DETECTION OF DEAD TREES WITH REMOTE SENSING TECHNOLOGIES FOR ASSESSING PLANTED FORESTS

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ABSTRACT: Forest management, especially in the forest plantation sector is vital for maintaining environmental stability and ecological biodiversity. Managing of planted forest requires a detailed understanding of the resources available concerning their quality and quantity to maintain regeneration processes and ensure the preservation of environmental quality. Remote sensing and geospatial technologies application play a tremendous rule in rapid spatial and temporal monitoring as well as an assessment of planted forest resources and hence in the formulation for the sustainable management compared to the conventional survey that is costly, time-consuming and problematic to large and remote areas. The emergence of modern remote sensing techniques to gather information on earth surface features from satellite platforms, combined with human-machine interactive processing and analysis has revolutionized the conventional survey. The main objective of this paper is to estimate the total number of dead trees in planted forest area using remote sensing technologies. The tree's crown was used to quantify the structure of planted trees as it is a component for standing density which can be easily identified from the high-resolution satellite image. Principally, the method uses in this research consist of two techniques: morphological reconstruction to enhance the crown borders and ease the extraction of tree crowns and watershed transform. The result indicated that the methodology used in this study provides accurate and cost-effective estimates of individual trees in the planted forests.

1. INTRODUCTION

Planted forests are very important for the production of timber around the world. In some countries, they have made up most of the wood products from these resources. By 2050, the total forest plantation area is expected to exceed 200 million hectares, and due to their higher productivity than natural forests, planted forests being a major source of timber products worldwide (Evans 2009). So in the future, wood will be filled from the planted forest, and this will alleviate the pressure on remaining natural forests. On that, inventory information is important for forest management, not only for natural forests but also for planted forests. This information will assist in managing the forest plantations, which will intensify tree quality and stand growth through control of competing for vegetation, and attention to thinning and related operations. Besides, this information needed, not only for planning future forest plantations but also for recording the previous status of the forested area (Koch, et al. 2006). Therefore, detailed forest information such as tree counts, tree heights, crown base heights, and diameter at breast height (DBH), are critical for the effective management and quantitative analysis of planted forests (Kwak, et al 2007).

This forest information assessment, using digital imaging techniques is strongly encouraging and make direct substantial contributions to forest management. The specific contributions of resource information assessment activities using remotely sensed image include, (1) mapping forest details, (2) Crown counting and mapping and (3) as a tool for the physiognomy of the stand. The source of information reported that it is surprising to find out that this labor-intensive approach widely used in forest management agencies in many countries. Collecting forest information through this technique are essential to forest management activities. Through this information can build an activity by incorporating models as guidance, for example, timber harvesting, silviculture, and fire management activities, or predict timber and other resource supplies. Other priorities, such as minimizing the effects of harvesting are also increasingly important, as well as applications to deal with single management issues, such as timber production. This will further enhance the forest management system. This kind of information and modeling can also be used to pay attention to planted forests that will likely experience severe resource deficits. Besides, capabilities could be used to minimize the risk of destruction to the planted forests area.

Among the important research undertaken where to obtain information and observe the growth of planted trees. This is to ensure a better and more sustainable-planted forest development goal. Remote sensing not only provides a cost-effective tool to help forest managers better understand forest characteristics but also with this technology a variety of image processing techniques were developed for automated detection and delineation of individual tree crowns. However, it depends on the quality of the imagery, the skill and experience of the researcher. The techniques, make the possible estimation of characteristics such as tree crown size, canopy closure, and facilitate species level classification (Gougeon 1997, Leckie et al. 2005, Reitberger et. al., 2008, Heurich, 2008). Furthermore, such techniques enhance the derivation of parameters of interest for forest information such as segmentation methods for tree species classification (Yao et. al., 2012a), detection of standing dead trees as well as estimation of tree parameters such as stem volume and diameter (Yao et. al., 2012b) and biomass (Kankare *et. al*., 2013). In this work, they focus on detecting segments of fallen trees directly from remote sensing technology point clouds. They have discussed satellite imagery, which is convenient for large-scale surveys and has been widely used for forestry sectors applications for a different perspective. They have discussed that remote sensing technique can provide higher resolution and allows monitoring of forest health and identification of tree condition at an acceptable accuracy.

Practically, numerous studies and several reviews have been published on the application of remote sensing for assessment of natural forests, much fewer studies have focused specifically on the planted forest. Consequently, to enhance the management and protection of planted forest, studies need to be done to strengthen the industry cost-effectively. The use of digital and spatial data has many advantages over other methods, including a high degree of consistency, space accuracy, and subsequent analysis automation. This tool also identifies qualitative and quantitative information on the dead trees in a planted forest, which is important for government agencies and other investment organizations to identify problems in the investment climate. In which any dead tree problem can be determined precisely. In this reason, research should be conduct to ensure the success of this forest plantation program through gather information and evaluating forest damage.

Culvenor (2002) proposed delineation of individual tree crown from optical imagery. Interestingly, he develops the valley-following algorithm for the isolation of individual crowns in the Canadian Boreal forests. In this method, the local radiometric maxima and minima are the primary image features used for the crown delineation process, being indicative of crown centroids and boundaries, respectively. Other than that, Gougeon (1995), (Wang *et. al.*,2004) and (Leckie *et. al.,* 2005) developed algorithms that delineate crowns based on the optimal match of predefined geometric shapes with local radiometric values. The method that performed crown delineation in high-resolution imagery. They developed a marker-controlled watershed segmentation method on High-spatial-Resolution Imagery of a commercially thinned trial forest. They concluded that the promising agreement between the automatic methods and manual delineation results.

The delineation process from remote sensing data assumes that the tree crowns have the shape of a mountain, with bright peaks at the treetops and dark pixels at the border of the crown (Ke and Quackenbush, 2011). The treetop indicates as an individual point and its position. Meanwhile, the rounded crown not only defined its edges but also spatial extent. A rounded slice of the crown can be drawn at any height and each slice shows as a rounded slice contains the treetop, and indicates the rounded extent of the crown. While using the rounded slice of the crown, from top to bottom, multiple slices can be obtained and jointly to describe the shape of the crown. It is manifest that the bottom slice has a maximum size and best indicates the extent of the crown. Morphological reconstruction can alter the confusion of upper and lower crowns and can be used to enhance image contrasts based on structural elements. Here, this technique is used to distinguish the shade at the border of the tree crowns and further determine if a pixel was in a tree crown or the shade between the trees. Based on such Crown delineation modeling, the objective of this paper is (i) to present a method that segments single trees with a robust surface reconstruction method in combination with the watershed algorithm using full remote sensing data, and (ii) to show how the detection rate and position of single trees is improved. Where all of these will be useful for forest plant health assessment to ensure planted forest success.

2. MATERIALS AND METHODS

This section and its subsections describe the study area, methods and materials used for this study. An overview of the acquisition, processing and analysis of input data, and finally the description of the verification method.

2.1 Study Area

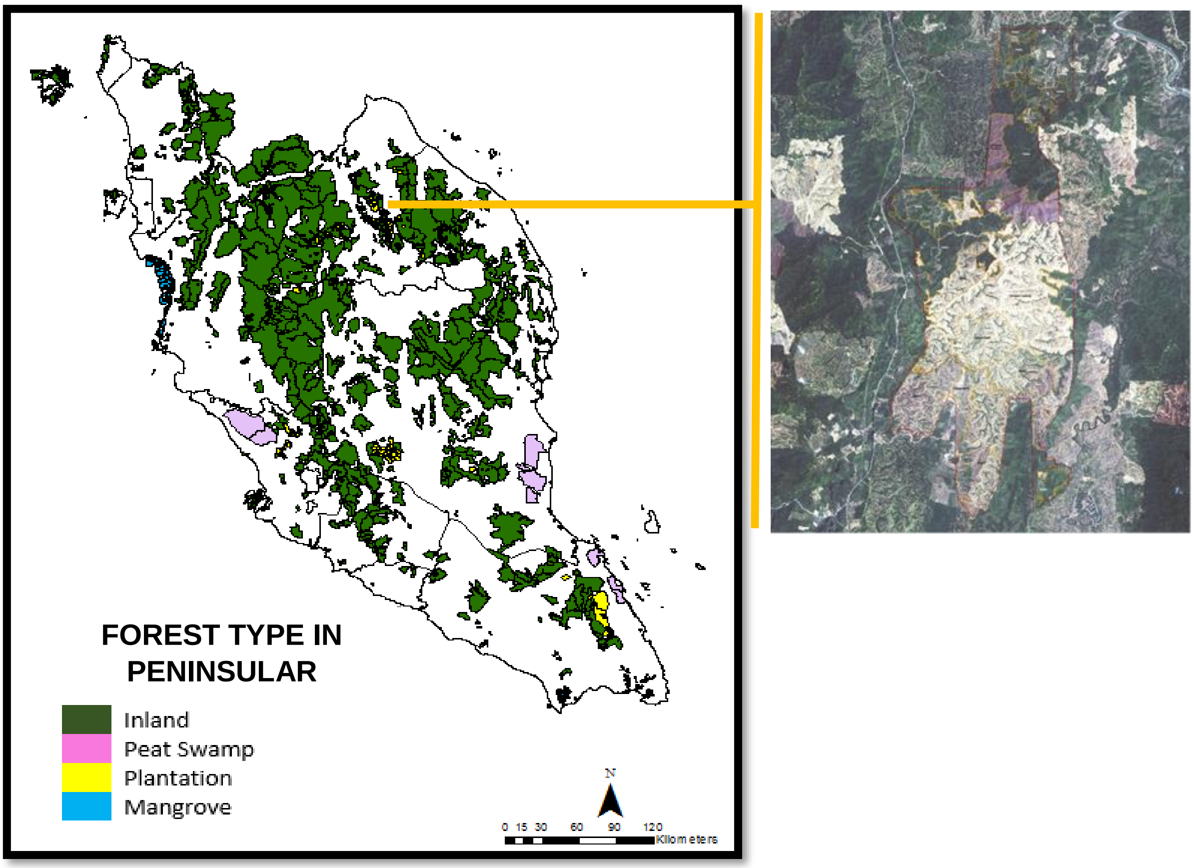

Figure 1: Geographical Locations Of Study Site Showing The Relai Forest Reserve, Located In The Kelantan Timur Forest District, Kelantan

The study was conducted at Relai Forest Reserve, located in the Kelantan Timur forest district, Kelantan and centered at 5° 8' 32.3" N and 102° 17' 42.2" E, as shown in Figure 1 above. This forest is a type of lowland dipterocarp forest and some of the areas have been converted into forest estates with Timber-Latex Clone (TLC), which can produce a good yield of latex as well as timber. The planted area under the Forest Plantation Project administrated by the Malaysian Timber Industry Board (MTIB).The area, 4 193 hectare have been planted on scaled phase plots since 10 years ago. As this is, the planted area dominated by one species of trees and consists of various-sized trees, with some stands have closed and multi-layered canopy structures. According to this, two plots were selected to test the method, which is based on different closed canopy forests. Plot 3 is a matured TLC while plot 1 and 2 consists mainly of young rubber trees. The planted forest canopy is mostly homogeneous but differently based on plant plots.

2.2 Methods

2.2.1 Images processing: The Pleiades of high-resolution images over the planted forest of Relai Forest Reserve, was taken in 2018. The spatial resolution of the bands is 50-cm for the panchromatic band (480-830 nm) 2-meter for the multispectral bands: Blue (430-550 nm), Green (490-610 nm) and Red (600-720 nm). The original Pleiades image were then pan-sharpened, that is, merged with the high-resolution panchromatic image to create a single high-resolution RGB image at 50-cm resolution. The multispectral bands were pansharpened with the panchromatic band using the PANSHARP fusion technique provided by the PCI GEOMATICS. The image was resampled by nearest-neighbour method and georeferenced to Rectified Skew Orthomorphic Malaya Grid (RSO). Sub-images that covered the study sites were extracted from the full images.

The next steps in this method, Morphology Strategic, and Watershed segmentation, in which it applied to grayscale images. The grayscale images converted must have preserved the salient features of the color image such as contrasts, sharpness, shadow, and image structure. The details of these the two methods are provided in Figure 2.

2.2.2 Morphology Strategic: Morphology Strategic is a technique widely used in very diverse image processing tasks of describing shapes using sets. It is a powerful technique to extract information from images that concentrate on the geometrical structure within the image. There are two basic operators in morphology strategic, opening, and closing. It is performed using the two basic operations, i.e. erosion, and dilation. The erosion consists of finding where the pixels fit the objects in the image. It makes an object smaller by removing or eroding away the pixels on its edges. The dilation, which is paired to the erosion, shows where the pixels hit the objects. Erosion shrinks and dilation expands the shape of image. From these basic operators, different combinations of operations can be constructed. Which is opening and closing. Opening operation detaches objects that are touching but should not be and enlarges holes inside the objects. As the opening operation uses both operator, erosion and dilation, image details, which are smaller than the structuring elements, can be eliminated without affecting its global geometric features. Opening operation generally smoothest contours by suppressing small islands, breaks narrow isthmuses, and eliminates thin protrusions.

The paired operation of the opening is closing. This operation joins broken objects and fills in unwanted holes in objects. It smoothest the contours by filling in narrow gulfs and eliminates small holes. It involves one or more dilations followed by one erosion.

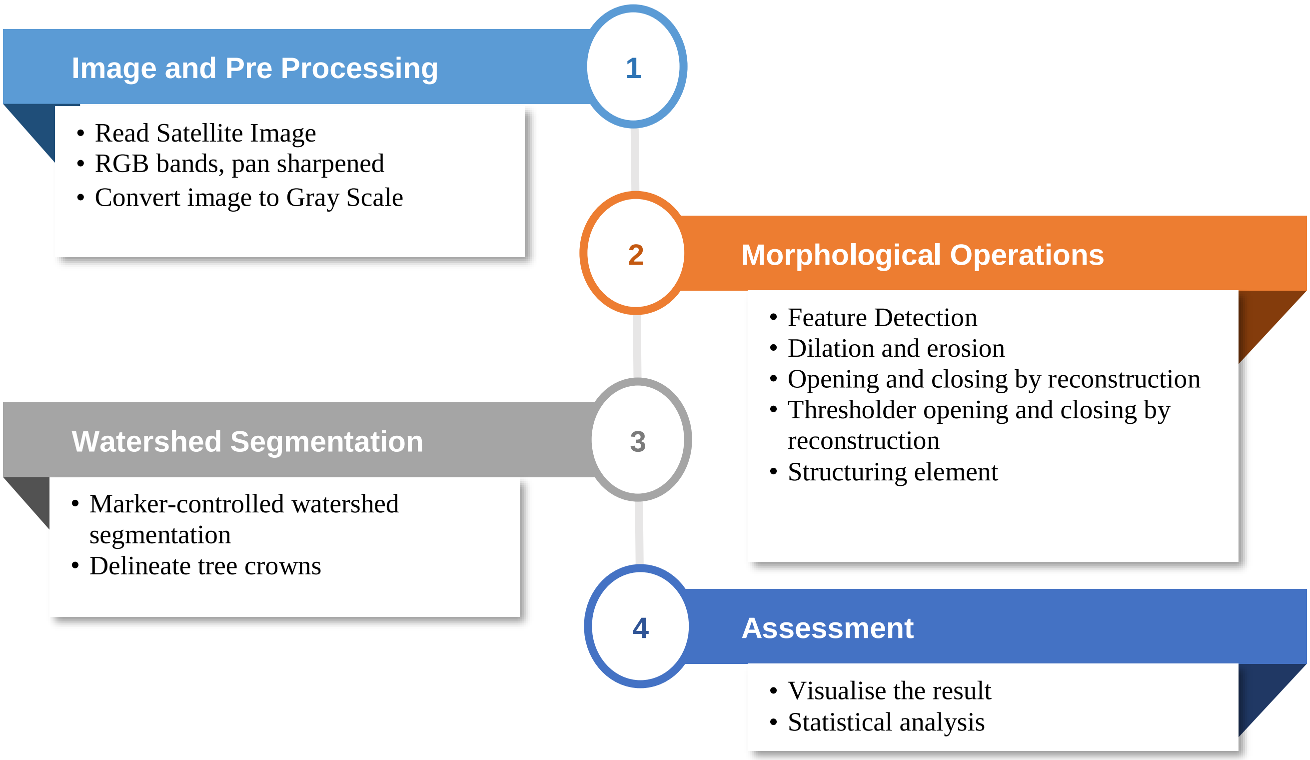

Figure 2: The Schematic Diagram In This Study: 1) Images And Pre-Processing; 2) Morphological Operations; 3) Watershed Segmentation; And 4) Visualise Assessment.

2.2.3 Watershed segmentation: Image segmentation is one of the challenging processes of image processing. The purpose of image segmentation is to divide an original image into homogeneous regions. There are several approaches for image segmentation methods for image processing. In this research, we used a method of a region-based approach to segment an image. It is more commonly known as watershed segmentation. The watershed segmentation applying flooding process in which considers an image as a topographic surface where the grey levels represent altitude. This flooding process was performed by using morphological strategic.

The main purpose of this technique is to find borderlines that isolate each region, in this case, each tree crown. However, in a certain condition, the isolated regions are over-segmented, in this case, each tree crown. However, after the complete transformation process, in certain circumstances, there is a problem such as an edge ambiguity and the output of a large number of regions, in this case, each tree crown. In order to avoid the over-segmentation caused by intensity variation within the region, marker-controlled watershed segmentation was introduced by Meyer and Beucher (1990). This approach has been used by Wang *et. al*. (2004), in which they identify specific points, to limit the number of segments created. The marker-controlled methods consider tree tops, where they are determined using a local maximum intersection in gray images, representing a high reflection, and maximizes locally in geodesic distance images. This representing the center of tree crowns based on the assumption of circular tree crowns. With the tree tops used as markers, the ~~proses~~ process can differentiate tree crown areas from the most significant background (shaded area), and watershed segmentation can be used to separate individual trees from neighboring trees.

2.2.4 Accuracy Assessment: In order to evaluate the results of this research, the resulting segment has been visually comparing and quantitatively assessed. The accuracy of tree crown detection is assessed on both plots and also at the individual tree level. This was conducted by comparing the delineated tree counts and the reference counts within the plots. The level of accuracy was analyzing the location match of reference and delineated crowns using the user's accuracy and the producer's accuracy. To quantitatively evaluate the accuracy of each segmented crowns, the reference crowns for each plot were placed into the following four categories according to their spatial relationships with target segments (Linhai et al. 2014):

1. Matched: If a reference crown and a target segment overlap exceeded 50 percent, the reference crown was considered as a crown matched by the target segment.

2. Nearly matched: For a reference crown and a target segment, if their overlaps exceeded 50 percent of only one segment, the reference crown was taken as a crown nearly matched by the target segment.

3. Omitted: If a reference crown had overlap less than 50 percent with any target segment and covered more than half the area of no target segments, it was considered as a crown omitted in the automatic delineation.

4. Merged: If greater than half the area of multiple reference crowns was covered by a single target segment, the multiple reference crowns were taken as crowns merged in the automatic delineation.

5. Split: If greater than half the area of multiple target segments was covered by a single reference crown, the latter was considered as a crown split in the automatic delineation.

Based on the definitions above, a confusion matrix table was introduced in order to demonstrate the detail of tree crown detection.

3. RESULTS AND DISCUSSION

As mentioned earlier, the process involved in the study, intricate four main steps. First step, determine the dominant of target tree crowns through morphological operations analysis and this will pertinent the shapes of the individual tree crowns. Second step, the individual tree crowns then will be smoothed corresponding to the treetops, and subsequently be segregated through the watershed approach, ruminate on treetops as the marks. Third step, using tree crown segments of the segmentation results, to produce a reasonable tree crown map. Lastly, after produce and identify the crown boundary, the next step is to locate the standing dead tree that needs to be identified for its management.

In the planted forest, where trees have the same age and species, tree crown extraction can take advantage of their relative uniformity. However, they may differ in shape, size, height, foliage arrangement, and density, and their spatial context varies with illumination, ground type, and inclination. As such, the task of this study become highly complex. In order to show an understanding of the problem, three experimental plots were set up to perpetuate the distribution of planted trees and into different condition. The first and second experimental plots are representing young trees and the third plots representing mature trees. The dissimilarity between the first and second experimental plots, where the trees have performed well in the first experimental plot compared to the second experimental plot.

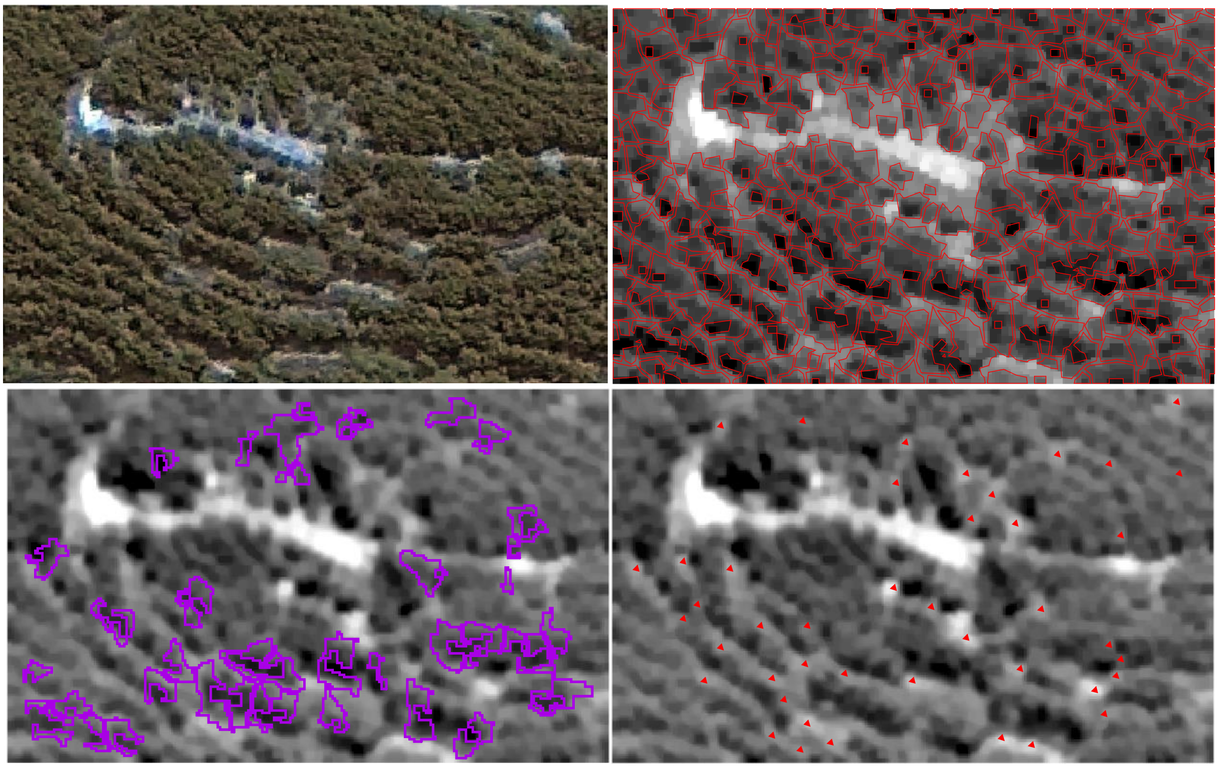

Figure 3: Individual Tree Delineation Steps For A Subset Image Of The Study Site (Plot 1): (A) Pleiades Of High-Resolution Images; (B) Morphology Strategic And Marker-Controlled Watershed Segmentation, Where Segmented Crowns Are Represented In Red (C) The Geometric Shift Reflects The Aggregated Proportion Crown Of Detected Trees; D) Number Of Standing Dead Tree (Shown In The Red Triangle)

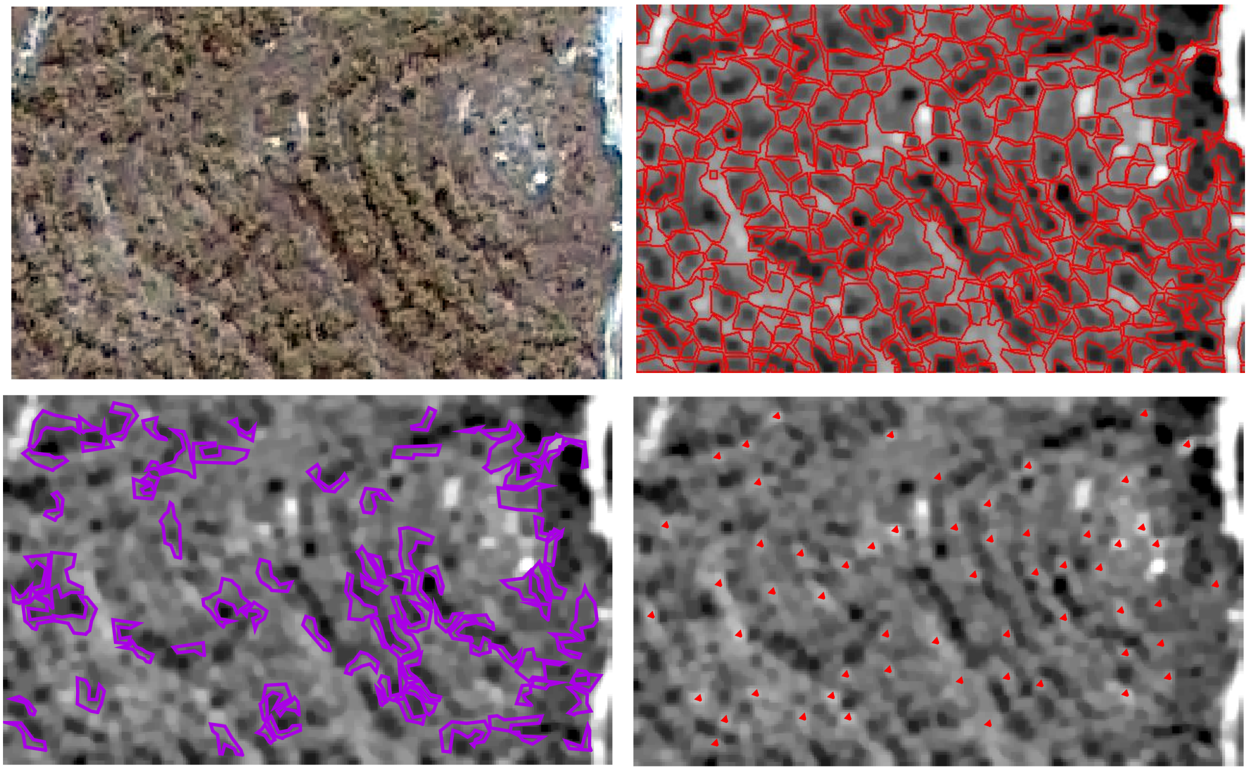

Figure 4: Individual Tree Delineation Steps For A Subset Image Of The Study Site (Plot 2): (A) Pleiades Of High Resolution Images; (B) Morphology Strategic And Marker-Controlled Watershed Segmentation, Where Segmented Crowns Are Represented In Red (C) The Geometric Shift Reflects The Aggregated Proportion Crown Of Detected Trees; D) Number Of Standing Dead Tree (Shown In The Red Triangle)

Meanwhile, the third plot represents the mature tree area, with the crowns touching each The plots of this study area having a size of 1.0 ha (128 m × 113 m) with the density of each plot should have 450 trees/hectares. The result obtained from these plots were evaluated using a complete accuracy assessment method including visual and quantitative assessment for the crown shape together with individual tree detection. The assessment was accomplished by comparing the individual delineated tree and the representative tree detection (references) within the plots. Meanwhile, in quantitative assessment, confusion tables were used to details out the result.

The high spatial resolution images over the study plots area are portrayed in Figures 3a, 4a, and 5a. Meanwhile, individual tree detection analysis and crown delineation results presented in Figures 3b, 4b, and 5b. In these Figures, the red line represents the individual tree with crown boundaries as defined by the analysis. The result shows that small trees (Figure 3b and 4b) spawned less distinct shadows, which reduced the effectiveness of using high-resolution imagery for crowns edge detection. Moreover, the underlying layer (e.g., grass, and shrub) reflectance had a strong influence on the spectral response. Different problems occur in Figure 5b, in which overestimation of

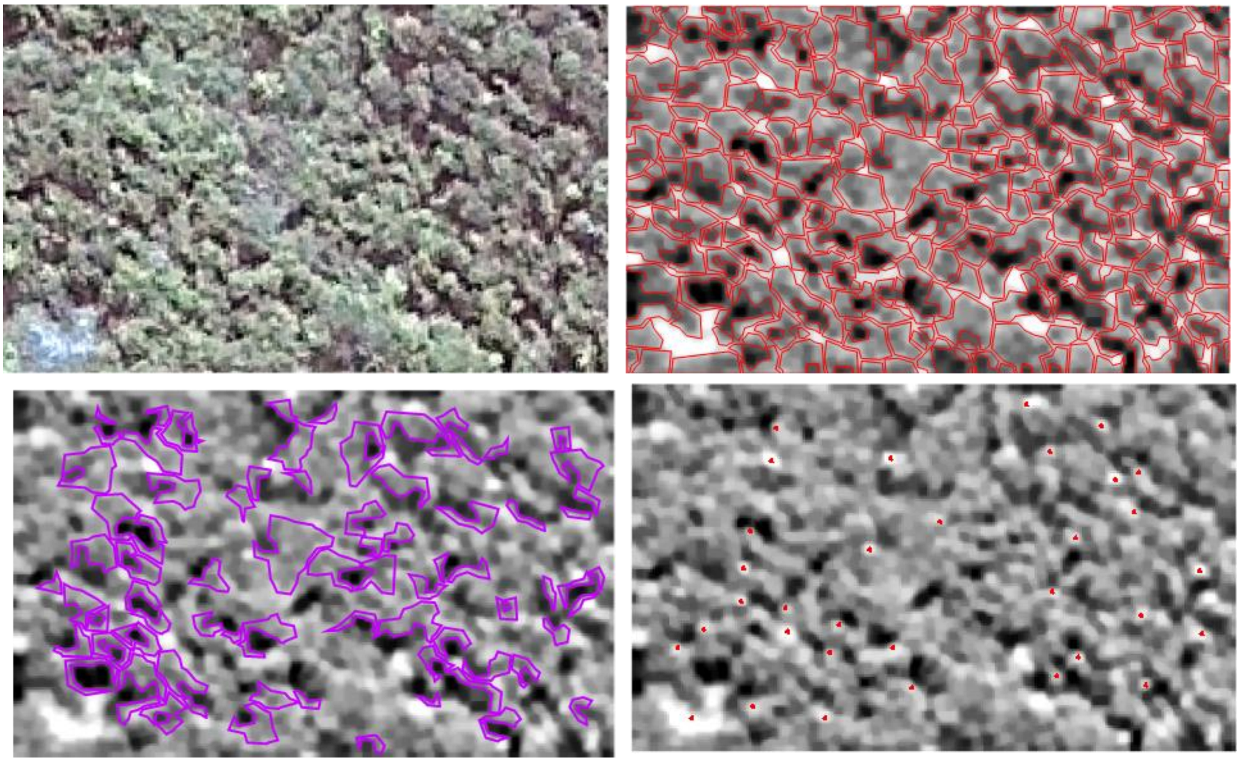

Figure 5: Individual Tree Delineation Steps For A Subset Image Of The Study Site (Plot 3): (A) Pleiades Of High-Resolution Images; (B) Morphology Strategic And Marker-Controlled Watershed Segmentation, Where Segmented Crowns Are Represented In Red (C) The Geometric Shift Reflects The Aggregated Proportion Crown Of Detected Trees; D) Number Of Standing Dead Tree (Shown In The Red Triangle)

large trees individual detection and crown delineation. This was probably the result of high spectral variance near crown edges, where the foliage was more open.

On average, the number of trees found by the algorithms corresponded to 77.6 percent of the number of trees measured manually. The average tree detection rate varied between the test sites, being 73.3 percent for the first plot, 80.0 percent for the second plot, and 79.7 percent for the third plot. These are based on the total number of trees in proportion to the number of trees in the field, i.e. 450 trees/hectares. Thus, ones can draw assumptions that the results from using this algorithm and technique for individual tree detection and crown delineation indicate two things. Firstly, the approach was moderately successful in detecting and delineating small tree, in particular, those that display low contrast to the field layer. Secondly, the low delineation accuracies for large trees suggest that the approach influenced by the effect of within-crown spectral variance.

Conversely, the visual interpretation also indicates that plots are likely to exhibit errors. The errors for each plot are illustrated in Figures 3c, 4c, and 5c and indicated by a solid magenta line. Succeeding the morphological processes, it will produce multi-scale tree crowns represented by multiple layers. Then, these results were consolidated into one layer. This is to produce a layer showing the spatial extension of the target crown and used it as an object to indicate the position in the watershed segmentation. These processes usually contribute errors, in which the resulting layer contains an unappropriated treetop and indicates the extent of the crown, which is a contributor to the omission and commission errors that occurred in all experimental plots. Such error was significant, and more encourage in the second experimental plot. Such error generated on the second plot can be attributed to the tree crown that had low mortality. This is because, the second experimental plot experiences competition with shrubs that grow abandoned in that plot, this contributes to error. This makes omission and commission errors in the second plot is higher compared to the first and third experimental plot.

It is important to note that the most important results and accomplish the objectives of this study are presented in Figures 3d, 4d, and 5. The standing dead tree have been identified through the detection of local maxima and after constructing crown segments. The technique of determination of dead trees achieved relatively good accuracies with the results ranging from 80.0% to 89.0% with the manual delineation. This indicates that the spectral information is preserved in this technique and is suitable for recognition, standing dead trees in planted forests. Although it seems that this technique only can be applied to the species in situations where the tree cover is characterized by high homogeneity in terms of tree crown size distribution and species diversity, it can also be applied to other situations from the forest plantation. However, should finding facilitates that improved understanding of tree cover structure, composition, and dynamics. This kind of information is important to forest manager in managing their planted forests more effectively. The results based on the study show strong relationships between multispectral imagery and the method, which suggests that the proposed method can be used to estimate standing dead tree and their location over relatively large planted forest areas.

The successfulness of the study was further analyzed and showed in Table 1. It summarizes the result of detection trees correspondence between fields and delineated. The results of this study are slightly modest: 73.3% of the trees in plot 1, 80.0% of the trees in plot 2 and 79.7% of trees in plot 3 were detected.

As can be seen from Table 1, the detection trees derived from the delineation agrees well with the reference data, but considerably lower in plot 2, and 3, in terms of percentage 72% and 74% accuracy respectively. This is due to the fact that, first: obstacle from the view of the satellite sensor, second: trees detection is expected to underestimate tree canopy cover slightly, and third: cause by the presence of adjacent field layer vegetation that diluted the crown edges.

Table 1: The Accuracy Statistics Of Generated Tree Crown And Number Of Standing Dead Tree

Plot	Total	Matched/ Nearly Matched	Merged/ Omitted	Split	Accuracy (%)	Omission Error (%)	Commission Error (%)	Standing Dead Trees
1	330	280	44	6	85	13	1	43
2	360	260	91	9	72	25	3	57
3	359	267	80	12	74	22	3	32

The results also showed, mean number of false detected trees for intermediate growth (plotmounts to 28 % and indicates remarkable reliability. However, the detection number is different in the individual plots. For example, the accuracy of tree detection in plot 1 is 85% but the number of tree detected is low, that is to say, 330 trees. Whereas the detection trees in plots 2, and 3 are significantly improved, but the number of false detected trees gets slightly larger, most notably in plot 2.

The omission errors are acceptable, in plot 1 (13%), plot 2 (25%) and plot 3 (22%), with omissions attributed mainly to misleading adjacent field layer vegetation, especially in plot 2. These mean that the method used in this study to detect tree enables separation between tree cover and field layer objects that are spectrally similar on the pixel level, however problematic to classification. In particular, the geometric information of small trees (i.e., crowns whose reflectance is highly influenced by the field layer), which are easily misclassified with purely spectral approaches.

The commission error is considered acceptable, with the result of 1% to 3%. However, this could possibly be further reduced by applying more advanced methods for tree detection or alternatively mask out small trees of field layer objects (e.g., grass, shrub and tree re-growth) before proceeding with the segmentation process. This will thus minimize commission errors in tree detection.

4. CONCLUSIONS

This study presents a method for detecting standing dead trees using multispectral high spatial resolution remotely sensed data in the planted forest. This approach seemly very useful for large-scale assessments, where it can provide valuable information to foresters for management. The result indicates that the detection of a single standing dead tree can provide relatively complementary information to serve as an intermediate step for object-level detection. This approach allows the forest manager to identify the location of the tree that needs to be replaced or manage for further action. Other interesting capabilities emerge, the study can identify more reliable information to determine the immediate needs, which minimize the expenditure used for removal and replacement of trees. In addition, it provides important tree information for the modeling and analysis of the environmental, social and economic services produced by the forest plantation.

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