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Comparison of Fusion of Different Algorithms in Mapping of Melaleuca Forest in Marang District, Malaysia

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ABSTRACT

Melaleuca cajuputi and Acacia auriculiformis trees are major sources of nectar and pollen for Apis dorsata and the colonies are a major source of honey to the rural poor, honey hunters. Honey is a supplementary income to many of these people (including school children) in the Marang district, Terengganu. In this study, Marang area with 270 square kilometers was chosen as pilot study area in Terengganu state for mapping M. cajuputi and A. auriculiformis as two dominant species in low land secondary forest in Terengganu state.

To inventory and produce land use map of Melaleuca forest in Marang area, in this study SPOT-5 satellite image in multispectral mode with 10 meter resolution which is acquired in 2007 as optical satellite was utilized. Most images from optical satellites have some null data from ground because of clouds and shadow of clouds. To solve this problem, Hue, Saturation and value (HSV) and Principal Component Analysis (PCA) were used as fusion techniques to replace null data with microwave data which taken from Radarsat-1 image in C-band with 25 meter resolution image. Accordingly, fusion technique which was used in this research not only was a technique to improve information but also caused the accuracy increasing than land use map by just only SPOT-5 image. Also between two different fusion techniques, PCA shows the better result than HSV as two different fusion techniques.

Keywords: Fusion, Optical, SAR, RADARSAT-1, SPOT-5, Marang, Malaysia

INTRODUCTION

Forests are important natural resource that play a major role in supporting the livelihood of human like in providing material goods, such as fuel wood, commercial timber, non-wood products, water for irrigation and drinking; preventing landslides or debris flows, providing protection from strong winds and purifying the atmosphere. It is a trove of biodiversity and genetic resource, as well as provider of other environmental services and a key player in poverty alleviation (F.A.O., 2005; Myers, 1992; Sellers, 1985).

Malaysia is located within the equator belt which currently has 32.8 million hectares of land area, of which 17.13 million hectares – 52 percent of total land – are classified as forest and tree cover in the end of 2007. 8.07 million hectares (47.11 percent) are found in Sarawak, 4.74 million hectares (27.6 Percent) are found in Peninsular Malaysia and 4.32 million hectares (25.2 Percent) in Sabah (Anon., 2007).

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In low land rainforest along the coastal corridor of Kelantan and North Terengganu in Peninsular Malaysia, *Melaleuca cajuputi* (*Gelam*) and *Acacia auriculiformis* (*Acacia*) are the two dominant trees. These trees are major sources of nectar and pollen for giant honey bee (*Apis dorsata*). The honey from these trees has strong flavor and weak density. It granulates quickly, with grain varying from fine creamy to coarse brown and dark if more than moderate heat is used during extraction, straining or packing. On the other hand, the trunk and branches of the Gelam trees are almost upright and the bark are papery and loose that it is unsuitable to serve as nesting support for *A. dorsata*. Therefore, other smooth barked trees with sloping branches in the vicinity of the *Melaleuca* forest are chosen as nesting supports for the *A. dorsata* colonies. It is important to understand what would be the choices of nesting support for *Apis dorsata* in the Melaleuca forest when there is plenty of nectars and pollen sources for the bees.

In order to find out the potential of Melaleuca forest to predict behavior of *A. dorsata* for nesting and collecting nectar and pollen, it is necessary to map vegetation coverage and land measurement of Melaleuca forest in the study area.

The manual (traditional) mapping method to measure and inventories the vegetation coverage of the Melaleuca forest will take a long time and cost. Better means are needed for land use inventory. In many of the developed countries and some of developing countries, Remote Sensing (RS) and Geographic Information System (GIS) are widely used to provide up-to-date information (Luney and Dill, 1970). Recent advances in RS and GIS technology have become cost effective and affordable, by virtue of the following reasons: (a) satellite images are sufficiently accurate and reliable, (b) changes over time can be identified, (c) computers have the power to rapidly process large quantities of data, and (d) object-oriented GIS provide enormous flexibility in storing and analyzing any type of data, providing decision support modeling for effective management (Buchan, 1997).

RS technology is particularly useful tool to produce a broadly consistent database at spatial, spectral, and temporal resolution which is useful for forest. As well, RS data can be made effective and economical for periodic preparation of accurate inventories and also for managing and monitoring forests. Different techniques are available for differentiating and mapping forest units. Studying large area, data can be processed in an automated way; for thematic mapping, images are visually interpreted, enabling the forestry experts to use their knowledge and experience.

In this investigation two different types of RS images were used as source for digital image processing. The first one was optical sensor which has been used to determine and map the distribution of *M. cajuputi* (Gelam) and *A. auriculiformis* (Acacia) trees, the two main sources of nectar and pollen in study area. Because of cloud and shadow of cloud, microwave images was used to fusion with optical sensor which enables penetration of atmospheric conditions to replace null pixels (Goetz *et al.* nod).

The objective of this research was determine processing techniques that improve land classification of Melaleuca forest, Marang district, Malaysia by using optical and radar data when compared to classifications using only the optical sensor data. By combining specially processed Radarsat-1 data with SPOT-5 data, the radar data can provide complementary information that can aid in land-cover mapping.

Data fusion is a process dealing with data and information from multiple sources to achieve refined/improved information for decision making (Hall, 1992). A general definition of image fusion is given as “image fusion is the combination of two or more different image to form a new image by using a certain algorithm (Genderen and Pohl, 1994).

In general, the fusion techniques can be grouped into two classes: (1) Color related techniques and (2) Statistical/numerical methods. The first comprises the color composition of three image channels in the RGB color space as well as more sophisticated color transformations, e.g. HSV and IHS. Statistical approach is developed on the basis of channel statistics including correlation and filters. Techniques like PCA which belongs to this group. The numerical methods follow arithmetic operations such as image differencing and ratios but also adding of a channel to other image bands. A sophisticated numerical approach uses wavelets in a multi-resolution environment(Pohl & Genderen, 1998).

The main function of the HSV is to separate the spectral information in the hue (H) and saturation (S) components, and the value that represents the image brightness in which high values indicate brighter color (V) component, starting from a RGB image (Pohl, 1998). Firstly, the process begins with the transformation of a RGB color composite into HSV. After that, radiometric normalization is applied between the PAN and I bands. Band I is substituted by PAN, returning to the RGB space, thereby obtaining a hybrid image with the spectral characteristics of the color composite and the spatial qualities of the panchromatic band. In the literature Cheisa and Tyler (1990) was used HSV technique as fusion technique.

The PCA is useful for image encoding, image data compression, image enhancement, digital change detection, multitemporal dimensioality, and image fusion. It is a statistical technique that transforms a multivariate data set of intercorrelated variables into a data set of new uncorrelated linear combination of the original variables (Pohl and Genderen, 1998). The exit images are called Principal Components (PCs) in which the diverse targets that are present in the scene are the most distinct because they are not spectrally correlated. The PCs are calculated simultaneously for a set of bands formed from multispectral and panchromatic images. Troya (1999) and Marcelino (2003) used a variation of this technique using PCA pairs from the PAN and TM bands. Next an inverse transformation to the RGB space was used on the first PCs, thus obtaining a hybrid image.

This study aims to evaluate the accuracy of HSV and PCA fusion techniques in mapping two main bee plants as sources of nectar and pollen for *Apis dorsata* in Marang district, Terengganu state of Malaysia.

STUDY AREA

This study was conducted in Marang district, located in the state of Terengganu at the northern east of Peninsular Malaysia (*Fig. 1*); between upper left of 5 01' N, 103 11' E and lower right of 4 50' N, 103 24'50" E. The district's topography consists of the South China Sea coast, peat swamps, hills, and plains.

The sub-districts of Rusila, Pulau Kerengga and Merchang lie on the coast with sandy plains gradually giving way to hills in the interior. The Jerong sub-district is mainly hilly, while the sub-districts of Bukit Payong and Alor Limbat consist of rolling plains and peat swamps. The dominant trees species in this area are Mangrove, Melaleuca, Acacia, Rubber, and Coconut trees.

Fig. 1: A map of study area

MATERIAL AND METHOD

The following steps were carried out to achieve the objectives of this research: (i) study area definition; (ii) pre-processing (images acquisition/band selection/radiometric normalization, speckle filter); (iii) implementation of the image fusion techniques; (iv) evaluation of the methods (spatial quality assessment, spectral quality assessment, visual assessment).

Two satellite images were used for this current inventory (Table 1), taken on acquisition dates that were near to each other so as to minimize the influence of time on landscape elements (Pohl & Genderen, 1998). However, according to these authors, in landscapes with low-spectro-temporal variability, the result of the image fusion is not significantly affected by this temporal aspec

TABLE 1
Satellite images used in mapping Melaleuca forest

Sensor/satellite	Pixel size	Bands	Resolution	Date
SPOT-5	10m × 10m	B1(B1: 0,50–0,59 μm/(Green) B2: 0,61–0,68 μm/(Red) B3: 0,79–0,89 μm/(Near-infrared)	10 m	03-05-2007
RADARSAT-1	12.5m × 12.5m	C-band/ HH Polarization/Standard 7	25 m	23-11-2007

Preprocessing

Before the image fusion process SAR images were pre-processed by the commonly used speckle reducing filter techniques. For the filtering of SAR images lee filter at windows 7was chosen (Lopes *et al.*, 1990). This selection was made based on the analysis of the mean vectors before and after filtering operation as well as the coefficient of variance (Paudyal and Aschbacter, 1993).

In this study image fusion was conducted at the pixel level. In order to avoid the combination of unrelated data spatial registration accuracies should be at the sub pixel. Therefore in fusion applications geometric correction is very important for registration of the images. After reducing the speckle effects of SAR images by using lee filter in 13×13 windows, SAR images were registered to SPOT image by using image to image rectification method with a root mean square error of less than 1 pixel. Cadastral maps in 1/5000 scale and topographic maps in 1/25000 scale were used for the rectification of SPOT images.

Image Processing

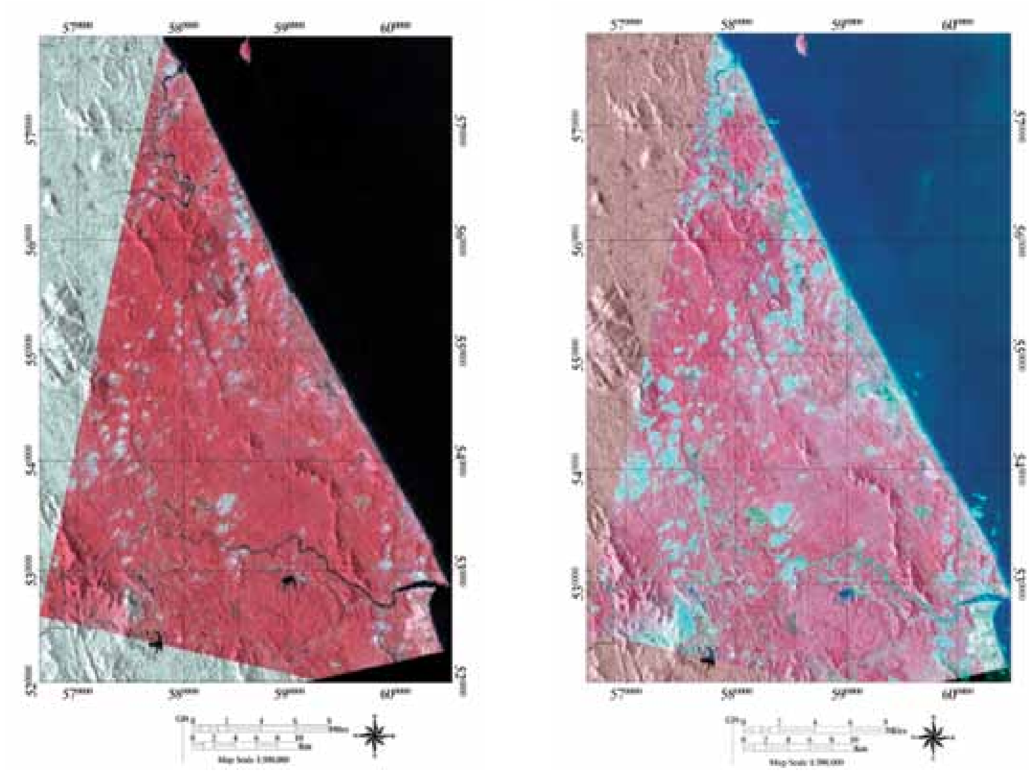
In this study two image fusion techniques were tested to select the one that was most able to mapping *Melaleuca Cajuputi* and *Acacia Auriculiformis* as two main dominant sources of nectar and pollen for *Apis dorsata.* These techniques used to combine to Radarsat-1 as SAR image with 321 SPOT-5 images.

The many classification algorithms define some measures of similarity between a pixel and each class and assign the pixel to the most similar class. We used the maximum likelihood classification (MLC). This is a fairly good method and most commonly used. It allows for incorporating class variance, which is provided by the maximum likelihood rule. The probability of the pixel belonging to a given class is determined from the class mean and covariance from the class mean and covariance. The pixel is assigned to the class for which it has the highest probability of membership. Maximum likelihood algorithm was used on the fused images of SPOT-5 image and Radarsat-1 from two different HSV and PCA techniques. The fused images were classified in 4 classes. (i) *Melaleuca Cajuputi* (ii) *Acacia Auriculiformis* (iii) water bodies (iv) non-vegetation.

Accuracy assessment was run to determine the degree of 'correctness or correspondence of the classification to reality and is performed by comparing classes in the land-use map with reference (ground truth) data by establishing an error (confusion) matrix. The confusion matrix quantifies the similarity between ground truth and classified pixels. The diagonal indicates the number of pixels where map and ground truth concur.

RESULTS AND DISCUSSION

The performance of PCA and HSV techniques in these two different data combinations was analyzed statistically, visually, and graphically. Comparisons were also made among the output classified maps from the fused images.



(a) (b)

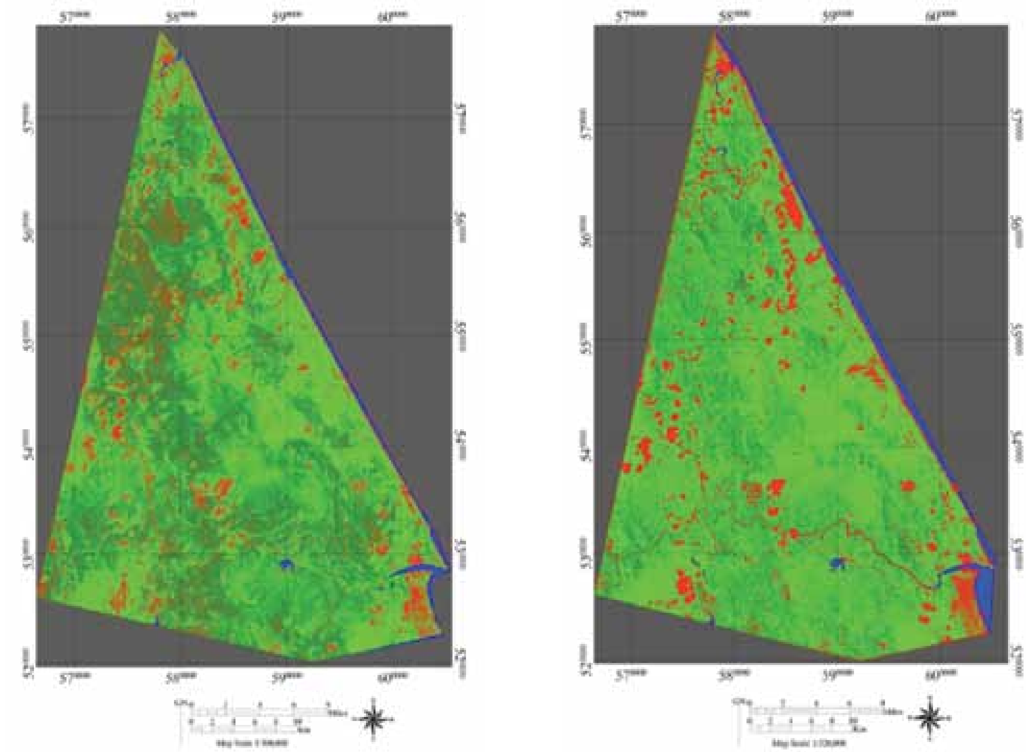
Fig. 2: Fusion Radarsat1- with SPOT-5 (321) (a) HSV (b) PCA

These four classes were selected because they were readily interpreted and also were the main land cover type found in this study area. *Fig. 3* shows the output of the supervised classification while Table 3 illustrates the statistics results of the supervised classification for both classified fused images.

TABLE 2
Map legend

Melaleuca cajuputi	Light green
Acacia auriculiformis	Dark green
Water bodies	Blue
Non-vegetation	Red

In Table 2 the light green chosen for *Melaleuca cajuputi*, dark green for *Acacia auriculiformis*, red for non-vegetation and blue for water bodies.



(a) (b)

Fig. 3: Maximum likelihood classification on (a) HSV fusion (b) PCA fusion

TABLE 3
Statistical result of maximum likelihood classification of fusion images

Classes	Area (ha)		Percent	
	PCA	HSV	PCA	HSV
Melaleuca cajuputi	68465	50471	56.05	42.25
Acacia auriculiformis	32887	47988	26.98	40.17
Non-vegetation	17081	19103	13.98	15.9
Water bodies	3597	1907	2.99	1.59

The classified maps from HSV techniques of two data combination showed overall accuracy 70.02% and kappa 0.4236 and for PCA technique the overall accuracy shows the 82.08% and kappa for classified HSV fused image was 0.42 and for classified image from PCA fused technique was 0.69 (Table 4). Refer to Landis & Koch (1977) Kappa's coefficient of near to +1 shows the best performance.

This means that the PCA fusion technique has better results in fusion Radarsat-1 and SPOT-5 to mapping land cover in Marang area.

TABLE 4
Accuracy assessment for two different fusion techniques

Fusion technique	Overall accuracy	Kappa coefficent
HSV	70.02%	0.42
PCA	82.08%	0.69

CONCLUSION

Radarsat-1 imagery fused with satellite optical imagery can provide accurate information about forest mapping especially in tropical rainy forest. Usually optical images from tropical rainy forest are covered by clouds. Fusion techniques can improve the quality and quantity of information from tropical rainy forest because of penetrates of radar wavelengths into clouds. In other word, these feature can help to fill in the null data in optical images because of clouds and shadows by microwave data.

Based on the assessment results, it may be concluded that PCA fusion of Radarsat-1 with SPOT-5 321 is the best available technique for preserving spatial and spectral information from the original images, so as to more clearly identify distribution of trees in tropical rainy forests.

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