Advanced Processing of UPM-APSB's AISA Airborne Hyperspectral Images for Individual Timber Species Identification and Mapping

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***Abstract*-**UPM-APSB's AISA airborne hyperspectral imaging offers the possibility of identifying and characterizing commercial and non-commercial individual timber species in the Malaysian tropical high mountain forests on the basis of the unique reflectance patterns that result from the interaction of solar energy with the molecular structure of the tree crowns. In this paper, a seminal view on recent advances in techniques for hyperspectral data processing was provided. It examines the performance of image processing techniques specifically developed for hyperspectral data in the context of individual timber species inventory mapping applications. The area chosen, located in Berangkat Forest Reserve, Kelantan near the locality of Kompleks Perkayuan Kelantan sawmill, had relatively virgin dense forest stand density at the time of imagery acquisition (dry month). The main focus is on the development of approaches able to naturally integrate the spatial and spectral information available from the hyperspectral data. Special attention is paid to techniques that circumvent the curse of dimensionality introduced by high-dimensional data spaces. Image processing was carried out in two steps, namely data conversion from radiance units to reflectance using a radiative transfer method and application of the mapping algorithm, specifically designed for identifying superficial materials based on similarities between image pixels and spectra from a spectral library of timber species. Experimental results, focused in this work on a specific case-study of individual timber species data analysis, demonstrate the success of the considered techniques. The results show that UPM-APSB's AISA airborne hyperspectral imaging can identify 22 individual species in Block 53, Berangkat F.R and separated damar from non-damar group of species. Kelat constituted the highest count of species (1,402) mapped followed by Kedondong (1,185 trees), Medang (1,116 trees) and others out of the total 13,861 trees. It is therefore a valuable tool for mapping and quantification of individual tree in tropical dense virgin forested regions. This paper represents a first step towards the development of a quantitative and comparative assessment of advances in UPM-APSB's AISA airborne hyperspectral data processing techniques.

***Keywords*-**Hyperspectral, Individual tree, Mapping, Advance processing

I. INTRODUCTION

Airborne hyperspectral remote sensing data were acquired for the first time in Malaysia in 2004 over some areas of Selangor, Malaysia, using UPM-APSB's Airborne Imaging Spectrometer for Different Applications (AISA). The airborne survey was part of the inaugural mission cum spectrometer calibration, a joint scientific mission between UPM-Specim Ltd, Finland and Aeroscan Precision (M) Sdn Bhd (APSB).

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The unique data set collected over Selangor, Malaysia represents the first airborne hyperspectral data ever acquired over a tropical ASEAN region. The primary objectives of the mission were aimed at individual timber species identification, mapping and forest inventory issues. A year later in June 2005, some airborne hyperspectral data consisting of four flight lines, were acquired over a mountain forested areas in southern Kelantan at the peak of the dry season. Due to some low clouds dominated the imagery over the mountain peaks, preventing the use of most of these data for land/surface applications, the data were flown over a 3,500 m above seal level (a.s.l) giving a spatial resolution of 1.5 m pixels for the whole study area of Block 53, Berangkat Forest Reserve (F.R).

The objective of the study is therefore to determine the best advance processing technique performance of UPM-APSB's AISA data for identifying individual timber tree species in a tropical rainforest region, considering the constraints imposed by cloud, weather, soil and heterogenous mixed and non-dipterocarp hill and mountain forest type coverage.

II. METHODS AND MATERIALS

A. Description of Study Area

The total land area of Berangkat F.R is 21,409 ha. Block 53 of the project area has a total land area of 269.85, comprising of mostly mixed hill dipterocarp and mountain logged-over forest in Berangkat F.R, south-west Kelantan (Figure 1). The project area is located to the north-east of Gua Musang and is about 300 km south-west of Kota Bharu, the capital city of Kelantan Darul Naim.

Fig. 1: A map of Peninsular Malaysia showing the location of Berangkat F.R study site (red dotted circle) in Kelantan

The majority (60%) of the project area consists of low elevation areas (below 300 m above sea level) with and relatively gentle topography with slopes of less than 15°. One-fifth of the project area lies between 300 m and 350 m a.s.l and consists of rolling hills with slopes of 15° to 25°. A relatively equal portion (20%) of the project area lies at high elevations, with generally hilly, broken topography and slopes above 25°. The highest peak in the area is 500 m a.s.l located in the west of Block 53. The soils of the project area are predominantly mudstones, sandstones and miscellaneous and igneous rocks of the Bang Associations. The geology of the eastern portion of the project area is dominated by chert-spilite-greywacke and limestone formations. In the west, the Tanjong Formation dominates with mudstone, siltstone and sandstone materials**.** The main rivers flowing in Block 53 and Berangkat F.R are Sg. Chelakor, Rela and Tajing.

B. Airborne Hyperspectral Image Pre-Processing

Earth's land and water surfaces are very complex to be recorded by relatively simple remote sensing devices that have constraints such as spatial, spectral, temporal and radiometric resolution. Consequently, error creeps into the data acquisition process and can degrade the quality of the remote sensor data collected. This in turn may have an impact on the accuracy of subsequent human or machine-assisted image analysis. Therefore, it is usually necessary to pre-process the remotely sensed data prior to actually analyzing it (see e.g. [1,2]) as shown in Figure 2. In order to correct the remotely sensed data, internal and external error must be determined. Internal error created by the sensor itself, however, the external error are due to platform perturbations and the modulation of atmospheric and scene characteristics, which are variable in nature. As an example, radiometric and geometric errors are the most common error in airborne remotely sensed data. UPM-APSB data already have its own preprocessing program (Caligeo) and can be generated automatically as long as the reference information was known.

C. Advance Airborne Hyperspectral Image Processing for Individual Species Mapping

Image Mosaicking, Edge & Cutline Feathering

Image mosaicking means overlay two or more images that have overlapping areas (typically geo-referenced) or to put together a variety of non-overlapping images and/or plots for presentation output (typically pixel-based). Figure 3 demonstrated how Feathering was performed to blend the edge of a top image with the bottom image based on a specified blending distance. The distance specified is used to create a linear ramp that averages the two images across that distance. For example, if the specified distance is 20 pixels, 0% of the top image is used in the blending at its edge and 100% of the bottom image is used to make the output image. At the specified distance (say 20 pixels) into the image from the edge, 100% of the top image is used to make the output image and 0% of the bottom image is used. About 50% of each image is used to make the output at 10 pixels in from the edge.

The distance specified was used to create a linear ramp that averages the two images across that distance from the cutline outwards (Fig. 4). For example, if the specified distance is 20 pixels, 100% of the top image was used in the blending at the cutline and 0% of the bottom image is used to make the output image. At the specified distance (20

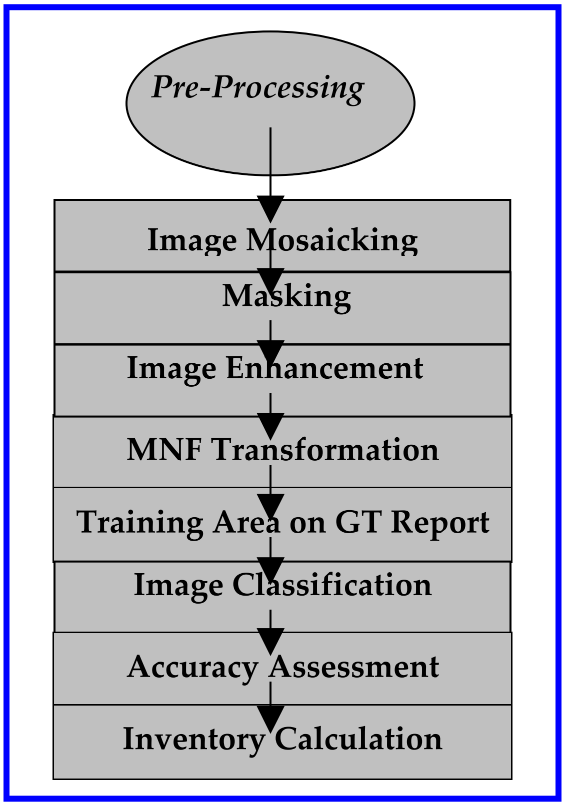

Fig. 2: Advance processing of UPM-APSB's AISA data for individual timber species identification and mapping

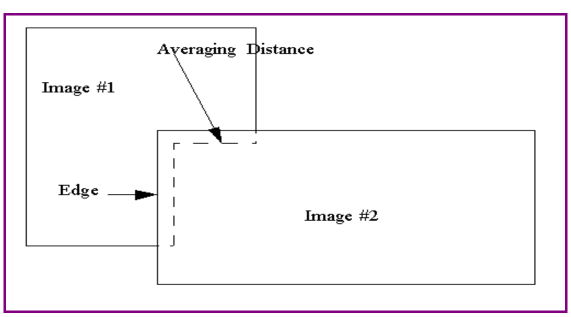

Fig. 3: An example of Edge Feathering process

pixels) out from the cutline, 0% of the top image was used to make the output image and 100% of the bottom image is used. About 50% of each image is used to make the output at 10 pixels out from the cutline.

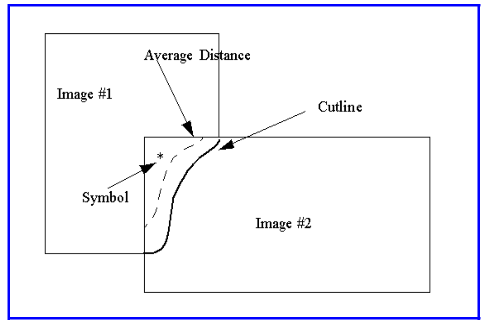

Fig. 4: Example of Cutline Feathering

Masking

Masking was used to create image masks. A mask is a binary image that consists of values of 0 and 1. When a mask is used in a processing function, the areas with values of 1 were processed and the masked 0 values were not included in the calculations. Masking is available for selected processing software (ENVI, ERDAS, PCI Tools) functions including statistics, classification, unmixing, matched filtering, continuum removal and spectral feature fitting. Build Mask was performed to build image masks from specific data values (including the data ignore value), ranges of values, finite or infinite values, Regions of Interests (ROIs), vector files, and annotation files (Fig. 5). Any combination of input to define a mask can be used and a mask can be permanently applied to an image.

Image Enhancement

The principal objective of image enhancement is to process a given image so that the result is more suitable than the original image for a specific application. It accentuates or sharpens image features such as edges, boundaries, or contrast to make a graphic display more helpful for display and analysis. The enhancement does not increase the inherent information content of the data, but it increases the dynamic range of the chosen features so that they can be detected easily. The greatest difficulty in image enhancement is quantifying the criterion for enhancement and, therefore, a large number of image enhancement techniques are empirical and require interactive procedures to obtain satisfactory results. The different categories of image enhancement operational methods which can be based on either spatial or frequency domain technique includes point operations (contrast stretching, noise clipping, window slicing, histogram modeling), spatial operations (noise smoothing, median filter, LP/BP/HP filtering, zooming) transform operations and pseudo/false coloring.

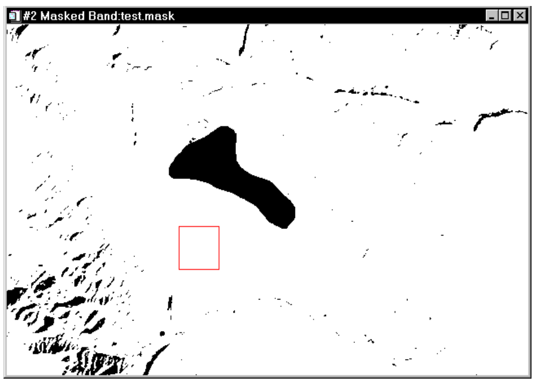

Fig. 5: Example of a Mask Image from a data range and imported ROI

MNF Transformation

MNF Rotation (minimum noise fraction) transforms has been used to determine the inherent dimensionality of image data, to segregate noise in the data, and to reduce the computational requirements for subsequent processing. The MNF was transformed and implemented in ENVI Version 4.0, is essentially two cascaded Principal Component's transformations. The first transformation, based on an estimated noise covariance matrix, décor relates and rescales the noise in the data. This first step results in transformed data in which the noise has unit variance and no band-to-band correlations. The second step is a standard Principal Components transformation of the noise-whitened data. For the purposes of further spectral processing, the inherent dimensionality of the data is determined by examination of the final eigenvalues and the associated images. The data space can be divided into two parts: one part associated with large eigenvalues and coherent eigenimages, and a complementary part with near-unity eigenvalues and noise-dominated images. By using only the coherent portions, the noise is separated from the data, thus improving spectral processing results. Also, the MNF Transform was used to remove noise from data by performing a forward transform, determining which bands contain the coherent images (by examining the images and eigenvalues), and running an inverse MNF transform using a spectral subset to include only the good bands, or smoothing the noisy bands before the inverse.

Training Areas & Ground Verifications

Ground data, in some cases called ground "truth" is defined as the observation, measurement and collection of information about the actual conditions on the ground in order to determine the relationship between remote sensing data and the object to be observed. Generally, ground data should be collected at the same time as data acquisition by the remote sensor, or at least within the time that the environmental condition does not change. It should not be inferred that the use of the word "truth" implies that ground truth data is not without error. Ground data was used as for sensor design, calibration and validation, and supplemental use. For this particular sensor, spectral characteristics were measured by a handheld spectro-radiometer to determine the optimum wavelength range and the band width. In this study, ground data mainly include identification of the timber species to be observed and measurement by a spectro-radiometer, as well as visual interpretation of image and survey by existing maps, and a review of existing spectral library database archives and statistics.

Image Classification

Digital image classification uses the spectral information represented by the digital numbers in one or more spectral bands, and attempts to classify each individual pixel based on this spectral information (see e.g.[3]) known as spectral pattern recognition**.** In either case, the objective is to assign all pixels in the image to particular classes or themes (Identified Tree Species). Spectral classes are groups of pixels that are uniform (or near-similar) with respect to their brightness values in the different spectral channels of the data. The objective is to match the spectral classes in the data to the information classes of interest. Rarely, is there a simple one-to-one match between these two types of classes. Rather, unique spectral classes may appear which do not necessarily correspond to any information class of particular use or interest to the analyst.

Accuracy Assessment

There must be a method for quantitatively assessing classification accuracy in order to make the map to be useful. To correctly perform classification accuracy assessment, it is necessary to compare two sources of information which are the image classification map and the reference test information. The relationship between these two sets of information is commonly summarized in an error matrix.

III. RESULTS AND DISCUSSION

The results presented here illustrate the potential use of hyperspectral imagery for individual timber species counting and mapping in areas where the superficial exposure of individual timber species is limited. Figure 6 showed a total of 22 tree species were successfully delineated from the UPM-APSB's AISA sensor using a supervised classification from the limited field samples. The applied scenario was based on a supervised classification method for identifying certain tree crown species that are spectrally separable. Due to high variation in radiance values (1 pixel allocates 16 bits) inherent with UPM-APSB's AISA data, the number of classes requested for classification was relatively small (22 species identified) to derive at a reasonable classification result. The alternative method which was not available in short time to overcome this issue was by developing classification algorithm which based on clustered/grouped of pixels (delineated pixels assumed as tree crowns) with certain restricting parameters instead of individual pixels. The complex heterogenous multiple dense tropical forest layers and vegetation pose the main constraint on such applications. A more detailed spectral analysis of these materials are being currently carried out in order to compare the spectra from field samples collected at some of the locations classified as above mentioned species with those obtained in laboratory.

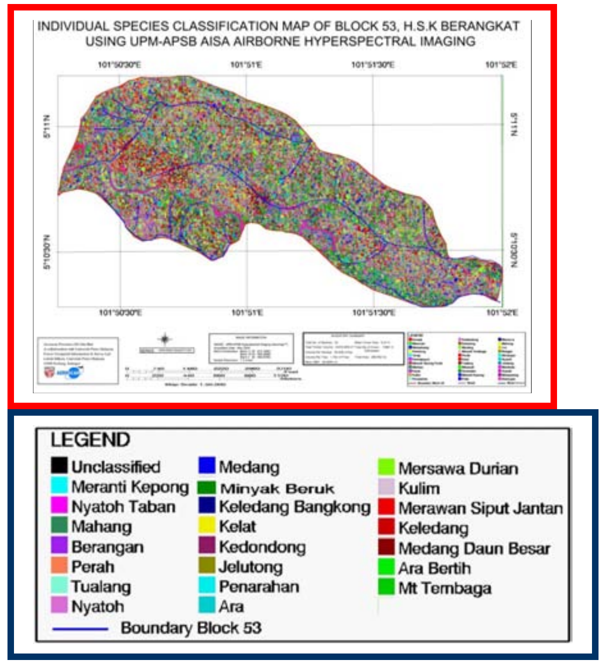

Fig.6: Individual species classification map of Block 53 overlaid with rivers.

IV. CONCLUSIONS

Based from the advanced image analysis performed, majority of the individual non-damar group of species can be easily quantified and mapped with the UPM-APSB's AISA sensor in Block 53, Berangkat F.R. A total of 17 species of non-damar (non-dipterocarp) timber volume was estimated with UPM-APSB's AISA sensor compared to only five species of the damar. Digital data advance analysis indicated that Kelat (1,402.5 trees) constitutes the highest percentage (10.12%) of the total 13,861.5 trees counted and mapped in Block 53, followed by Kedondong (1,185 trees or 8.55%), Medang (1,116 trees), Penarahan (1,072.5 trees) and others.

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