Mapping Bamboo in Berangkat Forest Reserve, Kelantan, Malaysia using Airborne Hyperspectral Imaging Sensor

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***Abstract*—**Bamboo mapping in the forest is neglected by the public and there are only a few research conducted regarding bamboo. Thus, an assessment of the distribution of bamboo resources is necessary for the utilization of bamboo and aid in the development of bamboo product manufacturing. Bamboo is ranked second to rattan in economic importance in Peninsular Malaysia. The general objective of this study is to assess the capability of UPM-APSB's AISA airborne hyperspectral imaging sensor for bamboo mapping in the forest while the specific objectives are to identify, quantify and map out the distribution of natural bamboo growing areas in Berangkat F.R, Kelantan. A False Colour Composite (FCC) image the study area was used in the study. Sobel filtering was used to enhance the image. Spectral Angle Mapper (SAM) was then used to classify the bamboo species among other vegetative species within the Berangkat F.R. A thematic map of bamboo distribution was produced and the bamboo species was identified as Gigantochloa scortechnii. The areal extent of bamboo acreage in the study area was 2.12 ha. With an estimated bamboo culms of 4 009 at a mapping accuracy of 60%. Bamboo mapping using UPM-APSB's AISA airborne hyperspectral sensing has a great potential and should be integrated with a GIS-based decision support system to support future decision making, development and utilization of bamboo by Kompleks Perkayuan Kelantan management.

Keywords—Mapping, Quantification, Airborne, Hyperspectral sensing, Spectral signature

I. Introduction

P. Malaysia is a fairy rich source of bamboo, which is currently being extracted from the natural forest. Bamboo is common from sea level up to 1 000 m. It occurs in significant quantities in disturbed areas such as logged - over forests, wasteland or in marginal localities fringing the forest, river banks and hill slopes. Bamboos are growing well on slope (20°-30°). It grows in pure stands or with other tree species in the forest. Climate, topography and soil also affect the growth and distribution of bamboos. It does not favor water-logged conditions and is seldom found in swampy areas. Bamboo is commonly cultivated in the rural areas for daily use by local communities and in urban areas as ornamental plants [1].

In Peninsular Malaysia, there are about 50 species in 11 genera but only 13 species are being utilized by industries [3]. There still have not a complete stock of bamboo resources in Malaysia but these have been estimated to be the region of about 320 000 ha [4, 5]. There are a lot of bamboo processing factories in Malaysia. At present, the industry mainly manufactures finished products such as satay sticks, toothpicks, chopsticks, bamboo splits, basketry, handicrafts, and furniture meant for the domestic market. Most of these mills are small and found in the west coast states of Peninsular Malaysia which offers bigger market potential, more developed infrastructure, communication services and other supporting services [2].

Remote sensing and Geographic Information System (GIS) are providing new tools for advancing ecosystem management. Airborne hyperspectral imaging is only one of many remote sensing tools available to resource managers, but it offers the most comprehensive perspective of all. Airborne hyperspectral imaging can provide accurate vegetation maps quickly and cost-effectively. Usually, it is difficult to map bamboo in the mountain forest, due to lack of information about the location of the bamboo species and inaccessibility. Information of the bamboo is still less and need more research to get the accurate data about their distribution and also the total resources in the natural forest. Most of the information of the bamboo comes from three sources such as National Forest Inventory (NFI), Post-F Inventory and Special Inventory. The sources are

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limited while the natural stands of bamboo need a suitable and effectively plan to control and maintain the sustained yield production of bamboo. It needs a systematic management for the population of bamboo, so airborne hyperspectral data can be used to gather the accurate bamboo information in the natural forest. While satellite based remote sensing technique using Landsat TM is limited and unsuitable for bamboo mapping, some researchers can still correlated the digital numbers with abundance of bamboo species within a natural hill forest despite it is a bit confusing and difficult although the results showed an accuracy of 70% [6].

The general objective of this study is to assess the capability of UPM-APSB's Airborne Imaging Spectrometer for Application (AISA) data for bamboo mapping in forest reserves. The specific objective is to identify and quantify bamboo species and map out the distribution of natural bamboo growing areas in Berangkat F.R, Kelantan for its future conservation and management.

II. Methods and Materials

2.1 Description of Study Area

The study area is located in Berangkat F.R in the state of Kelantan (Fig.1). This study area is composed of montane forest and hill dipterocarp forest which is situated at latitude 5° 7' 60 N and longitude 101° 49' 60 E . Most of the species found in the study area belongs to the Dipterocarpaceae family. There are also many others species of bamboo such as *Gigantochloa scortechinii* and *Schizostachyum grande*. Berangkat F.R is currently managed by Kompleks Perkayuan Kelantan (KPK). Berangkat F.R is generally warm throughout the year with temperatures ranging from 21° to 32°. The annual rainfall average is about 3 000 mm to 4 000 mm per year. Over the east coast districts, November, December and January are the months with maximum rainfall, while June and July are the driest months in most districts. The high humidity through the year falls within 70% to 90%.

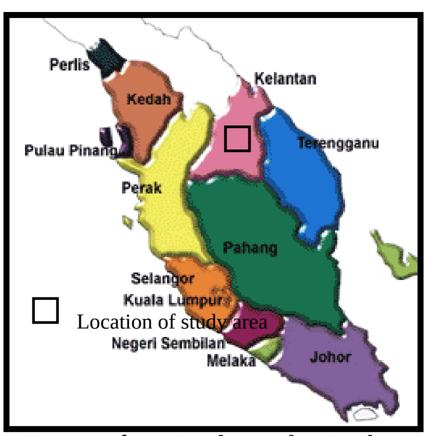


Fig. 1: A Map of Peninsular Malaysia showing the location of the study area

2.2 Equipment and Software

UPM-APSB's AISA is a commercially produced inexpensive hyperspectral push broom type imaging spectrometer system. It provides very compact system, consisting only of two units, the sensor head and a rugged portable personal computer. The versatile graphical user interface (GUI) provides flexible, easy-to-use instrument with several efficient operating modes and features which may be changed during flight within seconds. The data is stored as a default to a large capacity hard disk, which is providing higher frame rates compared to traditional tape storage based systems. The versatility of UPM-APSB's AISA lies behind the clever design of the front-end. The total system weight is less than 15 kg from which the front-end weights only 4 kg. Therefore, UPM-APSB's AISA can be easily mounted to any aircraft, even the lightest one. UPM-APSB's AISA airborne hyperspectral sensor is capable of collecting data within a spectral range of 430 to 900 nm. Although it is capable of collecting up to 286 spectral channels within this range, the data rate associated with the short integration times (sampling rates) required of the sensor in most operational/flight modes, limits the number of channels. Current operational collection configurations range from 10 to 70 spectral bands depending on the aircraft speed, altitude and mission goals.

2.3 Methodology

Hyperspectral image of Berangkat F.R and its surrounding was acquired on June 13 and 14th, 2005 using UPM-APSB's AISA hyperspectral sensor. The flowchart of the study methodology is illustrated in Fig.2. The sensor was flown at an altitude of 1,500 m from the ground at a spatial resolution of 1.5 m. The aircraft flying speed was 120 knots.

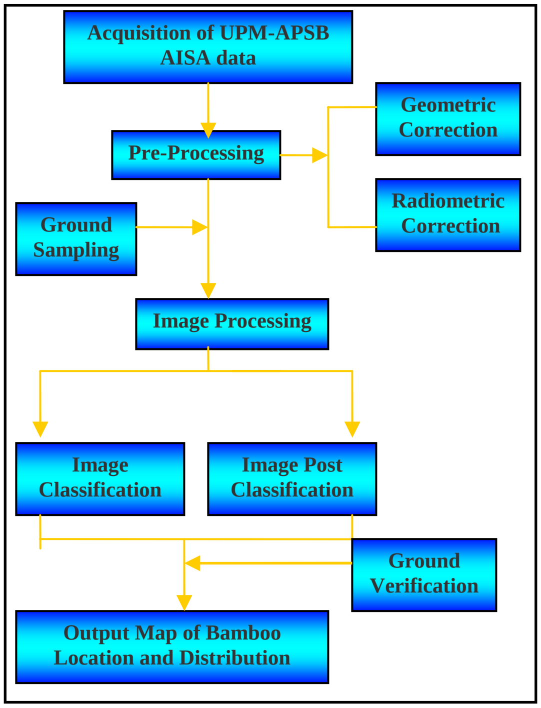


Fig. 2: Flow chart of study methodology

Image pre-processing is required to process the raw data to increase the accuracy and the interpretability of the image prior to image classification. This process involves correcting images to reduce the magnitude of unwanted effects to improve the quality of the image data for subsequent processing. Pre-processing operations, sometimes referred to as image restoration and rectification, are intended to correct for sensor and platform specific radiometric and geometric distortions of data.

Ground verification is executed by taking the exact location of the bamboo on the ground to assess the accuracy between the sensor DGPS and also the ground GPS. The data is collected in the form of latitude and longitude of the position of the bamboo in Berangkat F.R using GPS. All the data recorded were then matched with the data taken by the sensor DGPS. The GPS needs to receive at least three satellite signals to show the readings. In the ground truth, the image of the bamboo also had been taken by using digital camera. A specific site was chosen to verify on the ground. The size of ground verification plot was 1.5 ha which was located between latitude 5^0 10' 12" till $5^0$10' 15" and longitude 101^0 51' 32" till 101^0 51' 36" used to verify the accuracy percentage of the study. A total of 15 sample points were chosen randomly and visited during ground verification work. Ground verification points based on the GPS readings were prepared earlier according to the processed image.

UPM-APSB's AISA data were processed digitally by using the ENVI version 4.0, which have an added hyperspectral processing capability to their image analysis system. There are two main parts of image processing in this study which are image classification and image post classification. Spectral Angle Mapper was used to classify the bamboo in the image while sieve classes and clump classes were used in the post classification to produce a systematic map. At the end of this study, a thematic map of bamboo distribution in Berangkat F.R was developed from airborne hyperspectral imaging. It can be used to identify and quantify the bamboo species in Berangkat F.R. This information will definitely aid the management of the bamboo for bamboo based industry in Malaysia and elsewhere.

3 Results and Discussion

3.1 Band Combination, Image Enhancement and Spatial Filtering

Selection of band combinations is one of the essential studies for making enhanced colour composite image which is suitable for interpreting land cover pattern. In this study, band 25, 14, 2 (RGB) with a linear stretch were adopted to be the best combinations and was used for further analysis in image classification since it provide a well enhanced colour composite image with respect to its vegetation cover.

Filtering is typically used to enhance images by removing certain spatial frequencies. Spatial frequency describes the variation of brightness, or digital number (DN), with distance, and images contain many different spatial frequencies. The Sobel filter is a non-linear edge enhancement, special case filter that uses an approximation of the true Sobel function, and is a preset 3 x 3, non-linear edge enhancement operator. The size of the filter cannot be changed and no kernel editing is possible. In this study, Sobel filter was founded to be the most suitable filter to be applied to the airborne hyperspectral imagery especially for visual interpretation of vegetation on the image. The False Color Composite (FCC) images with the Sobel Filter that came out to be the best filter for this study.

3.2 Supervised Classification

The classification was done using the Spectral Angle Mapper (SAM) which is a physically-based spectral classification that uses an n-dimensional angle to match pixels to reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra, treating them as vectors in a space with dimensionality equal to the number of bands. This technique, when used on calibrated reflectance data, is relatively insensitive to illumination and albedo effects. Endmember bamboo spectra used by SAM were come from spectral libraries, which were taken during the ground sampling. SAM compares the angle between the end member spectrum vector and each pixel vector in n-dimensional space. Smaller angles represent closer matches to the reference spectrum. Pixels further away than the specified maximum angle threshold in radians are not classified. The radian used in this study was 0.6, which is the most suitable radian used to classify the bamboo from the trees in the forest. Pixels with an angle larger than this value will not be classified. The next step was therefore required and the post classification using clump classes was applied to the image using morphological operators.

3.2 Post Classification

Clump Classes was used to clump adjacent similar classified areas together using morphological operators. Classified images often suffer from a lack of spatial coherency liked speckle or holes in the classified areas. Low pass filtering could be used to smooth these images, but the class information would be contaminated by adjacent class codes. The selected classes are clumped together by first performing a dilate operation and then an erode operation on the classified image using a kernel of the size specified in the parameters dialog. Sieving classes removes isolated classified pixels in classification images using blob grouping. The sieve class method looks at the neighboring 4 or 8 pixels to determine that pixel is grouped with pixels of the same class. The numbers of pixels in a class that are grouped less than the value are removed from the class. When pixels are removed from a class using sieving, black pixels (unclassified) will be left. Fig. 3 showed the location and distribution of bamboo after using clumping and sieving classes for bamboo mapping.

3.3 Spectral Reflectance of Bamboo Species

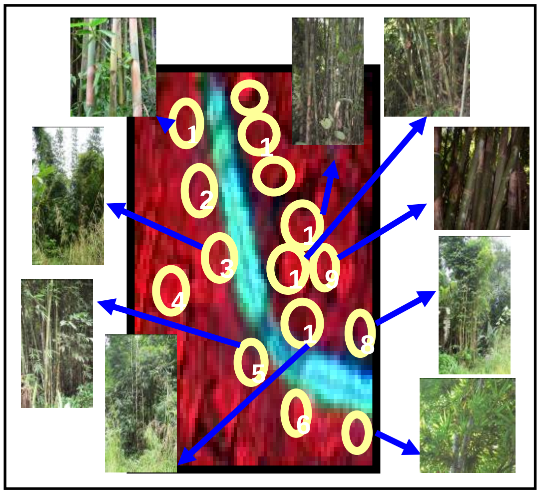
Spectral reflectance of bamboo species in the study area was selected randomly from the image to check the curve of spectral reflectance. This step was done to confirm the classes that have been map out were belonged to the bamboo species. From the Figure 8 showed that the spectral reflectance of bamboo species can conclude as the spectral belonged to the same species because of the pattern and curve of spectral reflectance almost same. However, the value of spectral library plots had a different range between 1,400 – 1,600 due to the condition of the age and stress levels of the bamboo's leaves.

3.4 Ground Verification and Accuracy Assessment

Field photos were taken during ground verification as evidences showed that it matched with the actual position in the image processed and the accuracy assessment of ground verification plot (Fig.3). In the ground verification, only one species was identified and mapped in the study area Berangkat F.R, Kelantan. The species is *Gigantochloa scortechnii* which was found dispersed along the secondary forest road. The ground verification witnessed that nine clumps of bamboo were confirmed available on the ground compared to 15 clumps in the image. Besides that, culms in every bamboo clump were calculated and recorded to estimate quantity of bamboo in the study area. There were nine clumps of bamboo confirmed verified on the ground instead of 15 clumps in the image. The mapping accuracy of this study is only 60% (9/15 X 100% = 60.0%). The mapping accuracy is poor (below 80%) probably due to the non-capability of such sensor's spatial resolutions to map bamboo distribution in the study area.

3.5 Quantification of Bamboo in Study Area

The ground verification results showed that each clump of bamboo consults of different number of culms. Assumption can be made based on image's pixel to quantify the quantity of bamboo on the ground. From the ground verification data, the number of pixel /culm can be counted as below:



891 pixels / 379 culms = 2.35 pixel /culm

Fig. 3: Verification of bamboo location plot using a hand-held GPS

The total pixels of bamboos within the study site of 20 ha are 9 420 pixels and the spatial resolution is 1.5 m, so the estimated quantity of bamboo is 4 009 culms and the estimated area of bamboo is 2.12 ha or 10.6% of entire study site. The calculations are shown as below:

9 420 pixels * 2.25 m^2= 21 195 (2.12 ha)

3.6 Output Map of Bamboo Distribution

Fig.4 illustrated the AeroMAP™ product of bamboo distribution and their unique spectral reflectance signatures in Berangkat F.R. The green colour represents the location of bamboo, red represents the tree species and blue represents the road and open up areas. This geospatial map is useful to estimate the location of bamboo, since there is a lack of information on the location and distribution of bamboo species in the mountain forest. With an airborne hyperspectral data, it can be used to gather the accurate bamboo information in the natural forest for future systematic management of bamboo in H.S.K Berangkat.

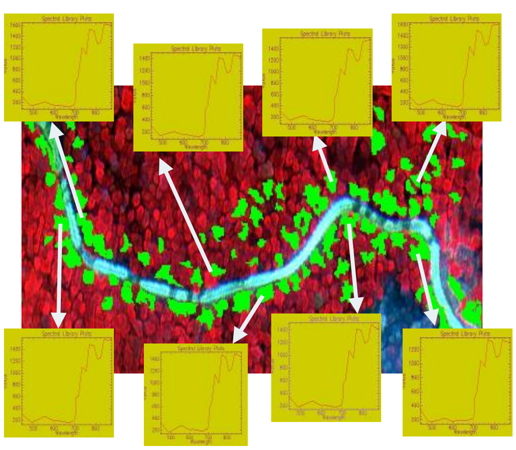


Fig.4: Spectral reflectance of bamboo species

4 Conclusions and Recommendations

From this study, it can be concluded that UPM-APSB's AISA airborne hyperspectral data is capable of quantifying and mapping bamboo species in Berangkat F.R, Kelantan. The bamboo species identified was *Gigantochloa scortechinii* (Buluh Semantan) with a mapping accuracy of 60%. The quantity of bamboo estimated was 4 009 culms and the coverage area was 2.12 ha or 10.6% of entire study site.

Further research should focus on identifying and differentiating bamboo species of commercial interest using higher spatial resolution (below 1.5 m) for better classification accuracy. The UPM-APSB's data should be integrated into a GIS format to better manage bamboo in a mountain forest.

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