Sains Malaysiana 40(2)(2011): 83–88

Remote Sensing for Mapping RAMSAR Heritage Site at Sungai Pulai Mangrove Forest Reserve, Johor, Malaysia

(Penderiaan Jauh untuk Pemetaan Tapak Warisan RAMSAR di Hutan Simpan Bakau di Sungai Pulai, Johor, Malaysia)

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ABSTRACT

The Sungai Pulai Mangrove Forest Reserve (SPMFR) is the largest riverine mangrove system in Johore. In 2003 about 9,126 ha of the Sungai Pulai mangrove was designated as a RAMSAR site. RAMSAR sites are wetland areas that are deemed to have international importance and are included in the List of Wetlands of International Importance. The SPMFR plays a significant socio-economic role to the adjacent 38 villages. Satellite remote sensing is a useful source of information where it provides timely and complete coverage for vegetation mapping especially in mangroves where the accessibility is difficult. This study was carried out to identify and map land cover types using SPOT-4 imagery at the Sungai Pulai-RAMSAR site and its surrounding areas. Through unsupervised classification technique a total of seven classes of land cover type were mapped, where about 90% mapping accuracy was gained from the accuracy assessment. Later, vegetation densities were classified into five levels namely very high, high, medium, low and very low based on crown density scale using vegetation indices model such as NDVI, AVI and OSAVI. Results from NDVI and OSAVI model were almost similar but AVI model detected more on medium vegetation which did not show the real ground condition. The study concludes that SPOT-4 imagery was able to discriminate mangrove area clearly from other land covers type. Vegetation indices model can be used as a tool for mapping vegetation density level in the SPMFR and its surrounding area. Therefore VI's models from remote sensing are useful to monitor and manage the mangrove forest for sustainable management and preserve the SPMFR as a RAMSAR site in Peninsular Malaysia.

Keywords: Conservation Management; mangrove mapping; RAMSAR site; remote sensing

ABSTRAK

Hutan Simpan Paya Bakau Sungai Pulai (SPMFR) merupakan sistem hutan paya bakau terbesar di negeri Johor. Pada tahun 2003, kira-kira 9,126 ha kawasan paya bakau Sungai Pulai telah diberikan taraf sebagai tapak RAMSAR. Tapak RAMSAR adalah kawasan tanah lembap yang mempunyai kepentingan antarabangsa dan termasuk dalam Senarai Kepentingan Tanah Lembap Antarabangsa. SPMFR memainkan peranan penting dalam sosio-ekonomi kepada 38 kampung yang berdekatan. Penderiaan jarak jauh merupakan sumber maklumat yang bermanfaat kerana ia menyediakan liputan masa yang tepat dan lengkap untuk pemetaan tumbuhan paya bakau terutama di kawasan yang sukar. Kajian ini dijalankan untuk mengenal pasti dan memeta jenis litupan tanah menggunakan imej SPOT-4 di kawasan Sungai Pulai dan kawasan sekitarnya. Dengan menggunakan teknik pengelasan tidak terselia, tujuh kelas tumbuhan telah dihasilkan dan kira-kira 90% hasil pemetaan adalah tepat. Kemudian kepadatan tumbuhan dikelaskan kepada lima iaitu sangat padat, padat, sederhana padat, kurang padat dan sangat kurang padat berdasarkan skala kepadatan silara menggunakan model Indek Tumbuhan (VI's) seperti NDVI, AVI dan OSAVI. Keputusan daripada model NDVI dan OSAVI adalah hampir sama tetapi AVI lebih tertumpu kepada tumbuhan berkepadatan sederhana dan tidak menggambarkan keadaan sebenar di lapangan. Kajian ini jelas menunjukkan data SPOT-4 mampu membezakan kelas hutan bakau daripada tumbuhan yang lain. Indeks tumbuhan boleh digunakan untuk menghasilkan peta kepadatan tumbuhan. Oleh itu, model indeks tumbuhan daripada data deriaan jarak jauh boleh membantu dalam pemantauan dan pengurusan hutan paya bakau secara berterusan serta mengekalkan SPMFR sebagai tapak RAMSAR di Semenanjung Malaysia.

Kata kunci: Pemetaan paya bakau; penderiaan jarak jauh; pengurusan pemuliharaan; tapak RAMSAR

INTRODUCTION

Mangrove forests are highly productive ecosystems that typically dominate the intertidal zone of low energy tropical and subtropical coastlines (Kathiresan & Bingham 2001). In all continents mangroves are distributed world-wide and FAO (2007) estimates that the total area for mangroves are 15.6 to 19.8 million ha. In 2006, mangrove forests area in Peninsular Malaysia is estimated to be about 107,802 ha, of which 82,091 ha have been gazetted as Permanent Reserved Forests (PRFs).

Mangroves, generally grow exceeding one half meter in height, and normally grow above mean sea level (Duke et al. 2007), constitute as one of the most threatened wetland ecosystems (Alongi 2002). Due to the mass distributions of most mangrove species, a few of them are listed in the IUCN Red List of Threatened Species (Polidoro et al. 2010).

In Johor, Sungai Pulai Mangrove Forest Reserve (SPMFR) is the largest riverine mangrove system. The SPMFR is managed primarily for commercial wood production using the silvicultural system that requires clear felling of trees under a 20-year rotation. About 80% of the SPMFR consists of mangrove stands less than 20 years of age. The Port of Tanjung Pelepas authority, located at the estuary, works hand-in-hand with environmental groups for the conservation of the estuary. The site is managed in line with the Integrated Management Plan for the sustainable use of mangroves in Johore. SPMFR is one of the lists in RAMSAR site in Malaysia includes Tasik Bera, Tanjung Piai and Pulau Kukup. RAMSAR is the first of the modern global intergovernmental treaties on the conservation and sustainable use of natural resources for the habitat of humankind in a way compatible with the maintenance of the natural properties of the ecosystem, but, compared with more recent ones, its provisions are relatively straightforward and general.

Managing a vast mangrove ecosystem is challenging due to its harsh ecosystem and accessibility. Satellite remote sensing however, has become an effective tool in the assessment of natural resources from land to ocean because it provides a timely and cost effective means to obtain reliable data over inaccessible areas. Remote sensing is perhaps the only way now to obtain useful information synoptically in mangroves area, complementing field surveys of higher information content but which are more difficult to carry out.

The use of remote sensing to study mangrove environments has increased over the past decade (Blasco et al. 1998; Diaz & Blackburn 2003; Thampanya et al. 2006; Vijay et al. 2005). Remote sensing studies have revealed much about mangrove ecosystems including canopy heights, leaf densities or leaf area index (LAI), deforestation, erosion, and pollution and other anthropogenic changes (Blasco et al. 1998). Remote sensors such as SPOT and Landsat, provide appropriate resolutions for studying changes in mangrove canopy extent and condition. More recently, higher spatial and spectral resolution systems have been used for analysis of within-stand variability and changes (Hirano et al. 2003; Vaiphasa et al. 2005).

Many mangroves ecosystem have been degraded over time as reported by researchers (Dahdouh-Guebes & Koedam 2008; Ellison 2008). The degradation is direct from anthropogenic activities (Alongi 2002; Farnsworth & Ellison 1997). In remote sensing studies, vegetation indices are popular approaches because they are simple mathematical expressions that combine remotely sensed measurements sampled at different spectral wavebands to provide nondestructive estimates of properties of vegetation (Boyd 2001). Thus, this study was carried out to identify and map land cover types using SPOT 4 image in the Sungai Pulai-RAMSAR site and its surrounding areas.

METHOD

STUDY AREA

The Malaysian SPFR is designated as RAMSAR Site No.1288 on 31st January 2003. The location of the site is at 01°23'N 103°32'E and covers an area of about 9,126 ha. The SPFR located at the estuary of the Sungai Pulai in the Pontian

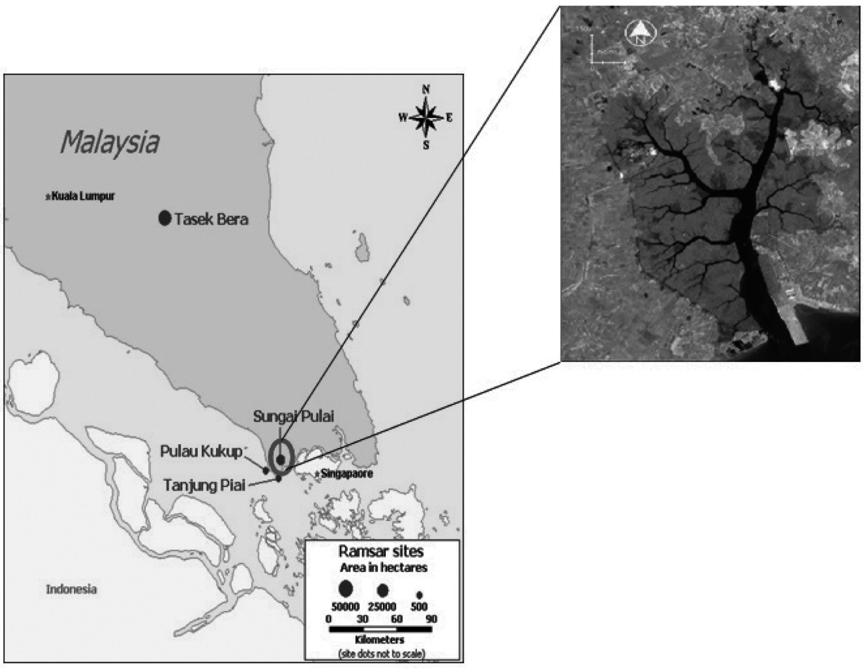

FIGURE 1. The location of Sungai Pulai Mangrove Forest Reserve

District, Johor, Malaysia (Figure 1) (22.6 km long, 2.83 km wide Sungai Pulai estuary). This area is typically represented by a tidal dominated estuarine mangrove swamp. It is the largest and most intact riverine mangrove system in Peninsular Malaysia. The site represents a rich biodiversity, with 24 mangrove species, 21 mangroves associated species, and 7 amphibians, 12 reptile, 55 bird, 26 mammal and 111 fish species. Mammals such as the near-threatened or vulnerable long-tailed and pig-tailed macaque, smooth otter, bearded pig, common porcupine, scaly anteater, the rare flat-headed cat occur, as well as the near-threatened birds mangrove pitta, mangrove blue flycatcher and mangrove whistler can be found. Relatively undisturbed parts including the nipa swamps may be nesting sites of the estuarine crocodiles.

The site is owned by the Johor state. Its surroundings are privately owned. The site is mainly used for mangrove production *(Rhizophora mucronata-Bruguiera parviflora)* and as many economically important fish and shrimp species occur in the area, marine fisheries (including prawns). Fisheries related activities in the mangroves and mudflats are an important supplementary income for local inshore fishermen. Mangrove is also used as wood, charcoal production, aquaculture activities and eco-tourism (e.g. a resort). The site is designated as Forest Reserve and managed in line with an Integrated Management Plan for the sustainable use of mangroves in the Johor state. The main procedure involved in the study were data acquisition, preprocessing such as geometric correction, image classification, ground verification, VI's analyses, and outputs. Figure 2 illustrates the flowchart of the study.

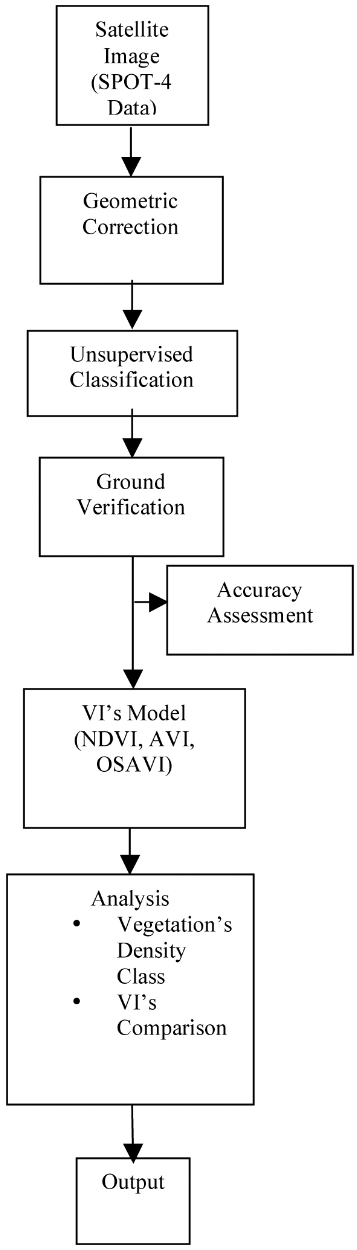

FIGURE 2. A flowchart diagram of the study

VEGETATION INDICES MODEL

There were three vegetation indices model tested.

Normalized Difference Vegetation Index (NDVI), Rouse et al. (1974). NDVI equations produce values in the range of -1.0 to 1.0. Area with green vegetation will have value greater than zero and values near zero or negative values indicate non-vegetated surface features such as water bodies and barren land. NDVI is given as:

$$NDVI = \frac{(NIR\text{-}Red)}{(NIR+Red)}.$$

Advanced Vegetation Index (AVI), Rikimaru (1997). AVI reacts sensitively for the vegetation quantity compared with NDVI which are examining the characteristics of chlorophyll. It same with NDVI that using near infrared and red bands with the following formula:

$$AVI = (NIR \times (256\text{-}R) \times (NIR\text{-}R) + 1)\ ^{1}/_{3},$$
$$(NIR - R) > 0.$$

Optimized Soil-adjusted Vegetation Index (OSAVI), Rondeaux et al. (1996). OSAVI is an adjustment of factor L by developing the new version of Soil- adjusted Vegetation Index (SAVI). It was formulated to minimize the soil and atmospheric perturbations (Steven 1998):

$$OSAVI = \frac{NIR - R}{NIR + R + L},$$

where, L= 0.16 is an optimal value to minimize the variation in soil background.

DENSITY CLASSES SCALE FOR MANGROVE

Mangrove canopy density refers to the percentage area of land covered by the canopy of trees. Percent crown cover is particularly easy to estimate from SPOT-4 data; it is simply the number of vegetation (non-ground) above a certain height divided by the total area of sample. Vegetation density classes were made by observation on the ground and interpretation of intensity on image based on scale by Paine (1981) and Mohd Hasmadi et al. 2008. The density scale class was classified as very high, high, medium, low and very low, where vegetation cover density were performed on VI's image by assigning threshold values for each class.

Results and Discussion

A total of seven classes were identified namely low density mangrove, high density mangrove, mixed horticulture, oil palm, rubber trees, open area/bare land and non-vegetation (Figure 3). The accuracy of mapping obtained from classification was 90%. This result clearly showed that mangrove areas were discriminated well, apart from other vegetation or land cover. Therefore the true capability of this method is how the data can be used to classifying mangrove area into subclasses such as low density and high density cover.

Figure 4 shows a VI's maps from NDVI, AVI and OSAVI. Light green indicate high density mangrove which are dominated SPMFR. According to the Johor Forestry Department, the vegetation age in the study area was mostly in between 4 and 15 years old. Meanwhile, very high density mangrove was detected in dark green. Low density is represented in white and very low in purple. This means that the area are planted by other vegetation like oil palm, rubber trees and mixed horticulture. Red color shows non-vegetation that including water body, open area or bare land and development area.

AVI model showed different pattern of vegetation compared to NDVI and OSAVI model. AVI model detected more on medium vegetation with black color. This means that AVI does not show the real ground condition. NDVI and OSAVI have shown not much different in image (Table 1).

Conclusion

AVI model showed a different pattern of vegetation density compared to OSAVI and NDVI. The area classified by AVI for high density class represent about 29%, meanwhile OSAVI and NDVI were similar with 7%. Furthermore, AVI clearly showed that the model was not appropriate for this area due to low accuracy and does not represent the real ground condition. In order to achieve viable wetland conservation in the Johore state, a great deal of effort has to go in systematizing the inventories at the desired spatial and temporal scales. The extent of synergetic public-private must be established to ensure a natural resource management, conservation are well sustain. This can be supported by giving financial incentives to the local population. Besides that public awareness and education effort is important to create a better understanding among the public and policy makers on the conservation aspects of mangroves forest management. The role of satellite imagery in mapping and managing of wetland area must be emphasized, especially in understanding the technology and science of the remote sensing and vegetation in management planning process. Furthermore, the success in the sustainable management of mangrove forests by the country has contributed to the sustainability

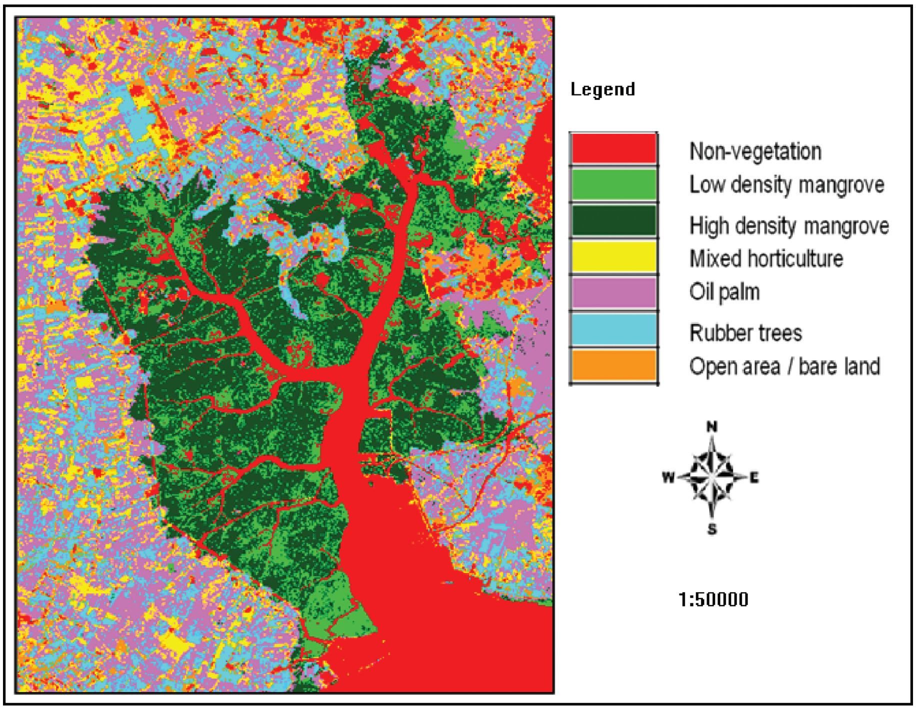

FIGURE 3. Unsupervised classification result

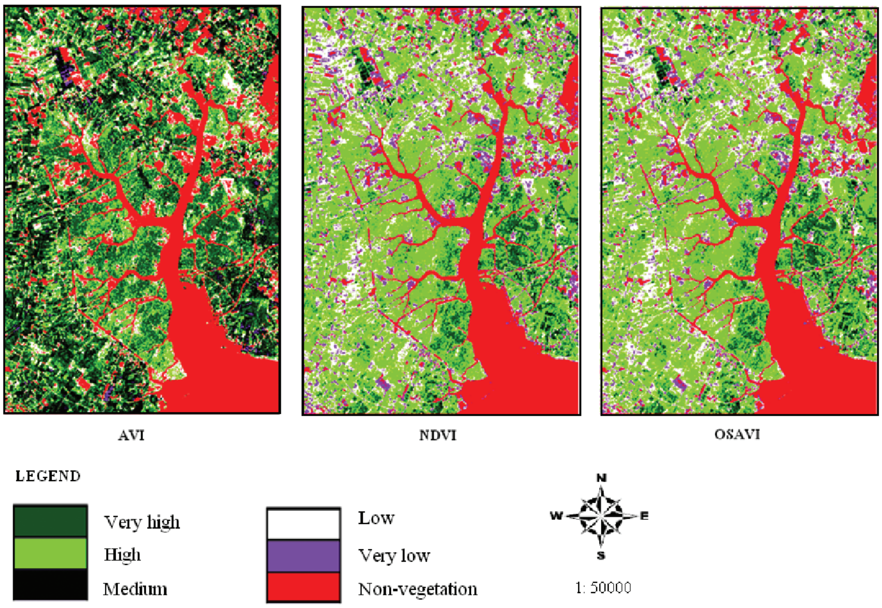

FIGURE 4. VI's Maps from AVI, NDVI and OSAVI model on SPOT-4

TABLE 1. A summary of VI's Models

VI Model	Area (ha)	Area (%)	VI's Value Range	Vegetation Density (%)
AVI				
Very high density	7696.12	29%	61 - 75	> 85 %
High density	5433.76	21%	50 - 60	55 - 85 %
Medium	2985.96	11%	76 - 110	40 - 55 %
Low	4017.36	15%	33 - 49	10 - 40 %
Very low	190.44	1%	110 - 163	< 10 %
NDVI				
Very high density	1943.8	7%	226 - 230	> 85 %
High density	12168.12	46%	211 - 225	55 - 85 %
Medium	137.96	1%	231 - 242	40 - 55 %
Low	5588.64	21%	190 - 210	10 - 40 %
Very low	1823.76	7%	170 - 189	< 10 %
OSAVI				
Very high density	1937.6	7%	226 – 231	> 85 %
High density	12119.56	46%	211 - 225	55 - 85 %
Medium	137.04	1%	232 - 242	40 - 55 %
Low	5288.08	20%	192 - 210	10 - 40 %
Very low	2171.68	8%	170 - 191	< 10 %

of the RAMSAR-Wetlands in Peninsular Malaysia which is crucial for future survival. Incorporation of remote sensing data may assist the inventories of mangroves resources as well as managing coastal ecosystem over time.

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Received: 5 November 2009
Accepted: 6 August 2010