Tagging and Mapping of Mixed Dipterocarp Mountain Forest at Species Level using an Airborne Hyperspectral Imager

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Abstract: Forest inventories describe the quantity and quality of trees and other organisms of the forest and the characteristics of the land on which the forest grows. Thus, to manage the resource of the forest systematically, the forest has to be precisely identified and classified before implementing decisions. A study on the spatial distribution of mountain mixed hill dipterocarp forest tree species in Gunung Stong Forest Reserve, Kelantan, Malaysia was conducted using an airborne hyperspectral imaging technique to identify, tag and map tree distribution at species level for future sustainable harvest and management planning. The general objective of this study is to assess the capability and usefulness UPM-AISA airborne hyperspectral sensor in Pre-Felling forest inventory while the specific objectives are to identify, map and tag individual trees in Gunung Stong Forest Reserve, Kelantan. A Sobel filter was used to enhance the image followed by a Spectral Angle Mapper (SAM) analysis to classify the individual tree species within the study plot. A digital map of tree tagging was produced with the tree species identified were Kelat (*Syzgium* spp), Keledang (*Artrocarpos* spp), Mengkulang (*Heritiera* spp), Tempinis (*Streblus elongatus*), Keranji (*Dialium* spp), Tulang Daing (*Callerya atropurea*), Meranti Sarang Punai (*Shorea parvifolia*), Kembang Semangkuk Jantung (*Scaphium macropodum*), Bintangor (*Calophyllum* spp), Nyatoh Minyak (*Sapotaceae* spp), Mersawa (*Anisoptera* spp), Resak (*Cotylelobium* spp), Sepetir (*Sindora* spp), Temponek (*Artocarpus rigidus*) and Petaling. The mapping accuracy of 89.66% was attained in the 1 ha study plot. Tree tagging using airborne remote sensing has a great potential in the Pre-F inventory and should be integrated with a GIS database management for future decision in management, development and utilization of sustainable forest resource.

Keywords: Tree tagging; airborne; hyperspectral imaging; tropical mixed dipterocarp forest; inventory; mapping

1. Introduction

The forests of Malaysia have contributed significantly towards socio-economic and industrial development of the country through the generation of income from the exports of timber produce and creation of employment in the wood based industry. In intangible terms, the forests are important in maintaining environmental stability, protection of flora and fauna, biodiversity and water resources. The significant practice of sustainable forest management and environmental protection in Malaysia has been long established as reported by Kamaruzaman and Skidmore (2009) and Kamaruzaman Jusoff and Dahlan (2008). The development from the National Forest Inventory of Peninsular Malaysia (NFI) was the use of satellite imagery and Geographic Information System (GIS) for forest resource monitoring, based on established criteria of forest stratification and supplemented by precise information of sampling locations through Global Positioning System (GPS). These data were regularly updated through medium term inventory (pre- and post-felling) and incorporated into digital maps produced with GIS. This system would enhance Forest Department Peninsular of Malaysia's capability in information capture analysis, thus contributing towards better sustained forest management. However, data collection is difficult and ground measurements are expensive due to poor infrastructure (Mikael *et al*., 1995). In Malaysia, forest inventories are carried out at the macro and operational level. The procedure used in each of the inventory differs in terms of sampling design, types of information being collected and the frequency of inventory being carried out (Masran and Samsudin, 1994). In general, forest inventory at the macro level aims to collect and generate the following information on the forest resource base, namely (a) to determine the acreage and location of forest areas according to the forest type stratification, (b) to assess changes in forest resources with respect to distribution, composition, forest stocking, forest stand and total tree volume according to its quality and productivity, (c) to determine the standing volume of forest areas in accordance with the forest type stratification, to estimate the net and gross standing volume of specific diameter classes according to species group/types and areas with potentials for exploitation, and to determine the location and asses both the quality and quantity of rattan, bamboo, palm and peanut resource. Data recorded during inventories (e.g. timber volumes, growth rates, size distribution pattern, species composition, stand conditions and location of stands) are also important for sound forest management. Information on precise stand volume and spatial distribution of the trees to be harvested is essential in order to plan precision forestry activities to minimize impact and efficiently extract the timber (Kamaruzaman, 2009a).

At the operational level, two types of forest inventory is being carried out for the inland forest, which are pre-felling (pre-F) forest inventory; and post-felling (post-F) forest inventory. The pre-felling forest inventory is carried out to determine the stand structure of the forest before harvesting commences in order to determine appropriate management (felling regimes, which will be equitable to the logger and forest owner as well as to ensure ecological balance and environmental quality. The inventory is carried out using systematic line plots of 50m x 20m with four sub-plots of 25m x 20m, 10m x 10m, 5m x 5m, and 2m x 2m. Currently, tree tagging or marking in the forest was done through manual methods and these traditional methods are expensive and time consuming. Remote sensing techniques, in order to be practical, provide necessary information in great quantity, better quality and also lower cost than existing methods. The need for forest data is increasing in Malaysia as forest management becomes more intensive. An airborne remote sensing technique is currently practical and has been use for several forestry applications. The development of multispectral imaging spectrometers during the early 1970's allowed scientists for the first time to classify large areas of terrain (Marmo, 1996). This led to the advent of hyperspectral sensors with many bands and high spatial resolution, allowing for the classification of large areas with finer spectral resolution (Cloutis, 1996). Current multispectral satellites that orbit the earth have their own limitations. The multispectral satellites such as Landsat and SPOT as well as high spatial resolution sensors such as IKONOS and QuickBird have broad spectral bands. These bands cover the visible, near and middle-infrared regions of the electromagnetic spectrum (Jakubauskas and Price, 1997). This greatly reduces the ability of the multispectral sensor to spectrally discriminate between two objects on the ground (Marmo, 1996). Multispecral sensors have been utilized for many purposes including regional mapping. Unlike the multispectral classifiers, hyperspectral classifiers are used to identify objects using spectral endmembers in spectral libraries. Many attempts have been made to classify hyperspectral data using the traditional multispectral classifiers. Another approach using hyperspectral data has been mapping of cover types based on their abundances by using spectral unmixing techniques (Adams *et al.*, 1986). Hyperspectral imagery can be considered as a single image dataset with a continuous spectrum of radiance (or reflectance) values associated with each image pixel (Bateson and Curtiss, 1996). Hyperspectral imagery can distinguish between slope and brightness variations and resolve absorption bands in the spectrum, which can allow one to identify surface material such as specific minerals or any material with absorption features (Clark *et al.*, 1992). Van Aardt and Wynne (2001) and YingZi (2004) reported successful use of hyperspectral remote sensing for spectral separability among six southern tree species with a new hyperspectral discrimination measure for spectral characterization for non-tropical forest conditions. However, Matthew *et al.* (2005) managed to discriminate tropical rain forest tree species at leaf to crown scales at the laboratory level. Similar studies at the operational field level in the tropical mixed hill and mountain forests of Malaysia have being carried out by Mohd Hasmadi et al. (2010); Kamaruzaman (2010); Kamaruzaman et al (2009); and Kamaruzaman (2009b). AVIRIS was the first airborne hyperspectral sensor to measure reflected solar radiation from 400nm to 2500 nm (Green *et al.,* 1998). Hyperspectral remote sensing can provide improved, consistent, and accurate measures of forests, which is crucial for producing forest inventory products of better quality (David *et al*., 2004). Therefore, the general objective of this study is to assess the capability and usefulness of an AISA airborne hyperspectral sensor in Pre-Felling forest inventory. The specific objectives are to identify, map and tag individual trees in Gunung Stong Forest Reserve, Kelantan to assist sustainable precision timber harvesting in Malaysia.

2. Methods and Materials

2.1 Description of the Study Area

The study was conducted in Gunung Stong Forest Reserve, Kelantan (Figure 1). It takes about five hour's car ride from Kuala Lumpur to Gunung Stong Forest Reserve. Total cover areas in Kuala Krai which is Gunung Stong was situated, are 222500 ha. The landcover of this area is hill land at the east, west and south while lowland at the

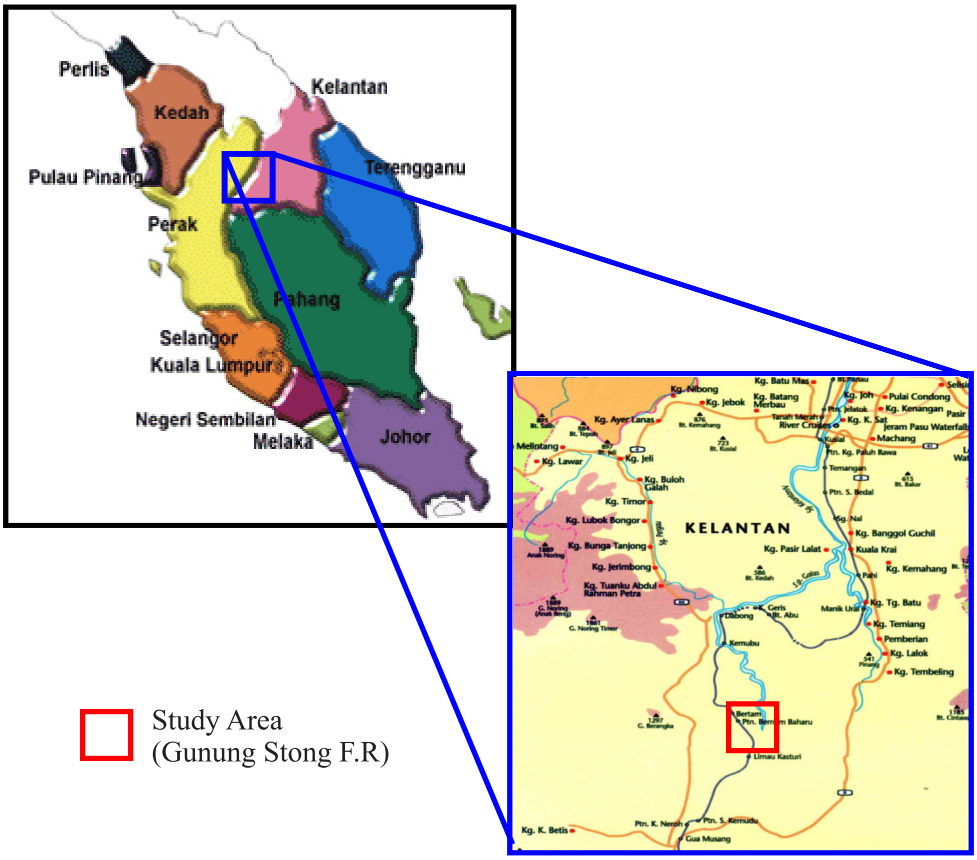


Figure 1. Map of Kelantan showing the location of study area

north area. The location of upland from sea level is about 153 m to 305 m. The annual rainfalls in Kuala Krai fluctuate from the lowest of 2.993 m to the highest of 4.002 m per year. Kuala Krai is generally warm throughout the year with temperatures ranging from 21° to 32°. The dominant species found in the study area belongs to the Dipterocarpacea family. Many interesting and beautiful places can be explored here such as the Pergau Hydro Electric Project and the highest waterfall in South East Asia, Gunung Stong waterfall (1,422 m) which is located at the Perdana Stong Hill Resort, Dabong Kuala Krai, Kelantan.

2.2 Data Acquisition and Image Pre-Processing

The flow chart of the airborne image processing for tree tagging is shown in Figure 2. The airborne hyperspectral data was first acquired using a Royal Malaysian Air Force (RMAF) Cessna C402B aircraft by flying a UPM-AISA imaging spectrometer. The image processing and analysis was done by a personal computer with Pentium III 450MHz, 384 SD RAM, 17 GB Hard Disk and 32 MB RAM Colour Display available at the Faculty of Forestry, Universiti Putra Malaysia after an automatic pre-processing was done on-board the aircraft. The Environment for Visualizing Images (ENVI) 4.0 system digital analysis and classification of the imagery ENVI is an all-in-one package providing easy-to-use, yet sophisticated tools for managing forests and habitat using remotely sensed images. Prior to data analysis, initial pre-processing on the raw data was carried out to correct for any distortion due to the characteristics

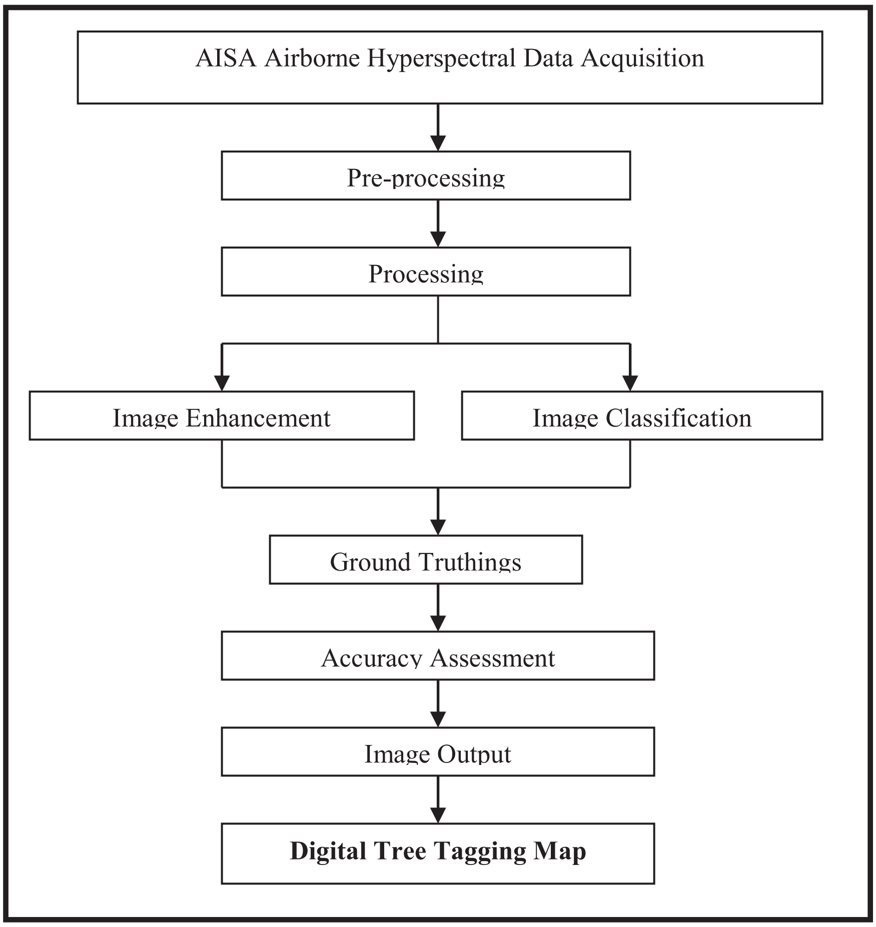


Figure 2. The flow chart methodology of the study

of the imaging system and to remove the sensor system detector error for any atmospheric influence on the radiance flux the sensor detects. These procedures include radiometric correction to correct for uneven sensor response over the whole image and geometric correction to correct for geometric distortion due to Earth's rotation and other imaging conditions (such as oblique viewing). The image was also transformed to conform to a specific map projection system. Ground control points (GCP's) were used to register the image to a precise map (geo-referencing). The image was also rectified for accuracy by which points in the image were registered to corresponding points on a map.

2.3 Advance Image Processing

In order to aid visual interpretation, visual appearance of the objects in the image can be improved by image enhancement techniques such as grey level stretching to improve the contrast and spatial filtering for enhancing the edges. The image was enhanced by a simple linear grey-level stretching. In this method, a level threshold value was chosen so that all pixel values below this threshold were mapped to zero. An upper threshold value is also chosen so that all pixel values above this threshold are mapped to 255. All other pixel values are linearly interpolated to lie between 0 and 255. The lower and upper thresholds were chosen to be values close to the minimum and maximum pixel values of the image. The individual trees were discriminated using special image classification algorithms with spectral features, i.e. the brightness and "color" information contained in each pixel. A supervised classification was used in the identification of individual tree species pixels or groups of pixels with similar spectral responses (spectral signatures) to incoming radiation due its generally known fact that it is more accurate then the unsupervised classification. The actual values associated with each pixel were analyzed mathematically using computer driven algorithms. These algorithms attempt to determine the uniqueness of classes and to cluster similar pixels and groups of pixels into classes. In this supervised classification, the spectral features of some known trees were extracted from the image as the "training areas". Every pixel in the whole image was then classified as belonging to one of the classes depending on how close its spectral features are to the spectral features of the training areas. Regions containing a material of interest within a scene were delineated graphically and stored for use in the supervised classification algorithm to identify other remaining tree species.

The resulting "tree tagging map" was later checked using ground truth information and field validation surveys. However, an unsupervised classification was also performed using the computer program where it automatically groups the individual tree species pixels in the image into separate clusters, depending on their spectral features. Each cluster was then assigned a tree species type. In this unsupervised classification, the computer was allowed to analyse all of the spectral signatures of all of the image's pixels and to determine their natural groupings, that is to say, to group the pixels on the basis of their similar spectral signatures in the spectral library. SAM was applied in the spectral classification process utilizing the n-dimension angle to match pixels to reference data. The angle between the spectra treated as vectors in n-space is the spectral angle (as illustrated in the diagram below). Using an algorithm, the spectral similarity of two (or more) tree species were calculated using the angle between the spectra, and the smallest angular difference is the correct tree species. A known field spectra using a handheld spectroradiometer were taken for the species that were not found in the archives. Both images (known and unknown) were treated as vectors and the angles between them were calculated as a measure of the individual tree discrimination. The radian used in this study was 0.5, which is the most suitable radian used to classify tree species in the forest (Kamaruzaman, 2007a).

2.4 Image Accuracy Assessment

Accuracy assessments determine the quality of the information derived from remotely sensed data. A quantitative assessment was attempted to identify and measure the airborne hyperspectral imaging-tree tagging based map error. In such assessment, the map data with reference or ground truth data (where ground truth data is assumed to be 100% correct) was compared. Both the location and classification accuracies were compared. The reference data or ground truth data was acquired before, during, and after the image acquisition. In order to estimate the timber volume of the tagged individual standing trees, a diameter tape was used to measure tree diameter at breast height which is 1.3 from the ground. A Suunto Clinometer was used to measure tree height. The tree height is measured by multiplying the distance during taking the reading with the tree degree from Suunto Clinometer reading. The measuring tape was used to measure tree crown diameter and tree distance to calculate tree height using Calculus from Suunto Clinometer reading. The ground truth information was also used for the basis of post-processing accuracy assessments and future timber volume estimation.

3. Results and Discussion

3.1 Image Processing and Ground Verifications

Selection of band combinations is one of the essential procedures for making enhanced colour composite airborne hyperspectral image most suitable for interpreting and mapping of individual tree species (Kamaruzaman, 2007a; 2007b). In this study, band 2, 23, 8 (RGB) with a linear stretch was found to be the best combination. It was used for further analysis in image classification since it provides a well enhanced colour composite image with respect to its vegetation cover. In this study, Sobel filter was found to be the most suitable filter to be applied to the airborne hyperspectral imagery especially for visual interpretation of the individual tree crowns identification on the image. Figure 3 illustrates the individual species classification formed using SAM analysis.

In ground verification, 15 species were identified and cross-checked in the study area located in Gunung Stong F.R, Kelantan (Table 1). Figure 4 shows the identification of one of the identified, mapped and tagged tree species by forest rangers. The species are Kelat (*Syzgium* spp), Keledang (*Artrocarpos* spp), Mengkulang (*Heritiera* spp), Tempinis (*Streblus elongatus*), Keranji (*Dialium* spp), Tulang Daing (*Callerya atropurea*), Meranti Sarang Punai (*Shorea parvifolia*), Kembang Semangkuk Jantung (*Scaphium macropodum*), Bintangor (*Calophyllum*

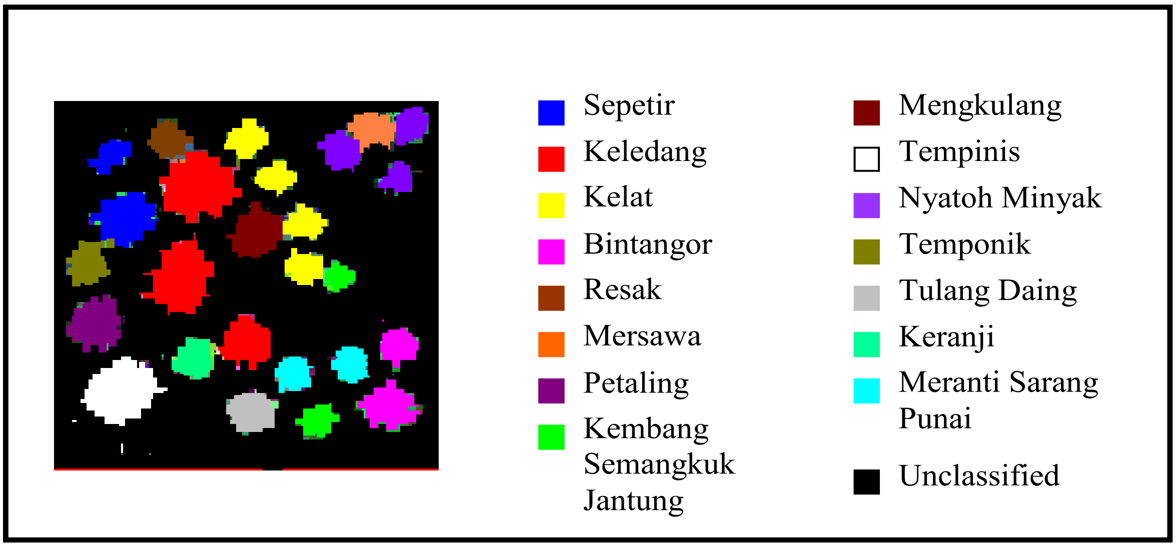


Figure 3. Individual species classification of the study area using SAM

spp), Nyatoh Minyak (*Sapotaceae* spp), Mersawa (*Anisoptera* spp), Resak (*Cotylelobium* spp), Sepetir (*Sindora* spp), Temponek (*Artocarpus rigidus*) and Petaling which were found scattered in the sample plot. Table 1 shows the result of the ground verification. There were 26 trees verified on the ground instead of 29 crown of trees in the image. The attribute information of trees in 1 ha sample plot at G. Stong F. R, Kelantan is shown in Table 2. The mapping accuracy of the study is 89.66% as calculated below:

$$\frac{26}{29} \times 100\% = 89.66\%$$

Table 1. Ground verification data

No. Tree	Local Name	Latitude	Longitude	Accuracy
1	Keledang	5º 20’ 34.33”	101º 58’ 19.42”	Confirm
2	Keledang	5º 20’ 35.71”	101º 58’ 17.68”	Confirm
3	Keledang	5º 20’ 34.99”	101º 58’ 18.91”	Confirm
4	Mengkulang	5º 20’ 36.16”	101º 58’ 17.36”	Confirm
5	Tempinis	5º 20’ 36.04”	101º 58’ 16.90”	Confirm
6	Keranji	5º 20’ 36.16”	101º 58’ 18.07”	Confirm
7	Tulang Daing	5º 20’ 35.83”	101º 58’ 19.37”	Confirm
8	Mt Sarang Punai	5º 20’ 33.62”	101º 58’ 18.71”	Confirm
9	Mt Sarang Punai	5º 20’ 33.81”	101º 58’ 19.23”	Confirm
10	Kembang Semangkuk Jantung	5º 20’ 35.83”	101º 58’ 18.33”	Confirm
11	Bintangor	5º 20’ 34.99”	101º 58’ 17.55”	Confirm
12	Bintangor	5º 20’ 35.06”	101º 58’ 16.77”	Confirm
13	Kelat	5º 20’ 34.40”	101º 58’ 18.06”	Confirm
14	Kelat	5º 20’ 34.21”	101º 58’ 18.97”	Confirm
15	Kembang Semangkuk Jantung	5º 20’ 35.52”	101º 58’ 17.03”	Confirm
16	Kelat	5º 20’ 34.08”	101º 58’ 18.38”	Confirm
17	Nyatoh Minyak	5º 20’ 34.34”	101º 58’ 17.54”	Confirm
18	Nyatoh Minyak	5º 20’ 35.44”	101º 58’ 18.59”	Confirm
19	Mersawa	5º 20’ 33.89”	101º 58’ 17.09”	Confirm
20	Nyatoh Minyak	5º 20’ 34.41”	101º 58’ 16.83”	Confirm
21	Resak	5º 20’ 35.83”	101º 58’ 18.91”	Confirm
22	Sepetir	5º 20’ 36.28”	101º 58’ 19.50”	Confirm
23	Sepetir	5º 20’ 35.31”	101º 58’ 18.13”	Confirm
24	Temponik	5º 20’ 35.05”	101º 58’ 18.52”	Confirm
25	Petaling	5º 20’ 36.22”	101º 58’ 19.11”	Confirm
26	Kelat	5º 20’ 33.88”	101º 58’ 18.06”	Confirm
27	-	5º 20’ 34.41”	101º 58’ 17.09”	Unfound
28	-	5º 20’ 34.73”	101º 58’ 18.00”	Unfound
29	-	5º 20’ 35.37”	101º 58’ 19.36”	Unfound

Figure 4. Identification of tree species by a qualified and experienced forest ranger before tagging being done

Table 2. Attribute information of trees in 1 ha sample plot at G. Stong F. R, Kelantan

No. Tree	Latitude	Longitude	Local Name	Scientific Name	DBH (cm)	Crown Average (m)	Crown Area (m^2)
1	5 20 34.33	101 58 19.42	Keledang	*Artrocarpos lanceifolius*	101.56	18.5	268.8
2	5 20 35.71	101 58 17.68	Keledang	*Artocarpus lanceifolius*	62.7	10.7	89.9
3	5 20 34.99	101 58 18.91	Mersawa	*Artocarpus lanceifolius*	47.1	9.3	67.9
4	5 20 36.16	101 58 17.36	Mengkulang	*Heritiera spp*	74.4	12.9	130.7
5	5 20 36.04	101 58 16.9	Tempinis	*Streblus elongatus*	51.6	7.7	46.6
6	5 20 36.16	101 58 18.07	Keranji	*Dialium spp*	82.4	13.7	147.4
7	5 20 35.83	101 58 19.37	Tulang Daing	*Callerya atropurea*	48.7	8.8	60.8
8	5 20 33.62	101 58 18.71	Mt Sarang Punai	*Shorea parvifolia*	62	12.2	116.9
9	5 20 33.81	101 58 19.23	Mt Sarang Punai	*Shorea parvifolia*	58	6.5	33.2
10	5 20 35.83	101 58 18.33	Kembang Semangkuk Jantung	*Scaphium macropodum*	50.5	7.5	44.2
11	5 20 34.99	101 58 17.55	Bintangor	*Calophyllum spp*	51.8	12.5	122.7
12	5 20 35.06	101 58 16.77	Bintangor	*Calophyllum spp*	40.3	10.6	88.2
13	5 20 34.40	101 58 18.06	Kelat	*Syzgium spp*	44.1	11.3	100.3
14	5 20 34.21	101 58 18.97	Kelat	*Syzgium spp*	45.7	8.6	58.1
15	5 20 35.52	101 58 17.03	Kembang Semangkuk Jantung	*Scaphium macropodum*	50.2	8.5	56.7
16	5 20 34.08	101 58 18.38	Kelat	*Syzgium spp*	42.8	9.7	73.9
17	5 20 34.34	101 58 17.54	Nyatoh Minyak	*Sapotaceae SPP*	48.8	8.7	59.4
18	5 20 35.44	101 58 18.59	Nyatoh Minyak	*Sapotaceae SPP*	58.3	11.4	102.1
19	5 20 33.89	101 58 17.09	Mersawa	*Anisoptera spp*	78.5	16.8	221.7
20	5 20 34.41	101 58 16.83	Nyatoh Minyak	*Sapotaceae SPP*	44	9.5	70.9
21	5 20 35.83	101 58 18.91	Resak	*Cotylelobium spp*	37.4	8.7	59.4
22	5 20 36.28	101 58 19.5	Sepetir	*Sindora spp*	73.6	12.4	120.8
23	5 20 35.31	101 58 18.13	Sepetir	*Sindora spp*	37.9	9.8	75.4
24	5 20 35.05	101 58 18.52	Temponik	*Artocarpus rigidus*	46.1	10.4	84.9
25	5 20 36.22	101 58 19.11	Petaling	*Ochanostachys amentacea*	72.7	14.5	165.1
26	5 20 33.88	101 58 18.06	Kelat	*Syzgium spp*	98	15.7	193.6

3.2 Spectral Reflectance of Tree Species

Image spectral signature of tree species in the study area was selected randomly from the image. Image spectra were established after confirming the appropriate match between field/laboratory spectra and pixel spectra (Kamaruzaman and Kasawani, 2007). This step was done to confirm the tree species classes that have been mapped out for each of the 26 trees. First-order derivatives have been shown to improve tree species classifications over the use of reflectance spectra (Kamaruzaman, 2007a). Figures 5a-5c illustrates how that the spectral reflectance of tree species found in the image were unique to the individual species identified. Figure 6 shows the individual trees tagged besides their unique spectral signatures developed from the image spectra. Kamaruzaman (2007a) found that leaf spectral variability among tropical mixed dipterocarp forest tree species was significantly greater than that within species.

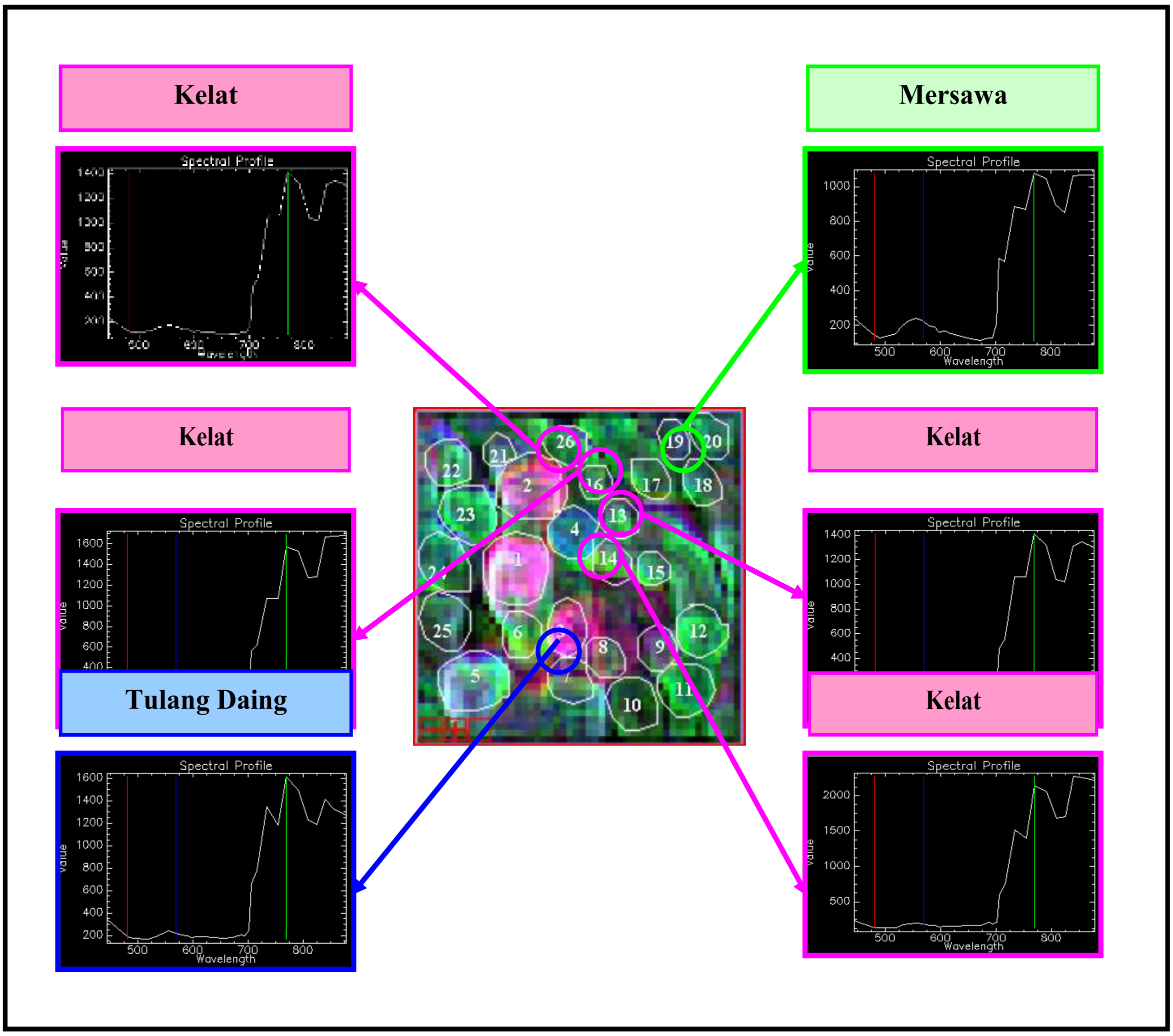


Figure 5a. Spectral signatures of Kelat, Tulang Daing and Mersawa

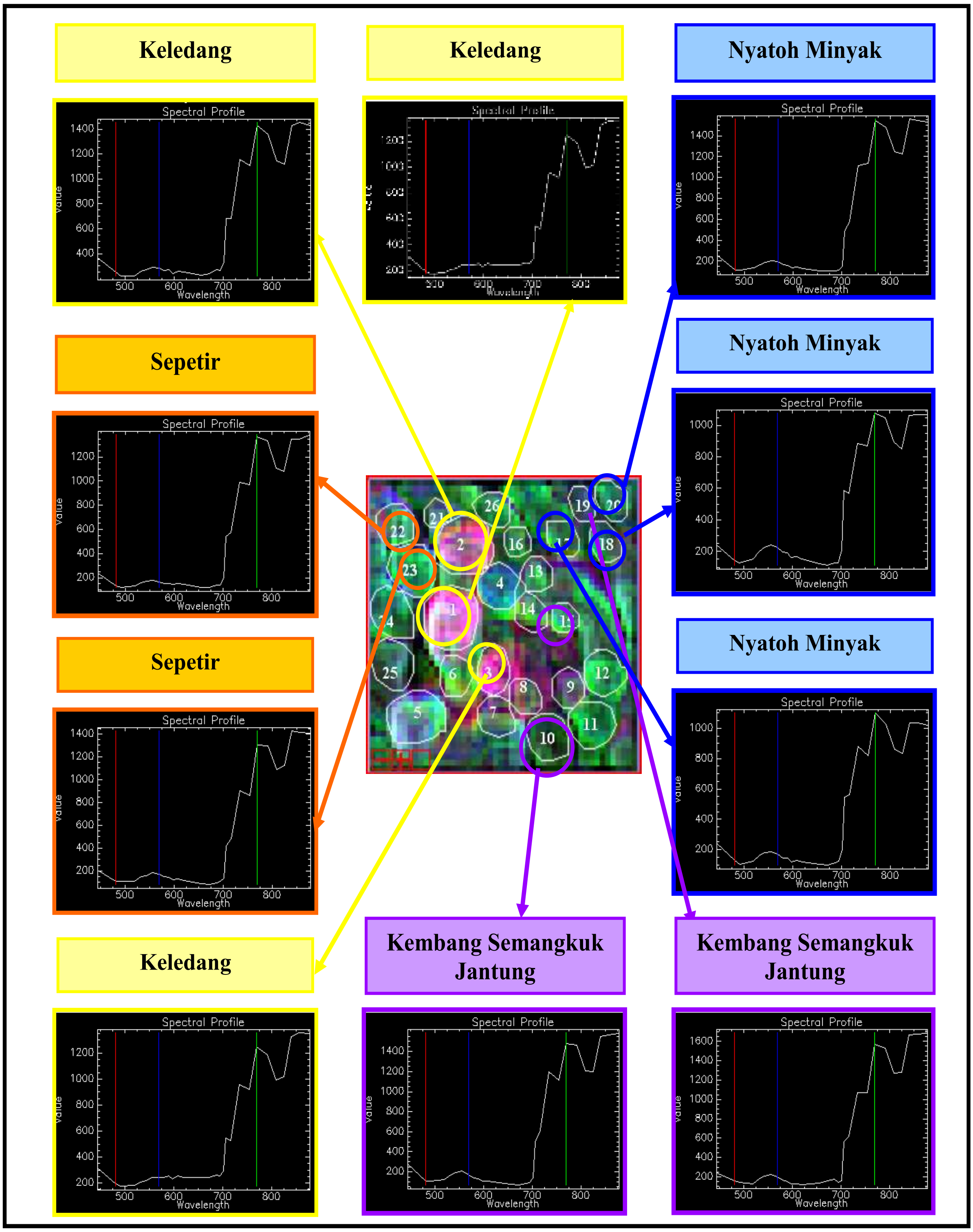


Figure 5b. Spectral signatures of Keledang, Kembang Semangkuk Jantung, Nyatuh Minyak and Sepetir

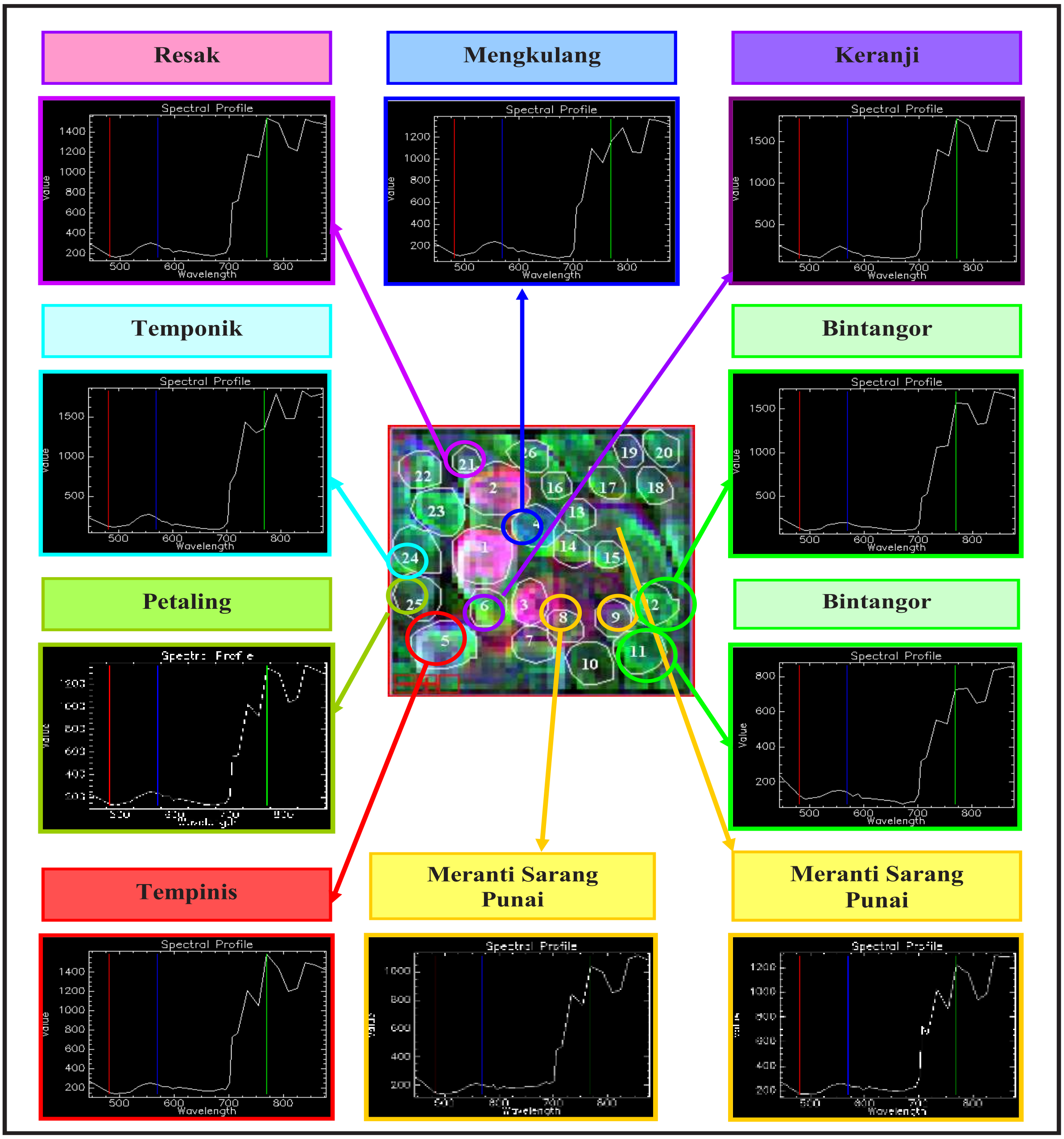
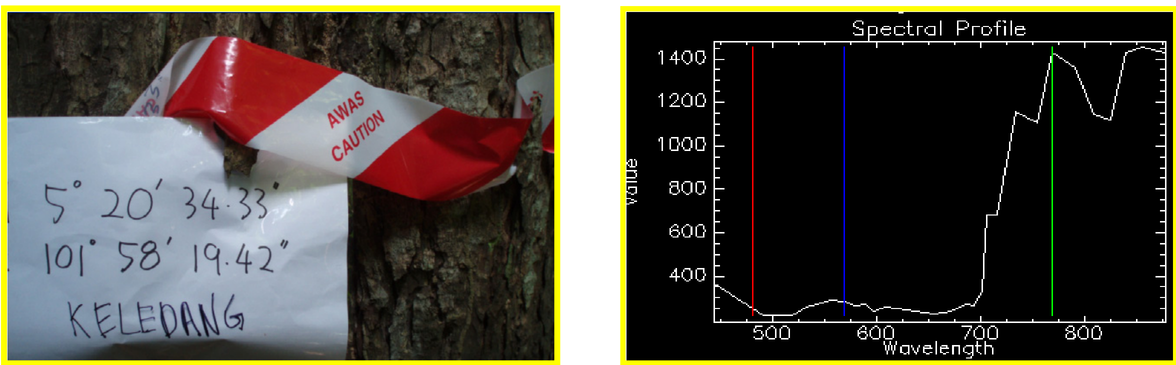
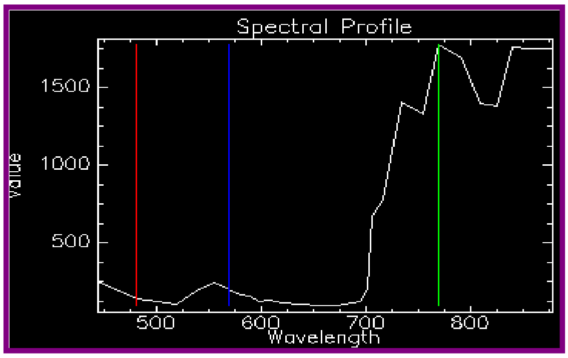


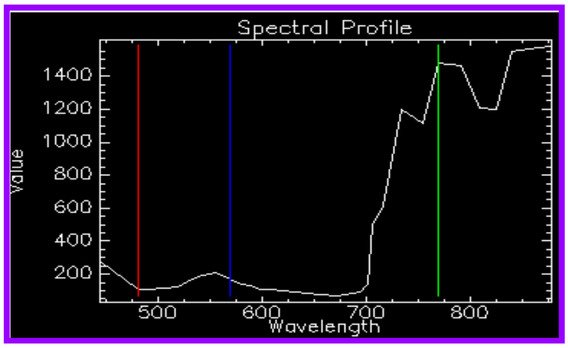
Figure 5c. Spectral signatures of Keranji, Mengkulang, Tempinis, Meranti Sarang Punai, Bintangor, Petaling, Temponik and Resak



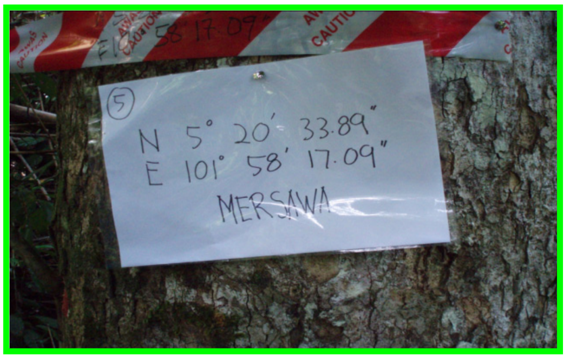
Tree No.1: N 50 20 34.33 E 1010 58 19.42 (Keledang)

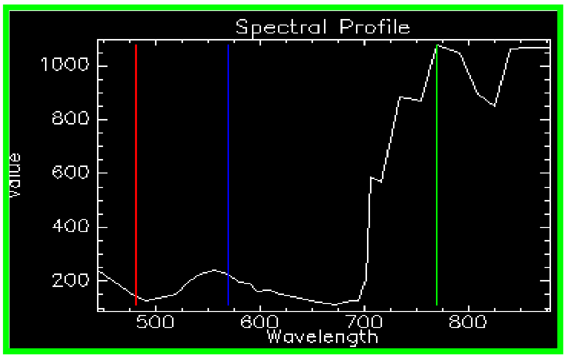


Tree No.6: N 50 20 36.16   E 1010 58 18.07 (Keranji)

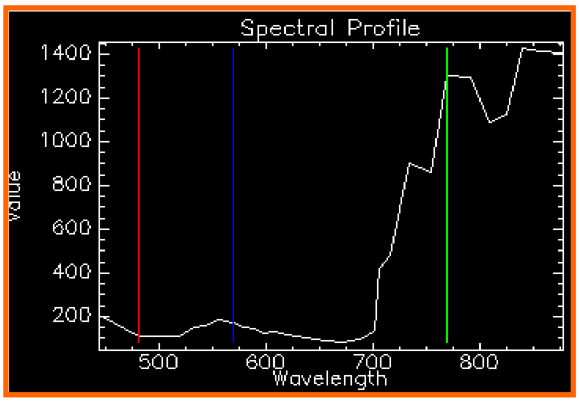


Tree No.10: N 50 20 35.83   E 1010 58 18.33 (Kembang Semangkuk)

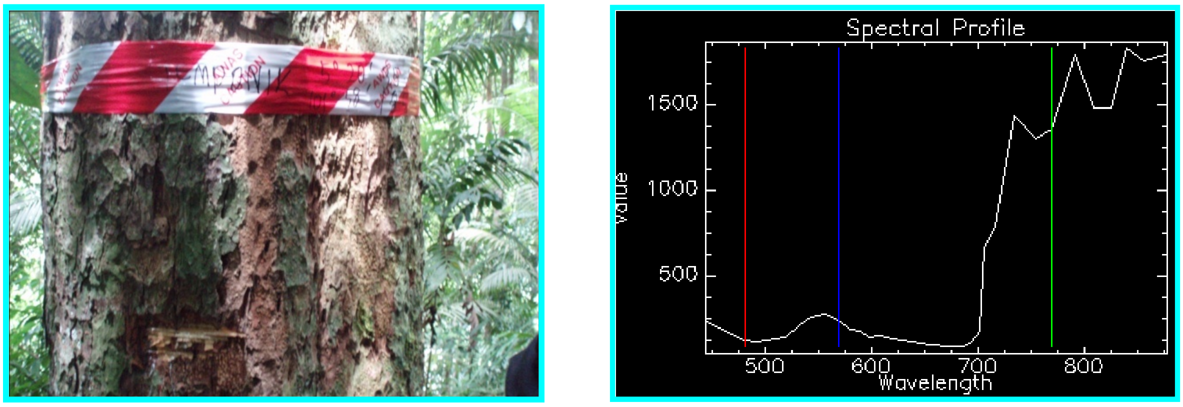




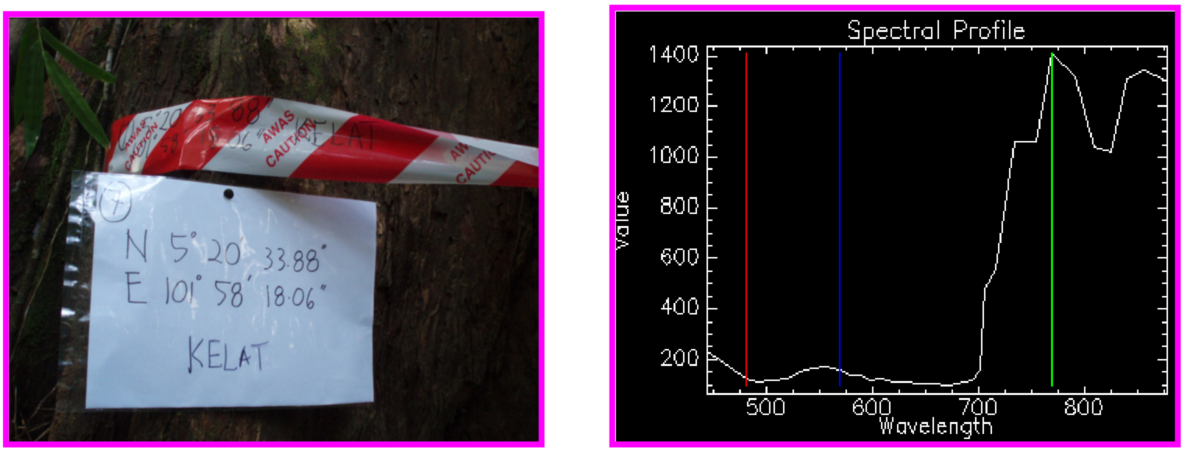
Tree No. 19: N0 5 20 33.89   E 1010 58 17.09 (Mersawa)



Tree No.23: N 50 20 35.31   E 1010 58 18.13 (Sepetir)



Tree No. 24: N 50 20 35.05   E 1010 58 18.52 (Temponek)



Tree No. 26: N 50 20 33.88   E 1010 58 18.06 (Kelat)

Figure 6. Ground verification photographs for 10 of the 26 tagged trees identified at species level with their unique spectral signatures

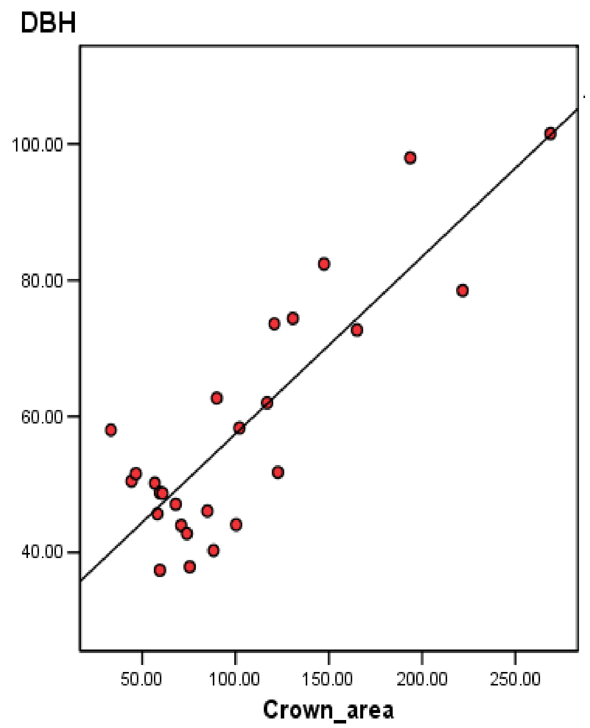


Figure 7. Measured DBH versus crown area of 26 trees in 1 ha sample plot

3.3 Relationship between DBH and Crown Area

The regression fit in this study shows a rather good correlation between field diameter at breast height (dbh) and crown area (Figure 7). Basal area and crown of a tree have good correlation with growing space and ground coverage of individual trees in the forest (Azuan, 2005). According to Dawkins (1963), the relationship between the crown diameter and DBH is an importance indicator in tree growth. A good correlation (r^2=0.72) is attained due to the small number of trees in the study plot (Gering and May, 1995).

3.4 Digital Tree Tagging Map

Finally, the digital tree tagging map for the study plot in Gunung Stong F.R is produced (Figure 8). This digital map can be used to precisely locate the trees for a sustainable precision forest harvesting. With an airborne hyperspectral data, it can be used to gather the accurate tree information in the hill and mountain mixed hill dipterocarp forest for future decision in management, development and utilization of sustainable forest resource.

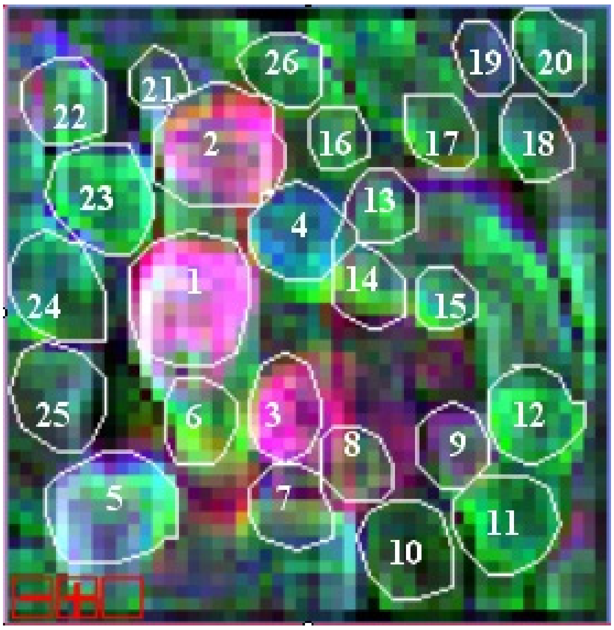


Figure 8. Digital tree tagging map of a 1 ha plot in Gunung Stong F.R.

4. Conclusion

It can be concluded that an AISA airborne hyperspectral data is capable of mapping individual tree species in Gunung Stong F.R, Kelantan. A total of 15 tree species were identified and tagged, namely Kelat (*Syzgium* spp), Keledang (*Artrocarpos* spp), Mengkulang (*Heritiera* spp), Tempinis (*Streblus elongatus*), Keranji (*Dialium* spp), Tulang Daing (*Callerya atropurea*), Meranti Sarang Punai (*Shorea parvifolia*), Kembang Semangkuk Jantung (*Scaphium macropodum*), Bintangor (*Calophyllum* spp), Nyatoh Minyak (*Sapotaceae* spp), Mersawa (*Anisoptera* spp), Resak (*Cotylelobium* spp), Sepetir (*Sindora* spp), Temponek (*Artocarpus rigidus*) and Petaling (*Ochanostachys amentacea*) with a mapping accuracy of 89.66%. This study implies that airborne hyperspectral imaging is a useful tool to be operationally tested and validated for the National Forest Inventory. It is recommended that future research should focus on identifying and differentiating trees species of commercial interest using higher spatial resolution (below 1m) for better classification accuracy. More numbers of samples need to be taken in the field to improve the accuracy of estimating future crown size-timber volume correlation for a sustainable and environmentally sound harvesting practice.

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