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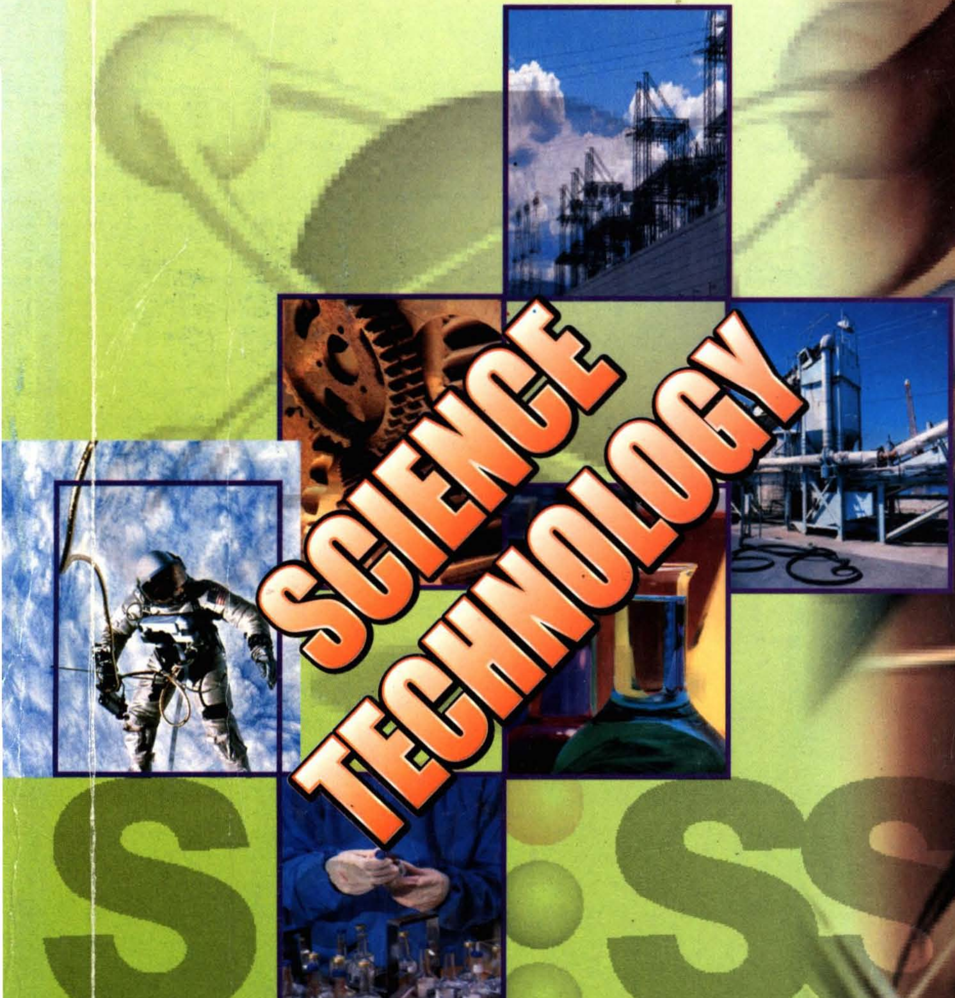

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UPM-APSB's AISA Hyperspectral Imaging for Individual Mangrove Species Mapping in Port Klang

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ABSTRACT

Every natural and synthetic object on the earth's surface and near surface reflects and emits electromagnetic radiation (EMR) over a range of wavelengths in its own characteristic way according to its chemical composition and physical state. With a narrow contiguous 288 maximum bands ranging from visible (VIS) to near infra-red (NIR) wavelength region available on hyperspectral sensors, a particular object/feature or condition often exhibits a diagnostic spectral response pattern that differs from other objects. The objectives of this study are therefore to assess the capability of AISA airborne hyperspectral imaging for individual mangrove species mapping and to determine the wavelength regions that define the inherent spectral characteristics amongst mangrove species. A total of nine groups of mangrove species spectral separability from 19 selected mangrove trees were identified in Port Klang, Selangor namely, Rhizophora mucronata, Rhizophora stylosa, Sonneratia alba, Avicennia officials, Rhizophora apiculata, Bruguiera parviflora, Bruguiera gymnorhiza, Bruguiera cylindrical and Sonneratia caseolaris. The nine groups of individual mangrove species were easily identified and separated in the NIR range (700 nm to 900 nm) with the following spectral values namely (a) 1,750-6,000:Bruguiera cylindrical, (b) 2,000-7,750: Bruguiera gymnorhiza, (c) 1,875-8,250: Bruguiera parviflora, (d) 1,875-5,500 :Avicennia officials, (e) 1,625-6,250 :Sonneratia caseolaris, (f) 1,875-5,250: Sonneratia alba, (g) 1,750-7,500: Rhizophora apiculata, (h) 2,000-8,000: Rhizophora stylosa, (i) 2,200-7,000: Rhizophora mucronata. The results of this study indicated that the mangrove species under study could only be identified at the near infrared (NIR) wavelength (700 nm to 900 nm) and not in the visible (VIS) spectrum.

Keywords: *airborne, hyperspectral sensing, mangrove, mapping*

Introduction

Remote sensing provides a means of quickly identifying and delineating various forest types, a task that would be difficult and time consuming using traditional ground surveys (Kamaruzaman 2005). Hyperspectral images from an airborne hyperspectral sensor possess a much higher resolution and therefore give considerably more information, allowing a more detailed study of the local vegetation and floristic characteristics.

Spectral features of vegetation are closely related to physical properties of leaves and stems of trees. Those features give strong spectral reflectance and absorption in VNIR and SWIR regions. Some researchers have reported the possibilities of mangrove mapping by using those spectral features derived from satellite data (Kotera et al. 1997 and Blasco et. al. 1998). NDVI values were examined to separate vegetative areas from barren areas. Satellite imagery has been used to map and assess vast coastal areas such as mangroves (Aschbacher et al. 1995; Ravan and Roy, 1997; Ramachandran et al. 1998). However, the coarse resolution of these data sources rarely allows identification at the species or generic level, or the typology of assemblages necessary to detect changes within a mangrove forest (Holmgren and Thuresson 1998).

In mangrove forests, the early detection of changes on a species or generic level can be extremely important for the ecosystem, for associated ecosystems and for the human population that depends in many ways on the mangrove. Mangroves forest, for instance, as a living dyke against the effects of Tsunami and the tides along many tropical coasts. The disappearance of mangroves has direct consequences for associated ecosystems such as seagrass beds and coral reefs that will be affected by the process of sedimentation of suspended material in river deltas displaced from the mangroves to their vicinity. Local people depend on the mangrove as a resource for wood, and more important for food, since mangroves act as breeding, spawning, hatching and nursing grounds for many commercial and non-commercial marine animal species (Ronnback 1999). Mangrove forests have been studied worldwide and at present, considerable research effort is put into the assessment of the state of mangroves on a large scale (Spalding et al. 1997; Dahdouh-Guebas 2001 and Kairo 2001). This includes the study of mangrove dynamics in time and space, the increase or decrease in its areal extent, changes in species richness; and regeneration capacity (Dahdouh-Guebas et al. 2000). The understanding of mangrove dynamics can lead to conservation and management directives, such as the establishment, protection and management of reforestations plots in the framework of regeneration and/or restoration projects, as described by Lee et al. (1996).

The general objective of this study is therefore to assess the capability of UPM-APSB's AISA airborne hyperspectral imaging for individual mangrove species mapping using UPM-APSB'S AISA hyperspectral sensor in Port Klang, Selangor. The specific objectives of this study are two-folds, namely to identify species group of mangrove and to identify the wavelength regions that defines the inherent spectral curve between each mangrove species.

Methodology

Description of Study Area

Port Klang mangrove forest is located in Klang River and Northport of Klang (Figure 1). The geographical position of Port Klang mangrove forest is located at latitudes 2°59'24" N-2°59'12" N and longitudes 101°22'36" E-101°23'12" E. The study area comprises of four major families of mangrove species (Avicenniaceae, Rhizophoraceae, Bruguiera and Sonneratiaceae). A total of 19 samples of mangrove trees were randomly selected for this study.

The mangrove species that were randomly selected in the area includes *Rhizophora mucronata* (Bakau Kurap), *Rhizophora stylosa* (Bakau), *Rhizophora apiculata* (Bakau Minyak). *Bruguiera parviflora* (Lenggadai), *Bruguiera gymnorhiza* (Tumu), *Bruguiera cylindrical* (Bakau Putih), *Sonneratia caseolaris* (Berembang), *Sonneratia alba* (Perepat), and *Avicennia officials* (Api-api Ludat).

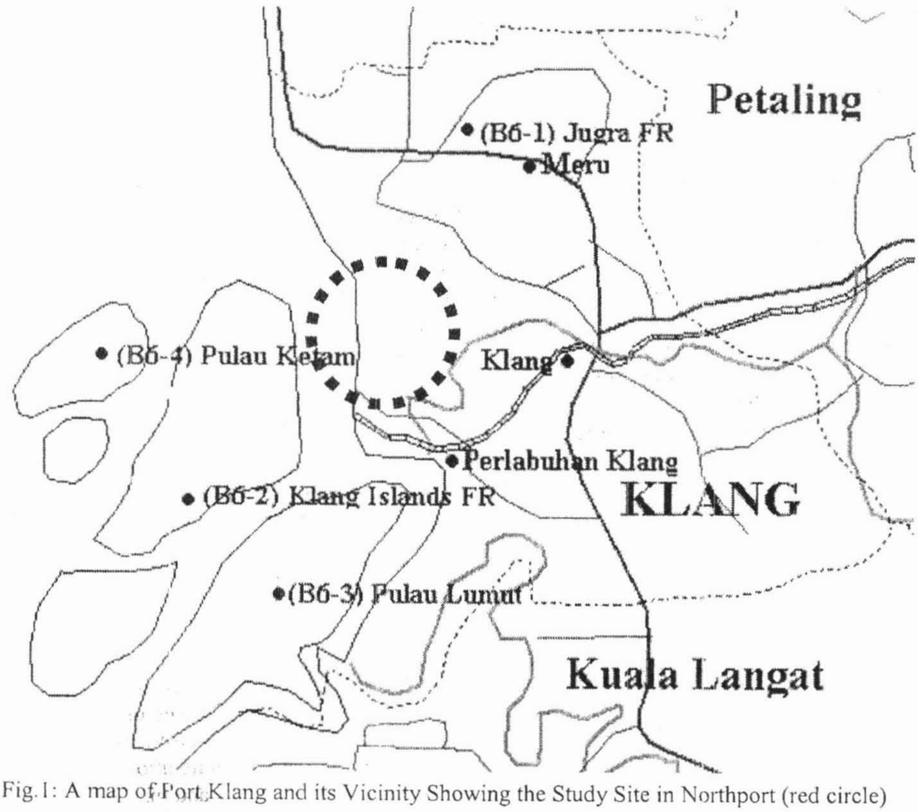


Fig.1: A map of Port Klang and its Vicinity Showing the Study Site in Northport (red circle)

Instrumentation

Global Positioning System (GPS)
The necessity of geographical referenced data involves a positioning system which gives (x, y) coordinates of the field specific data at the time they are collected. Using a Global Positioning System (GPS) model 76s, locations were noted in geographic coordinates such as latitude/longitude in degree, minutes and seconds (Figure 2). According to the system configuration, a positioning accuracy was obtained from 1-100 mm, with an exponential relation between the price and the accuracy.

UPM-APSB'S AISA Airborne Hyperspectral System Description
UPM-APSB's AISA is a state-of-the-art aircraft mounted commercial hyperspectral sensor manufactured in Oulu, Finland and operated by Forest Geospatial Information & Survey Lab (FGISL)/Aeroscan Precision (M) Sdn Bhd. in

Lebuh Silikon, Universiti Putra Malaysia (Figure 3). It is designed to provide real time, frequent, repetitive, accurate and reliable pushbroom instrument that acquire images in hundreds of registered, contiguous narrow spectral bandpasses such that for each element it is possible to derive a complete reflectance spectrum. UPM-APSB's AISA sensor is a complete system that consists of a compact hyperspectral sensor head, miniature GPS/INS sensor for precise positioning, data acquisition unit and Caligeo post-processing software.

Fig. 2: A Garmin GPS used in Ground Measurement

This small portable instrument, with a total weight of only 15 kg can be mounted on an aluminium metal plate that is compatible with a standard aerial camera mount, available in any fixed wing aircraft such as that of a Short SkyVan SC7 (Kamaruzaman 2004a, 2004b and 2004c). Swath width is 360 pixels and field of view (FOV) in cross track direction 20^0 which makes ground resolution from 1 km altitude approximately 1 m at a flight speed of 120 knots (60 m/s). In addition, 20 pixels per swath for downwelling irradiance were acquired via a fiber optic irradiance sensor (FODIS). Accurate position information, necessary for image rectification is measured with Systron C-MIGITS II integrated GPS/INS unit, which includes 3-axial inertial measurement unit based on solid-state gyros, GPS receiver and real time Kalman filter. The effect of the aircraft such as the lateral roll is monitored using data from an onboard gyroscope. The advantage of UPM-APSB's AISA over other hyperspectral instruments is the flexibility in selecting the sensor's spatial and spectral resolution characteristics. Reflected light from the target below the aircraft is transmitted through a sensor lens and directed to a prism-grating-prism optical system, which splits the light into its component wavelength spectra. The refractive properties of the two opposing prisms allow for a linear projection of light onto the CCD array. The two dimensional array consists of a spatial axis of 364 detectors, and a spectral axis of 288 detectors. UPM-APSB's AISA is capable of collecting data within a spectral range of 430 to 900 nm and up to 288 spectral channels within this range. Current operational collection configurations range from 10 to 70 spectral bands depending on the aircraft speed, altitude and mission goals.

Methods

Acquisition of UPM-APSB's AISA Data

Data for hyperspectral image were collected by Forest Geospatial Information & Survey Lab (FGISL)/APSB from 18-19 February 2004. The AISA hyperspectral data presented here was only from five flight lines of the total 20 flight lines collected during the UPM-APSB airborne hyperspectral sensor mission calibration.

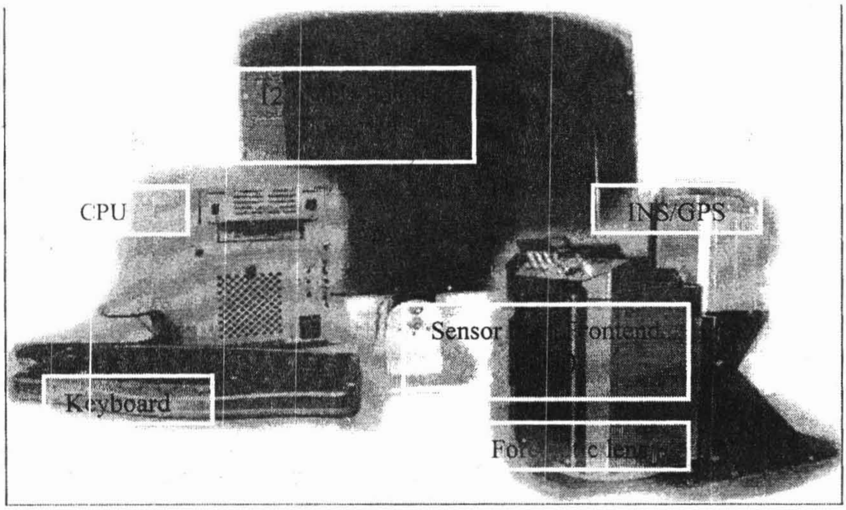


Fig. 3: A Complete UPM-APSB's AISA Airborne Hyperspectral Sensor System Mounted onboard a SkyVan SC-7

Data Pre-Processing and Image Analysis

The UPM-APSB's AISA spectrometer was configured to measure 20 spectral bands/channels. The data was first pre-processed by a Caligeo software (a plug-in of the latest Environment for Visualizing Images {ENVI}) version 4.0 for calibrated, rectified and georeferenced hyperspectral images after performing the atmospheric and geometric corrections. Only two ground control points (GCP's) were required for the georeferencing process with IKONOS and/or SPOT 5 data. The data were later subjected to a minimum noise fraction transform, pixel purity index, n-dimension visualizer, identification, spectral angle mapper (SAM) and mixture tuned matched filtering processing before getting the final output. The turn around time was 24 hours from collected data during airborne to visualized information since a short-turn around time is required to keep data processing costs down and to achieve the maximum end user satisfaction.

Results and Discussions

Spectral Reflectance of Mangrove Species

The spectral libraries for the 19 randomly selected mangrove species were developed both from the field spectro-radiometer (Figure 4) and the image data (Figure 5). From the 19 samples that were randomly selected, a total of nine individual mangrove species was easily identified, classified and mapped (Figure 4). Within the VIS light region (400-680 nm), the spectral profiles for the nine species showed only subtle differences in their spectral profiles and wavelength absorption because each mangrove species emitted or radiated varying VIS and NIR light at different wavelength.. Only three groups of mangrove categories can be classified and mapped as shown in Figure 4. Figure 4 also shows that the wavelength range between 450-700 nm absorbed sunlight below 3,000 and all emittance in this range did not show much different from each other. In the wavelength range of 700-900 nm, the spectral values tend to increase from 1,750 to nearly 8,500. The spectral profiles of 19 selected trees were separable within this wavelength range because the intensity of solar energy reflected by the mangrove species is dependent on the chlorophyll's ability to absorb the red and blue energy and the spongy layer to reflect the NIR energy. Perhaps, this is the reason why multispectral based satellites do not have such capability to identify individual mangrove species in a mangrove forest.

Spectral Separability of Individual Mangrove Species

Based on the AeroMAP™ products in Figure 5, the following species were identified based on four different distinct colours:

- Yellow coloured canopy were represented by Bruguiera species. *Bruguiera gymnorhyza* species were represented by intermediate yellow with a single canopy. *Bruguiera cylindrical* species were represented by light yellow while *Bruguiera parviflora* species were represented dark yellow.
- Rhizophora species were represented by the orange colour of the canopy. *Rhizophora apiculata* species were represented by intermediate orange, *Rhizophora stylosa* species by light orange while *Rhizophora mucronata* species by dark orange.
- Green colour representing of Sonneratia species. Dark green were *Sonneratia alba* and light green were *Sonneratia caseolaris*.
- Avicennia species were represented by red coloured canopies with Avicennia *officials* in dark red.

The image spectral profiles of individual mangrove species were developed from the measurement tools in ENVI software. Each different colours of canopy showed different spectral profiles at varying wavelengths and spectral reflectance values. Figure 5 shows that all the above four distinct coloured canopies representing Avicennia, Rhizophora, Bruguiera and Sonneratia within 700-900 nm wavelengths NIR region of the spectrum, were easily separable from each other.

Fig. 4: Spectral Profiles of Nine Mangrove Trees Species Obtained from a Handheld Spectro-Radiometer

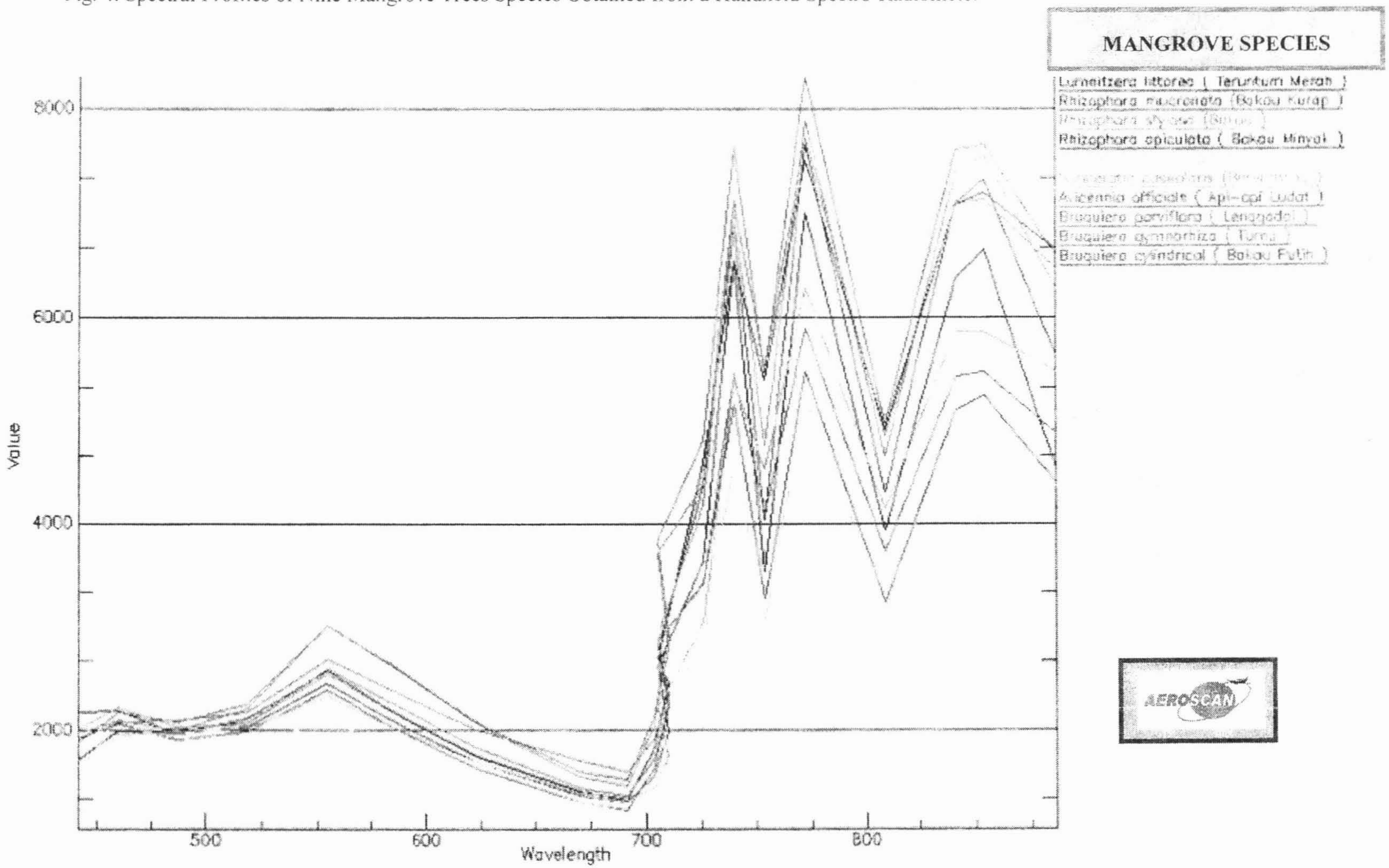
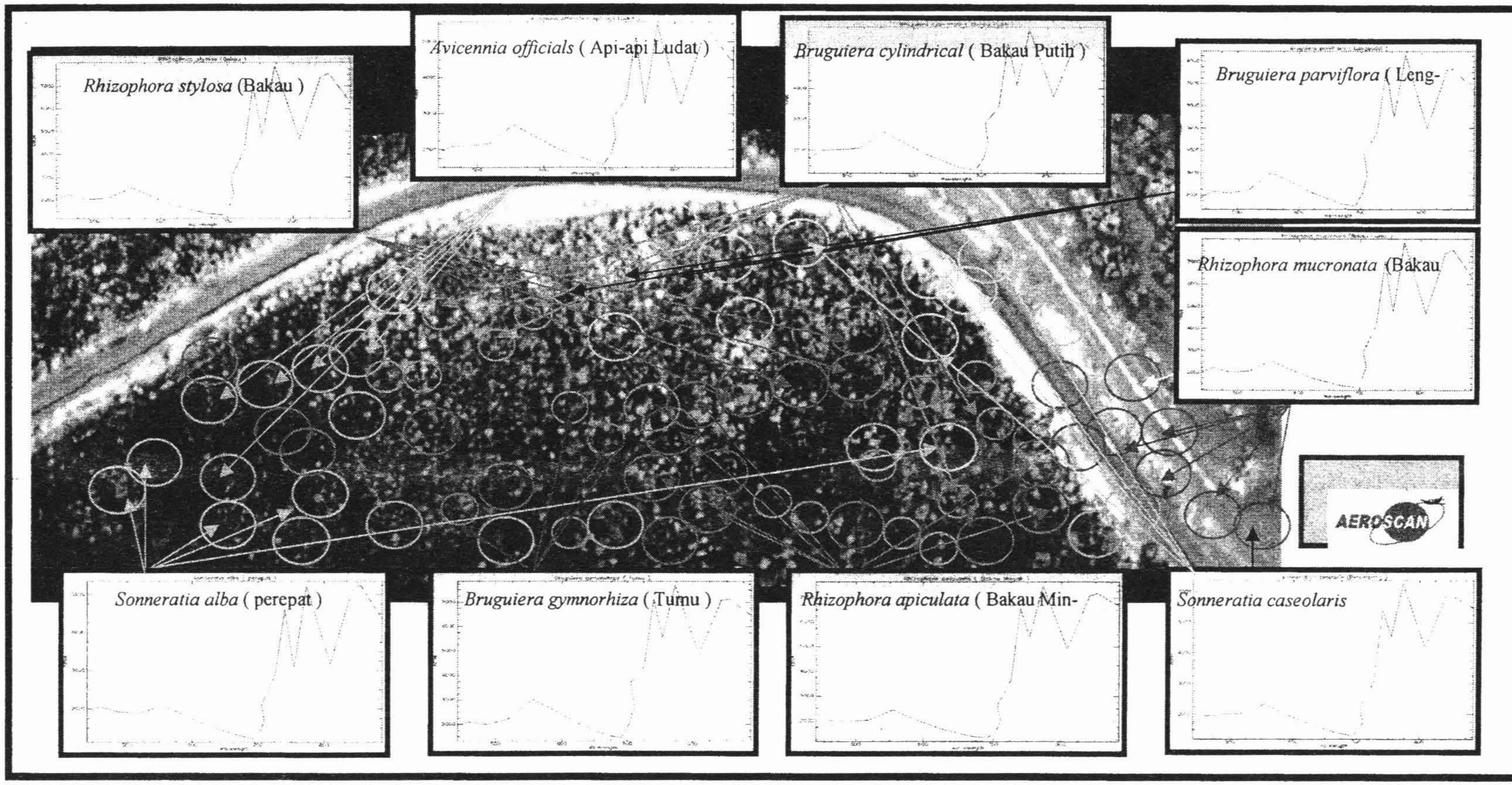


Fig. 5: Image Spectral of Individual Mangrove Species in Port Klang using UPM-APSB's AISA Hyperspectral Sensor



Conclusions and Recommendations

Based on the results of this study, the following conclusions can be derived as follows:

1. AeroMAP™ products derived from UPM-APSB's AISA airborne hyperspectral imaging is capable of developing a spectral library for four main families and nine groups of species., namely (1) Family Rhizophora: *Rhizophora mucronata* (Bakau Kurap), *Rhizophora stylosa* (Bakau), *Rhizophora apiculata* (Bakau Minyak), (2) Family Bruguiera: *Bruguiera parviflora* (Lenggadai), *Bruguiera gymnorhiza* (Tumu), *Bruguiera cylindrical* (Bakau Putih), (3) Family Sonneratia: *Sonneratia caseolaris* (Berembang), *Sonneratia alba* (Perepat) and (4) Family Avicennia: *Avicennia officials* (Api-api Ludat).
2. Spectral reflectance curves of nine mangrove trees species can be separated at the NIR range covering from 450 nm to 900 nm wavelengths with a value of 1,625-8,250 nm.
3. A total of nine groups of species that were recognized with the values of 700 to 900 nm wavelength, namely 1,750-6,000 nm (*Bruguiera cylindrical*), 2,000-7,750 nm (*Bruguiera gymnorhiza*), 1,875-8,250 nm (*Bruguiera parviflora),* 1,875-5,500 nm (*Avicennia officials),* 1,625-6,250 nm (*Sonneratia caseolaris),* 1,875-5,250 nm (*Sonneratia alba),* 1,750-7,500 nm (*Rhizophora apiculata),* 2,200-7,000 nm (*Rhizophora stylosa), and* 1,875-7,750 nm (*Rhizophora mucronata)*

Several recommendations that can be derived from this study are as follows:

1. Future studies may be extended to inventorize and determine the timber volume of the standing mangroves. This information is useful for a future Mangrove Pre-F Inventory Programme.
2. For an effective mangrove monitoring and management system for conservation and sustainable development, State Forestry Department should embark on an airborne hyperspectral sensing to precisely map individual mangrove trees their respective states for sustainable development and conservation programme.
3. A higher spatial resolution airborne imagery (below 1m) may provide the ability to classify individual mangrove stands more accurately within a mangrove forest. Long term mangrove forestry management and record keeping might be simplified when such data is inputted into a GIS database since AeroMAP™ data is a "ready-made" GIS input data for future mangrove management.

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