Sub-Pixel Technique of Remotely Sensed Data for Extracting Bamboo Areas in Temengor Forest Reserve, Perak, Malaysia

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ABSTRACT

Various approaches can be used to map bamboo in forested areas, including the use of airborne and space-borne remote sensing data. In remote sensing, thematic maps are created from numerical data collected by sensors that measure the amount of reflected energy from different land cover types. These data are then translated into an image by assigning visible colours to the numerical value. Remote sensing technique has been proven to be effective for mapping timber resource but the use of this technology in the mapping of bamboo resources in Malaysia is still new and yet to be explored. The traditional method of classification in remote sensing is by using supervised classification of mixed pixel; however, the use of sub-pixel classifier is recently gaining momentum. This study applies the sub-pixel classification technique in processing SPOT 5 (path/row: 268/339) satellite data to identify and map bamboo areas in Compartment 26 of Temengor Forest Reserve in Perak. Ground verification was done to check the accuracy of classification from the sub-pixel technique. This study identified about 4.61 ha (15.4%) bamboo areas from the 60 ha of the total area in compartment 26 of Temengor Forest Reserve. The estimated bamboo culms were 4,062 and the accuracy of mapping was 86.6%. This paper demonstrates that remote sensing is capable of identifying bamboo areas through sub-pixel-based technique with acceptable results. In future studies, high resolution satellite remote sensing should be considered for better results.

Keywords: SPOT 5 data, sub-pixel classification, bamboo mapping

INTRODUCTION

Natural stand bamboo grows profusely in forest throughout the whole of Malaysia. Wild bamboo populations are found in forest gaps, especially in post-logging areas, river

banks, hill side and ridge tops and sometimes in patches on flat lands and hill slopes (Ng & Noor, 1980). Most of the bamboos found wild in forests are *Gigantochloa scortechinii*, *Schizotachyum grande*, *Schizotachyum zollingerii*, *Dendrocalamus pendulus*, and *Gigantochloa ligulata* (Azmy, 1991). Bamboo sometimes occurs as a secondary growth on abandoned clearing where shifting agriculture is being practiced. The areas where bamboos grow have an annual rainfall of 1200 to 1400mm and a mean annual temperature of around 32°C or less. The plants can be found up to 1,530 meters on the hills. Once established, bamboo thickets are difficult to eradicate (Ng & Noor, 1980).

One of the most important aspects in managing bamboo resource is acquiring reliable information on the status of the resource availability in forest. This includes knowing the spatial distribution of the bamboo areas and ability in pinpointing the areas on the map. Information on bamboo distribution in natural forests is essential for bamboo management and productivity. Classification of the bamboo and their quantification in the past were done through manual surveys and these traditional methods are rather expensive and time consuming. Voluminous amount of the data collected cannot be updated quickly when involving large areas, while the cost of manual update can be very high. In the case of mapping bamboo areas, appropriate digital analysis can be done to differentiate between bamboo and other bushes or secondary vegetation areas. Various approaches can be used to map

the resources, including remote sensing technique. In space-borne remote sensing, maps are created from numerical data collected by sensor on the satellites that measure the amount of reflected energy from different land-cover types. These data are then translated into an image by assigning visible colours to the numerical values. Image generated from this procedure reveals distinction in habitat such as forest types, bamboo areas, logging track, and rivers (Khali, 1995).

However, the usefulness of the remote sensing data in bamboo inventory has not been fully explored. Uncertainty arises when the behaviour or ecology of bamboo is not well examined. Attempt was made to use data obtained from space-borne satellite to map bamboo areas in the forest (Kamaruzaman, 2007; Wan Zuraidi & Kamaruzaman, 2000). Optical remote sensing images contain a mix of pure and mixed pictures element (pixels). Meanwhile, digital image classification techniques consider a pixel as a unit belonging to a single land cover class. However, due to limited image resolution in some remote sensing data, pixels often represent ground areas, which comprise two or more discrete land cover classes (Foody & Boyd, 1996). Thus, in order to measure the strength of membership in a pixel, the sub-pixel technique can be used as fuzzy logic (Foody *et al*., 1997; Anastasios *et al*., 1999). A sub-pixel classification assigns a pixel to different classes according to the areas and yield a number of fraction spectral members equal to the of land cover classes.

Classification of mixed pixels leads to errors that make the subsequent area estimation inaccurate. These errors are caused by the premise of classification that all pixels are pure, i.e., consisting of a single ground cover type, while in fact they are not. The spectral confusion caused by mixing of ground cover types is outlined in Fig.1. It has been proven that the remote sensing technology is extremely useful and has been widely used in the extraction of forest information and monitoring of forest changes (Mohd Hasmadi *et al.*, 2006). However, the conventional technique of pixel-based classification of remotely sensed data can not accurately identify the bamboo resources due to complexity of bamboo spectral signature in forested areas.

The approach in remote sensing image classification using the sub-pixel classification method has the potential to identify and distinguish features more efficiently and accurately as compared to the classical parametric method approach. Thus,

identification and classification of bamboo using sub-pixel classification method was applied in this study. The approach was implemented using Erdas Imagine software and SPOT-5 image that covers the Compartment 26, Temengor Forest Reserve, Gerik, Perak.

METHODOLOGY

Description of the Study Area

The study area is located in Compartment 26, Temengor Forest Reserve, Gerik Perak (Fig.2). Temengor Forest Reserve in northern Perak is a 130 million year old forest, designated as an Environmentally Sensitive Area (ESA) Rank 1 under the National Physical Plan. It is situated nearest to Royal Belum Forest Reserve and lies between the latitudes 5˚53.704'N to 5˚53.371'N and the longitudes 101˚61.679'E to 101˚61.763'E. Temengor Forest Reserve covers an area of about 300,000 hectares in the Belum Valley. Meanwhile, Royal Belum that is bordered by Royal Gerik, Perak, is located about
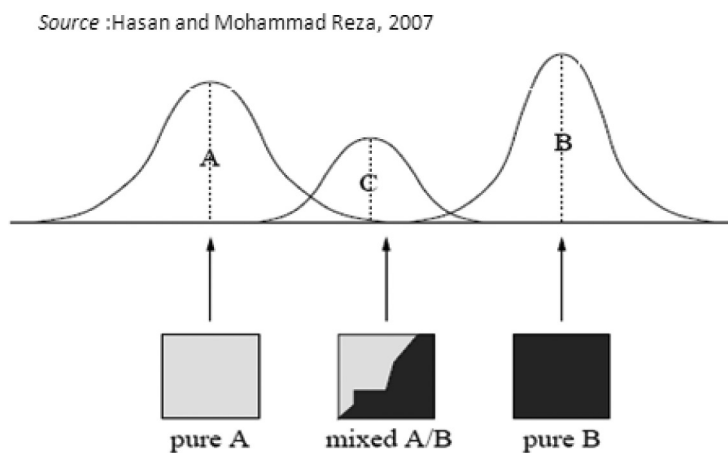

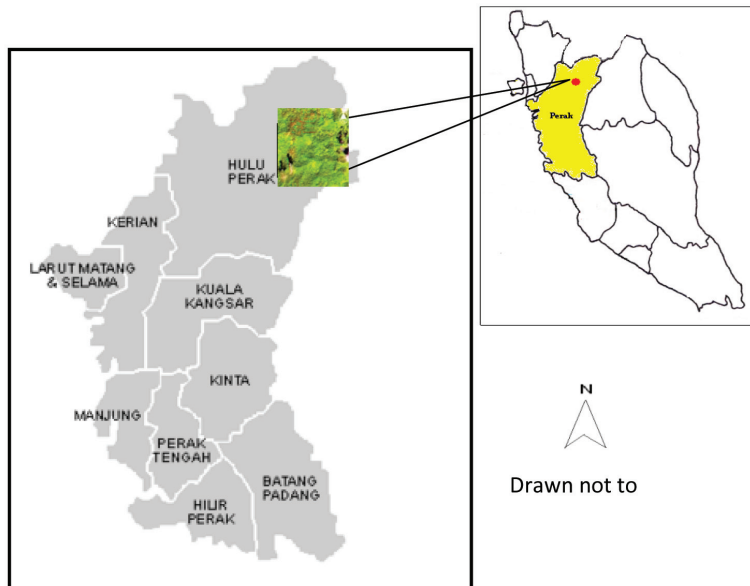Fig.1: The confusing ground cover types by mixed spectral/pixel.

Fig.2: A map of Peninsular Malaysia showing the study area

30 km from Jeli, Kelantan. The average rainfall is about 2,700mm per year with a minimum of 2,665 mm and maximum 2,890 mm per year, respectively. The mean daily temperature is 24.3˚C with the minimum at 20.8 and the maximum at 33.5˚C. The topography of the area is undulating plain with alternating hilly terrain.

Materials and Methods

SPOTt-5 digital satellite image of the study area (path/row 268/339), with a spatial resolution of 20 m taken on 4 November 2009, was acquired for the study (Fig.2). The image was provided by the Malaysian Agency of Remote Sensing (MARS). Garmin Global Positioning System (GPS) was used to determine the position of the bamboo in Temenggor F.R. It was used during the ground verification to verify the location of bamboo on the ground.

GPS receiver is accurate to within ± 10 m radius. The software used in this study was Erdas Imagine version 9.1, with a sub-pixel classifier extension module. ArcView Version 3.2 was used to produce the bamboo map.

Methodology

The composition of bamboo in the forest is basically trees, grass, soil and shrubs. Each bamboo class is a combination of these basic materials in different proportions. Thus, the sub-pixel analysis is useful for decomposing pure bamboo materials and the abundance of each material can be extracted from the image. The steps involved in the approach are illustrated in Fig.3. To extract bamboo material, automatic endmember method was used. Considering the nature of forest endmember mixture, a linear sub-pixel analysis model was applied to remotely-
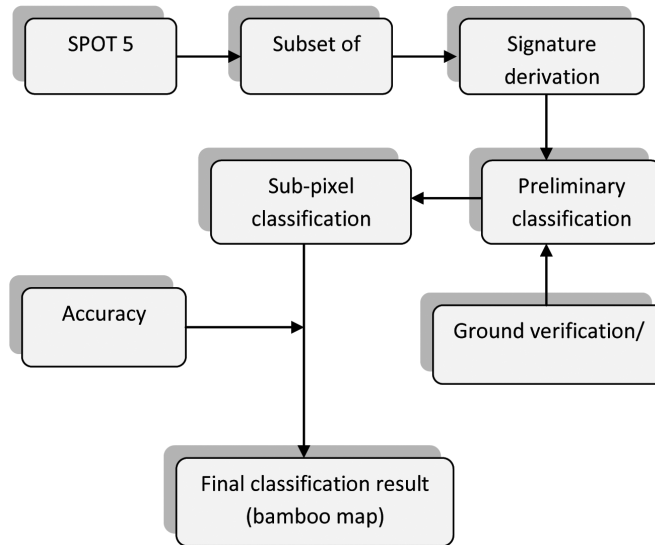
Fig.3: A flowchart of the bamboo mapping in the study

derived surface reflectance data using endmember to extract abundance images of bamboo materials. The supervised sub-pixel techniques based fuzzy and statistical approaches used is Maximum Likelihood Classifier (MLC). Meanwhile, the statistical methods are based on the assumption that the frequency distribution for each class is multivariate normal. Once this assumption is met, sets of parameters (such as mean, standard deviation, variance, covariance, etc.) were calculated from the data.

The procedure to estimate the accuracy of these parameters is called the parametric method. The decision rule assigns each pixel having pattern measurements or features X to the class c, whose units are most probable or likely to have given rise to feature vector X. It assumes that training data statistics for each class in each band are normally distributed as Gaussian in nature. In other words, the training data with bi- or tri-modal histograms in a single band are not ideal. In such cases, the individual modes probably represent individual classes that should be trained upon individually and labeled as separate classes. This would then produce uni-modal, Gaussian training class statistics that would fulfil the normal distribution requirement. MLC makes use of the statistic including the mean measurement vector $\overline{x}_j$, for each class and the variance covariance matrix $\sum_j$. It allocates the pixel to a class having the highest probability density. The probability function can be written as follows (Polubinskas *et al*., 1995):

$$p(x/j) = \frac{1}{(2\pi)^{n/2} \left| \sum_j \right|^{1/2}} e^{(-1/2[(X-\overline{x}_j)^T \sum_j^{-1} (X-\overline{x}_j)]}$$

where $p(x/j)$ is the probability density function of a pixel X as a member of class j, n is the number of bands, X is the vector denoting spectral response of pixels $\overline{x}_j$ the

mean vector and $\sum_j$ variance covariance of a class are given by the following equations, respectively;

$$\bar{x}_j = \frac{\sum_{i=0}^{N_t} X_i}{N_t}$$

$$\sum_j = \frac{\sum_{i=0}^{N_t}(X_i - \bar{x}_j)(X_i - \bar{x}_j)}{N_t(N_t - 1)}$$

where N_t is the total number of the training pixels for class j. The soft classification output was derived from MLC using a posteriori probability, which was computed from:

$$p(x/j) = \frac{p(j)p(x/j)}{\sum_{j=1}^{c} p(j)p(x/j)}$$

where, p(x / j) is the a posteriori probability of a pixel belonging to class j, p(j) is the a priori probability of the class j and c is the number of classes. The posteriori probabilities were used for class proportion in a pixel and thus, reflected soft classified outputs.

Digital Image Classification Using Sub-Pixel Classifier

Environmental correction was performed to compensate the variation in the atmosphere and environmental conditions during image acquisition. This corrected image was applied for signature derivation and classification. In order to derive a sub-pixel signature other background was removed leaving a candidate of material of interest (MOI). The output signature file was created using the training set, along with the source image, the environmental correction file, and the material pixel fraction in the training set. The mean material pixel fraction was specified by MOI and the fraction of the pixels was estimated. A sub-pixel of the training set considers the material signature as common to all pixels resulting in an equivalent whole pixel signature. The whole-pixel signatures of MOI used in this study are more than 80%.

Ground Verification

The reference points for the ground verification of the classified bamboo areas were selected from the preliminary classified image of SPOT 5. Field work was carried out in a period of four days in Mac 2011. On the ground points that were selected for bamboo areas that appeared in the preliminary classification were identified and recorded. It is important to note that some bamboos classified in the image were different on the ground. This is due to the fact that the ground cover has confused spectral by mixed pixel. A total of 35 sample points were recorded using the GPS receiver for verification data through line transect survey. The survey teams collected field data following transects across the study area. Fig.4 depicts a sampling technique conducted during field work. The bamboo stand characteristics such as culm and clump were measured and recorded. In forest,
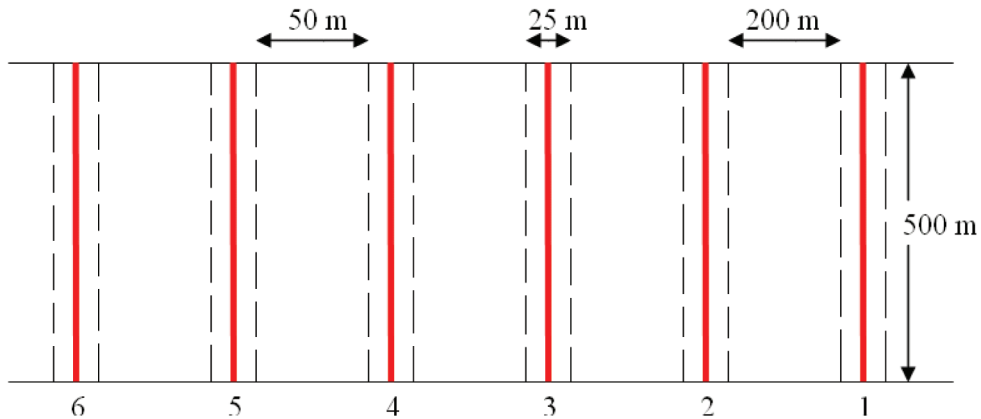
Fig.4: The sampling technique of line transect survey

bamboo has low coverage unless occurs in open, shrub land, logged over forest and forest roads. The coverage of 25% or higher of bamboo areas were used for this study.

Accuracy Assessment

The classification result was assessed using field verification based on the final classified image. The data were organized in confusion or error matrix, from which both the overall classification accuracies on the individual classes could be calculated. The overall accuracy of the classification is 86.6% and the kappa coefficient is 0.84. The assessment indicated that the sub-pixel classification for bamboo mapping could achieve good result in the study area.

RESULTS AND DISCUSSION

Output Overall Bamboo Distribution

The classification algorithms mentioned in this study were used as the supervised sub-pixel classification technique. Results of the bamboo classification approach in compartment 26 of Temengor Forest Reserve, Perak are presented in Fig.5. Light green indicates the location of bamboos while dark green represents non-bamboo. In general, each clump of bamboo consults of different numbers of culms. The quantification of bamboos in the study area was made based on the image's pixel in the image (Kamaruzaman, 2007). From the field survey, the number of pixel/culm was counted as 2470 pixels/ 869 culms = 2.84 pixel/culm. The total pixels of bamboos within the study area of 30 ha are 11,536 pixels and the spatial resolution of imagery is 20 m, so the estimated quantify of bamboos is 4062 culms and the estimated area of bamboo is 4.61 ha or 15.4%. The calculation is shown below:

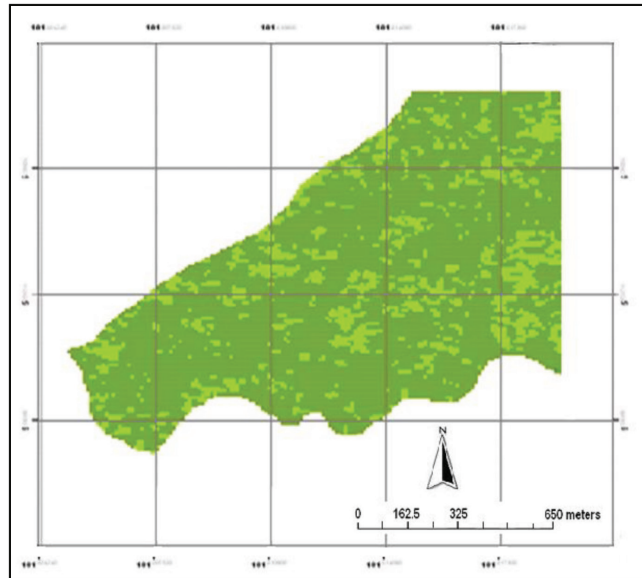| 11,536 / 2.82 pixel/culm | = 4062 culms of bamboo |
| 11,536*400 m² | = 4,614400 m² = 4.61 ha |

Fig.5: Bamboo distribution (light green) in compartment 26,
Temengor Forest Reserve, Perak

Ground Verification

Bamboo photographs were captured during ground verification as evidences to show that it matched with the actual position and bamboo features in the classified image. Fig.6 shows ten of the sample bamboo photographs on the ground during field work and their locations. On the ground, the most common bamboo species found was *Schizostachyum grande* (Buluh Semeliang), but other species found were *Gigantochloa Scortechnii* (Buluh Semantan) *and Bambusa vulgaris (*Buluh minyak). This particular species can be easily found dispersed along the secondary forest road, in ex-log yards and forest camps. The overall accuracy of the classification is 86.6% and the kappa coefficient is 0.84.

CONCLUSION

Bamboo resources are significant for non-wood forest products especially for furniture industry, and as sources of income. They also provide significant effects on the biodiversity on the forest ecosystem. Therefore, understanding the spatial patterns and temporal dynamics of bamboo stock is important for biodiversity conservation resource management. In natural forest, bamboo "pure" compositional materials are basically trees, shrubs and soil/bare soil, and a bamboo class is somewhat a linear mixture of these materials. This study proposed an approach that uses a sub-pixel analysis to map bamboo areas. The study in compartment 26 of Temengor Forest Reserve, Perak showed that the proposed technique could classify bamboo pixels and reduce difficulty, and consequently improve
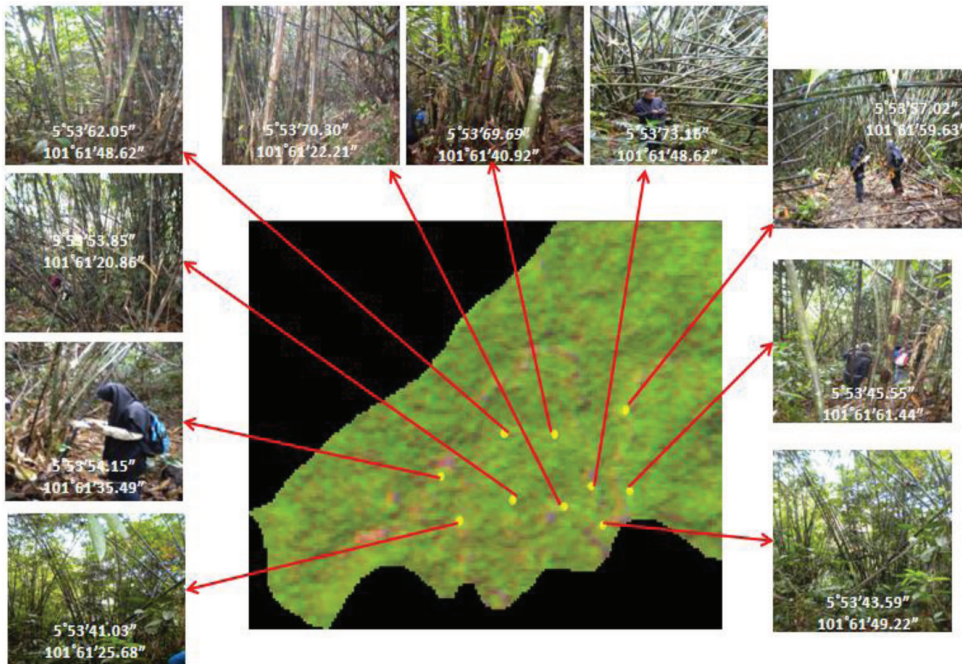
Fig.6: Some ground photographs of bamboo areas during field work.

the classification accuracy. Apart from using the sub-pixel classifier on SPOT 5 data, it is recommended that the use of higher resolution image (such as Quickbird, Ikonos and Hyperspectral) be attempted to examine the possibility of getting better results. Further study may focus on the extraction of more spectrally pure bamboo by integrating human knowledge and ecological factors.

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