller objects of targeted mapping unit. The tree crowns produced from the pan-sharpened WV-2 showed realistic polygon boundaries compared to the aerial photograph. In most of the cases within the tree level, the tree crown delineation algorithm successfully identified the boundary of the tree crown.
However, there are several issues associated with the results. First, it needs to test the consistency of the PC analysis result to other mangrove sites or larger extent as PC analysis result is highly influenced by the image scene variation. Second, part of the mangrove tree canopies in the test area are very dense and have overlapping canopy arrangements. As a result, the definite borders of tree canopies were difficult to detect and delineate from the image. Some delineation errors were attributed to a single large tree with multi-canopy crowns which was identified as more than one tree canopy (Fig. 5a,b,c). Third, another error was caused by small size mangrove shrubs with canopy dimension less than 2 m which were unable to be delineated from the image (Fig. 5d,e,f). Therefore, as suggested by Gougeon (1995) and Culvenor (2003), the use of high-spatial resolution image data with pixels significantly smaller than the tree canopy size is an essential requirement for tree crown delineation.

Figure 5. Large tree canopy size represented in (a) image combination of PC1, PC2, PC1, (b) aerial photograph, (c) field photo, and small size canopy crown represented in similar order (d, e, f).

4.2 Accuracy Assessment

To assess the geometric accuracy of the tree crown delineation an area-based accuracy assessment was used (Whiteside et al., 2010). This method aimed to measure the degree of similarity between the results of the tree crown delineation and reference data from different aspects, including overall quality, user’s accuracy, and producer’s accuracy. In addition, we also calculated the overall accuracy measure, which is defined as the ratio between the correctly classified area and the total area of observation. To perform this calculation, the reference data used in this measurement should have area dimensions that match the classified objects. In this study we visually delineate the mangrove tree crowns form a very high-spatial resolution aerial photograph (7.5 cm pixel size) and used some polygon samples as a reference to assess the geometric mapping accuracy of the GEOBIA approach (Table 1).

Table 1. Area-based accuracy descriptive statistics in percentage (%).

<table>
<thead>
<tr>
<th>Class</th>
<th>Pan-sharpened WorldView-2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall Quality</td>
</tr>
<tr>
<td>Tree crowns</td>
<td>64</td>
</tr>
<tr>
<td>Canopy gaps</td>
<td>34</td>
</tr>
</tbody>
</table>

The overall quality (OQ) shows the class-related area accuracy; for instance, the area of correctly classified as tree crowns was 64% out of the total area of tree crowns. On the other hand, the overall accuracy (OA) of 68% was calculated as the percentage of all correctly classified classes (tree crowns and canopy gaps) in comparison to the total class area (an entire image). Producer’s accuracy (PA) depicts the omission error or the probability of a reference object being correctly classified, whereas the users’s accuracy (UA) or commission error indicates the probability that an object classified on the map actually represents that category on the ground. For instance, for the delineation of tree crowns using the pan-sharpened WV-2 image, 81% of the tree crown areas were correctly classified as tree crown, but only 76% of the areas called tree crown on the map were actually tree crowns on the ground.
5. CONCLUSIONS AND FUTURE WORK

The mangrove tree crowns were mapped using pan-sharpened WV-2 image (0.5 m) and GEOBIA approach. Based on the results of the study, GEOBIA approach was able to delineate mangrove tree crown with medium-high accuracy (overall accuracy of 68%). PC1 and 2 of the pan-sharpened WV-2 provides the best tool for discriminating tree canopy and gaps. However, we found some problematic delineation issue in the large size trees with several tree crowns, and small shrub crowns with less than 2 m in diameter. We also found that high-spatial resolution image data with pixels significantly smaller than the tree canopy size is an essential requirement for tree crown delineation. The future research agenda are (1) how to refine the approach to address the large tree delineation issue, (2) to test the replicability of the approach at other mangrove sites, (3) to incorporate the lidar derived information for tree crown delineation and evaluate the result.

ACKNOWLEDGEMENT

Funding for this work was provided by Australia Awards Scholarships and The School of Geography Planning and Environmental Management, The University of Queensland (UQ), Australia. Access to images, field equipment, and software were provided by the Remote Sensing Research Centre (RSRC-UQ). WorldView-2 imagery was provided by Digital Globe and ongoing support of Trimble for use of eCognition Developer 8.7.

REFERENCES


