Journal of Biodiversity and Ecological Sciences

No.1, Vol.1, Issue1
ISSN: 2008-9287
Winter 2011 JBES

Original Article

Performance of intrinsic and soil line-based vegetation indices to mangrove mapping in Malaysia

Received Date:Oct/29/2010
Accepted Date:Dec/30/2010

Mohammad Hasmadi Ismail[1*]

Che Ku Akma Che Ku Othman[1]

Norsaliza Usali[1]

1-[*]Forest Surveying and Engineering Laboratory, Faculty of Forestry, University Putra Malaysia 43400 UPM, Serdang, Selangor, Malaysia
Tel: 603 89467220,
mhasmadi@putra.upm.edu.my

Abstract

The use of vegetation indices of remote sensing data in vegetation mapping has been long recognised. However, the accuracy of mapping through the use of vegetation indices model has limitations, and has so far not been investigated. This study analysed the performance of the several intrinsic-based vegetation indices (Normalized Difference Vegetation Index-NDVI and Ratio Vegetation Index- RVI) and soil line-based vegetation indices (Perpendicular Vegetation Index-PVI, Soil-Adjusted Vegetation Index-SAVI and Modified Soil-Adjusted Vegetation Index-MSAVI) for mangrove mapping in Kelantan Delta, Malaysia. Landsat TM was used as a primary data set to derive mangrove vegetation class from five vegetation indices model. A total of five mangrove classes consisting of *Avicennia-Sonneratia*, *Avicennia*, *Acanthus-Sonneratia*, Mixed-*Acrostichum* and Mixed *Sonneratia* with accuracy 72.67% were determined from unsupervised classification. Then the models were applied on classified image, resulting in mangrove classes which were mapped into three and four classes, respectively. The performance of each VI's was analysed in accuracy assessment. The accuracy assessment of vegetation indices were ranged from 69.17% to 79.14%. The results revealed that the SAVI was the better performance discriminate mangrove class amongst the four classes compared to others indices with accuracy 79.14%. It might be due to sensitiveness of SAVI model in discriminating the full range of vegetation covers in muddy area. The capability of Landsat TM in mapping mangrove in this study using VI's models showed the better result, However, the performance of VI's need to be further investigated for specific use of mangrove resources. This is important where accurate information on mangrove biodiversity status in all habitat level is needed for conservation and monitoring towards achieving sustainable development to the country.

Key-words: *mangrove mapping, vegetation indices performance, Landsat TM, accuracy assessment*

Introduction

Mangrove is defined as the plant community that colonizes the muddy shores of sheltered coasts and river estuaries (Soepadmo, 1998). Mangrove is a unique group of forest wetland that is dominant in tidal and saline estuaries of tropical and subtropical coasts (Twilley, 1998). According to Saenger *et al.* (1983) there are around 80 species of mangroves found throughout the world and they can be divided into two distinct groups as exclusive and non-exclusive. Exclusive mangrove are the largest group, comprising around 60 species and confined to intertidal areas and have not been found to exist within any other type of vegetation communities.

Peninsular Malaysia is covered by approximately 101,877 ha of mangrove forest (Mohd Lokman and Sulong, 2001), and they develop well in sheltered estuaries where water is brackish, and the wave and tidal conditions are conducive for mud accumulation (Mastaller, 1997). The east coast of Peninsular Malaysia is more exposed and thus only small mangrove areas confined to river mouth; 2,400 ha in Terengganu, 4,640 ha in Pahang and 150 ha in Kelantan. The naming of the mangrove forest types were based on the presence of one or more dominant species on the ground. If the number of particular dominant species was more than 80%, then the forest type was named that species. If there were two dominant tree or forest types, showed 50-50% of each type then this class were refer as both dominant tree or forest type. The class will be referred to as mixed of the dominant species if the species have only one dominant type and the other tree type were found to be only a few. If more than three dominant species are present, the class is referred to as mixed mangrove (Sulong *et al.,* 2002).The role and importance of mangrove wetland has been long recognised. Mangrove wetlands maintain high level of biological productivity, export nutrients to outside water and provide habitat for valuable plant and animal species (Clark, 1996). Mangrove ecosystems maybe directly exploited by extraction goods such as fish, agricultural products, wildlife, and wood (Kovacs, 1999). Changes in mangrove directly impact surface water and energy budgets though plant transpiration, surface albedo, emissive, and roughness (Aman *et al.*, 1992).

There have been tremendous efforts made in mapping mangrove areas since the launching of the first remote sensing satellite in 1970’s. The advancement of image processing established many techniques and models for mapping vegetation including vegetation indices (VI’s) model approaches. VI is formed from combination of several spectral values that are mathematically recombined in such a way as to yield a single value indicating the amount or vigor of vegetation within a pixel (Campbell, 1996). VI's were also defined as the number generated by some combination of remote sensing bands that may have some relationship with the amount of vegetation in a given image pixel (Ray, 1995). VI was also defined as the combination or algebra manipulation of band (spectral) information to enhance vegetation and subdue other influences like unequal illumination and soil background reflectance which are commonly referred to as vegetation indices. As reported by Green *et al.* (1998), the earliest attempt to classify mangroves using vegetation indices was done by Blasco *et al. (*1986). The mangrove was classified using the SPOT imagery but was unable to determine the species type. However, according to Chaudhury (1990), two dominant species of Sunderbands mangrove forest in Bangladesh could be determined using VI's. Later vegetation indices have been used commonly to estimate other aspects of plant parameters such as crop production, vegetation stress, vegetation density, species class and age detection. The application of VIs in mangrove forest also has been well documented in other literatures (Ramsey and Jensen, 1996; Green *et al.*,1998; Wang *et al.*, 2004; Mohd Hasmadi *et al.*, 2008). The understanding of the relationships between mangrove canopy reflectance, structure and species are important to fully exploit remote sensing of mangrove from satellite platform (Badhwar *et al.*, 1985; Nagelkerken *et al.,* 2008) and cost effective way to gain insight mangrove area (Dadouh-Guebas,2004). Vegetation indices have typically been obtained from spectral reflectance's of red and near infrared bands to evaluate vegetation canopies.

In Malaysia, mangrove mapping by VI's is relatively new and not yet explored. An early study on VI's was conducted by Hussin and Hashim (1997), but demonstration has been made to identify forest plantation species. Suffian (2001) used VI's to identify mangrove vegetation species in the east coast of Peninsular Malaysia using Landsat TM. A more recent study by Mohd Hasmadi *et al.,* (2008) found that VI's was very useful in monitoring of coastal vegetation in a large scale especially for ecological and coastal protection. Accuracy of mapping from image processing method should be determined and evaluated. No matter how sophisticated the classification approach, the value of satellite image map is severely compromised if its accuracy is argued. The objectives of this study therefore is to analyse the performance of the several intrinsic-based vegetation indices (Normalized Difference Vegetation Index-NDVI and Ratio Vegetation Index-RVI) and soil line-based vegetation indices (Perpendicular Vegetation Index-PVI, Soil-Adjusted Vegetation Index-SAVI and Modified Soil-Adjusted Vegetation Index-

MSAVI) for mangrove mapping in Kelantan Delta, Malaysia.

Intrinsic-based vegetation index and Soil Line –Based vegetation indices

Intrinsic indices or simple ratio is the simplest and the most widely used index in remote sensing for vegetation studies. Vegetation has a characteristics spectral response pattern where visible blue and red (630-690 nm) energy is absorbed strongly, visible green light is reflected weakly (hence giving vegetation its green colour) and NIR (760-900 nm) energy is very strongly reflected. Because of this characteristics spectral response pattern, many of the VI's models use only the red and near infrared imagery bands. The performance of VI's especially NDVI and RVI over various types of vegetation in tropical forest plantation from Landsat TM was studied by Hussien and Hashim (1997). They found that NDVI and RVI were of significance in discriminating the forest species.

The soil line is a linear relationship between the NIR and R reflectance of bare soil originally discovered by Richardson and Wiegand (1977) with NIR = aR + b, where 'a' being the soil line slope and b the intercept. The spectral reflectance of a plant canopy is a combination of the reflectance spectra plant and soil component, governed by the optical properties of these elements and photon exchange with the canopy. In general soil reflectance is relatively low (≤ 10%), the blue channel, but decrease monotonically with wavelength through the visible and NIR regions. The severity of soil noise decreases in both sparser vegetation canopies and in more humid, dense vegetation conditions. This background influence must be removed in order to better interpret spatial and temporal variation associated with vegetation and from variation associated with the canopy background. It also must be removed in order to get an exact reading of vegetation indices without any alteration by canopy background or soil noise.

Material and Methods

Study area, data acquisition and image processing

Kelantan Delta located at the eastern of Peninsular Malaysia, lies between latitudes of 06° 11'N to 06° 13'N and longitude of 102° 10'E to 102° 14'E (Figure 1). The total area is approximately 1,200 ha. Landsat TM was acquired from scene 127/56 (path/row), with spatial resolution of 30 m. Image was obtained from The Malaysian Remote Sensing Agency. This image was taken on 28th May 2006. Geometric correction process was done based on the ground control points (GCP's) collection, which were taken during the ground verification work and also from previous July 2004 geocoded image. All corrected images were justified based on root mean square error (RMS) of less than half a pixel (Lillesand *et al.,* 2004) by using the first polynomial order. The image use Rectified Skew Ortomorphic (RSO) projection with spheroid of modified Everest and Kertau 1948 as the datum. Erdas Imagine 8.7 was used as image processing software. Unsupervised classification technique using Iterative Self Organizing Data Analysis Technique (ISODATA) was applied for image classification. The classification was started from the 100 classes of unknown land covers with 60 iterations. This process was then followed by redefining the criteria for each class and reclassifies the class again into 4 or 5 classes. VI's is calculated using near red and infrared bands of Landsat TM (band 3 and 4)

Ground verification was carried out in September 2007 to verify the land cover features from classification outputs. A random sampling was conducted from 300 samples sites. The location of each sites were determined using GPS with probable radius error of 2-5 m. All collected samples on the ground were used for the accuracy assessment. The accuracy assessment of mapping was evaluated by error matrix (Congalton, 1991). The sample points were carefully chosen making sure that the test and the training data set were equally spread geographically. Each classified image was then crossed with the test data to generate a confusion matrix.

In image processing steps image enhancement was not performed. A 3 X 3 majority enhancement filter was applied to the imagery. The linear nature of mangrove was determined through a side boundary of each composition species. VI's is calculated using near red and infrared bands of Landsat TM (band 3 and 4). The VI's models were performed and analyzed using Spatial-Modeler module. The models involved in analysis are as follows;

$$\text{NDVI [24]} = \frac{\text{(NIR-Red)}}{\text{(NIR+Red)}} \quad (1)$$

$$\text{RVI [25]} = \frac{\text{NIR}}{\text{Red}} \quad (2)$$

$$\text{PVI [21]} = \sin(a)\,\text{NIR} - \cos(a)\,\text{Red}$$

where, a = angle between soil line and NIR axis. (3)

$$\text{SAVI [26]} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R} + \text{L}} \times (1 + \text{L})$$

where, L = 0.16 is an optimal value to minimize the variation in soil background. (4)

$$\text{MSAVI [27]} = \frac{(\text{NIR} - \text{R}) \times (1 + \text{L})}{(\text{NIR} + \text{R} + \text{L})}$$

Where, L = 1-2a X NDVI X WDVI, a = soil line intercept WDVI= Weighted differentiate vegetation index. (5)

Results and Discussion

The intrinsic-based vegetation indices and soil line-based vegetation indices were analysed by the clustered digital number (DN) or digital value of the classified pixel. The use of DN from each VI's model is adequate to differentiate mangrove species. The distribution and development of mangrove communities are largely affected by several factors such as sediment transportation, landform characteristics and physical process of coastal environment. Five species of mangrove classes namely *Avicennia,*

Avicennia-Sonneratia, Acanthus-Sonneratia, Mixed-Sonneratia, Mixed Acrostichum were mapped for the Kelantan delta. Table 1 summarized the mean and range of each class for five VI's model from Landsat TM. Generally, VI's model overlapped in indices classification, mostly to all species except to *Acanthus-Sonneratia* with their own class. The classification of mangrove classes based on their DN reflectance after applying each VI's model is illustrated in Figure 2. Due to mixed species composition in the delta the classification was recoded, where NDVI, PVI, SAVI output were classified into three classes, while RVI and MSAVI into four, respectively. Most *Avicennia* spp. was dominated near or along the coastal area, meanwhile other species such as *Sonneratia* spp., *Acanthus* spp. and *Acrostichum* spp. were found in saline estuaries area. A few species also were identified along mangrove terrestrial such as *Hibiscus* spp. and *Nypa fructicans* which grows along river banks and act as a buffer zone.

The performance of VI's model applied is shown by the accuracy assessment results in Figure 3. In accuracy assessment, a total of 300 random sampling points were used to determine the overall accuracy for each output image of the models. It is shown that the influences of texture feartures of VI's model to classification are slightly different. The highest accuracy obtained for all indices was SAVI (79.17%, kappa statistic 0.73). The accuracy results when using MSAVI shows an overall accuracy of 78.89%, followed by RVI and NDVI similar with 74.44, and RVI with 69.17%.The results show that different VI's model have a different spatial features in the classification. The higher accuracy as shown by the SAVI model suggests that the mangrove species has a sufficiently spectral distribution that is able to represent the respective classes. In addition, the large range of index and small susceptibility to atmospheric effects, offers the best slicing possibilities at improving the classification of mangrove forest. In this study, the number of mangrove forest can be increased by adjustment of the parameter of L from 0.5 into 0.16 as recommended by Rondeaux *et al.*, (1996). The value of L=0.16 rather than 0.5 is found to give satisfactory reduction of soil noise both at low and high vegetation cover. SAVI also can be applied for general purpose vegetation classes because of belief that it had more constant sensitivity over the full range of vegetation cover.

NDVI enabled discriminate three classes respectively similar with MSAVI and PVI. MSAVI present as second higher performance (78.89%) compared to PVI and NDVI (74.44%). It was because of the weakness of PVI to reduce the soil noise background from vegetation area. It also suggested by Rondeaux *et al.*, (1996), which mentioned that PVI is still significantly affected by soil. RVI distinguished four classes and has accuracy of 69.17%. Graetz (1990), stated that the canopy background is the main effect to RVI model, although it has ability to distinguish the soil and vegetation well, but not in shady area. The mangrove forest with dense of species or trees was also difficult for VI's especially intrinsic based index to separate the classes. Mohd Suffian (2001) noted, the NDVI become saturated when its value reaches 0.63 (DN), whereby it no longer responds to variations in green biomass. Consequently, the area might be difficult to identify forest type for mapping.

Conclusion

The study using Landsat TM image of Kelantan Delta in Malaysia showed the performance of different VI's model in mangrove classification. It is shown that SAVI model can improve the classification accuracy compared to other models. SAVI had shown the best performance with accuracy 79.14% and determined four mangrove classes namely *Acanthus-Sonneratia, Avicennia, Avicennia-Sonneratia*, Mixed *Acrostichum* and Mixed *Sonneratia*. Therefore SAVI is an effective spatial feature to improve the performance mangrove classification in Kelantan delta. The external factors such as background materials like soil, water and atmospheric (cloud and gasses) can affect the reflectance of each VI's model. Even mangrove physiologically exposed to high salt levels is not affected by high variability of NIR reflectance, whereas NIR is the most important spectrum in discriminating mangrove vegetation. It is necessary and important to find effective spatial features from high resolution remotely sensed data. A accurate information is important on mangrove biodiversity status in all habitat level for conservation and monitoring towards achieving sustainable development to the country. Further studies to improve the use of the other VI's model to mangrove mapping techniques are required. This includes development of new algorithms that work well in tropical mangrove forest using hyperspectral data.

Reference

1. Aman, A.; Randriamanantena, H.P. ; Podaire, A. ; Froutin, R., (1992). Upscale integration of normalized difference vegetation index: The problem of spatial heterogeneity. *IEEE Transactions on Geoscience and Remote Sensing*, 30: 326-338.

2. Badhwar, G.D.; Verhoef, W.; Bunnick, N.J.J., (1985). Comparative of suits and SAIL canopy reflectance models. *Remote Sensing of Environment*, 17:179-260.

3. Blasco, F.; Lavenu, F.; Bareza, J., (1986). Remote Sensing data applied to mangrove of Kenya coast. Proceeding of the 20th International Symposium on Remote Sensing of the Environment. Pp: 1465-1480.

4. Campbell, J.B., (1996). Introduction to Remote Sensing. Taylor and Francis, London, 622p.

5. Chaundry, M.U., (1990). Digital analysis of remote sensing data for monitoring the ecological status of the mangrove forests on sunderbands in

Bangladesh. Proceeding of the 23rd International Symposium on Remote Sensing of the Environment. pp: 493-497

6. Clark, J.R., (1996). Coastal Zone Management Handbook. CR Press, Boca Raton, Florida. 68p.

7. Congalton, R.G., (1991). A review of assessing the accuracy of classification of remotely sensed data. *Remote Sensing Environment*, 37(5):35-46.

8. Dadouh-Guebas, F.(2004). Qualitative distinction of congeneric and introgressive mangrove species in mixed patchy forest assemblages using high spatial resolution remotely sensed imagery (Ikonos), *Systematics and Biodiversity*, 2(2):113-124.

9. Graetz, R.D., (1990). Remote sensing of biosphere functioning. Springer-Verlag,New York,U.S.A.

10. Green,E.P.; Clark,C.D.; Mumby,P.J.; Edwards, A.J., (1998). Remote sensing technique for mangrove mapping. *Int. J. of Remote Sensing*, 19(5): 935-956.

11. Hussein, N.A.; Hashim, M., (1997). Separation (recognition) of tree species or species composition in an old growth forest plantation in peninsular Malaysia using the vegetation index approach. Proceeding of the 18th Asia Conference on Remote sensing of the Environment,20-24 October 200,Kuala Lumpur.pp:194-202.

12. Jordan, C.F., (1969). Deviation of LAI from quality of light on the forest floor. *Ecology* , 50 : 663-666.

13. Kovacs, J.M., (1999). Assessing mangrove uses at the local scale. *Landscape Urban Plan*, 43: 201-208.

14. Lillesand, T.M.; Kiefer, R.W.; Chipman, J.W., (2004). Remote Sensing and Image Interpretation. 5th edition. : John Wiley & Sons, USA. 345p

15. Mastaller, M., (1997). Mangrove: The forgotten forest between land and sea. 1st edition, Tropical Press Sdn Bhd, Kuala Lumpur.67p

16. Mohd Hasmadi,I.; Pakhriazad,H.Z.; Kamaruzaman, J., (2008). Mangrove Canopy Density of Sungai Merbok Forest Reserve, Kedah from Landsat TM. *Journal Malaysian Forester*, 71(1):67-74.

17. Mohd Lokman, H.; Sulong, I., (2001). Mangrove of Terengganu. MARU, KUSTEM and FDPM. 58p.

18. Mohd Suffian, I., (2001). Identification of vegetation species in the east coast mangrove of Peninsular Malaysia using vegetation index. M. Sc. thesis. Kolej Universiti Sains dan Teknologi Malaysia. 190p.

19. Nagelkerken, I., S. Blaber, S. Bouillon, P. Green, M. Haywood, L.G. Kirton, J.-O. Meynecke, J. Pawlik, H.M. Penrose, A. Sasekumar, P.J. Somerfield (2008). The habitat function of mangroves for terrestrial and marina fauna: a review. *Aquatic Botany*, 89(2): 155-185.

20. Qi, J.; Chehbouni, A.; Huete, A.R.; Kerr, Y.H.; Sorroshian, S., (1994). A Modified Soil Adjusted Vegetation Index. *Remote Sensing of Environment*, 47: 1-25.

21. Ramsey, E.W.; Jensen, J.R., (1996). Remote sensing of mangrove wetlands: Relating canopy spectra to site specific data. *Photogrammetric Engineering and Remote Sensing*, 62 (8): 939-948.

22. Ray, T.W., (1995). Remote monitoring of land degradation in arid/semiarid region. Ph. D thesis. California Institute of Technology, Pasadena, CA. 415p.

23. Richardson, A.J., Wiegand C.L., (1977). Distinguishing vegetation from soil background information. *Photogrammetric Engineering and Remote Sensing*, 43:15-41.

24. Rondeaux, G.; Steven, M.; Baret, F., (1996). Optimization of soil adjusted vegetation indices. *Remote Sensing of Environment*, 51: 375-384.

25. Rouse, J. W.; Haas, R. H.; Schell, J. A.; Deering, D. W.; Harlan, J. C., (1974). Monitoring the vernal advancement of retrogradation of natural

vegetation. NASA/GSFC, Type III, Final Report, Greenbelt, MD, USA. 371 p.

26. Saenger, P.; Hergerl, E.J.; Davie, J.D.S., (1983). Global status of mangrove ecosystem. Commission on Ecology Papers number 3. IUCN. Gland, Switzerland, 88p.

27. Soepadmo, E., (1998). Plants. The Encyclopedia of Malaysia. Kuala Lumpur, Archipelago Press.78p

28. Suffian, I., (2001). Identification of Vegetation Species in the East Coast Mangrove of Peninsular Malaysia Using Vegetation Index. M.Sc. Thesis, Kolej Universiti Sains dan Teknologi Malaysia, Terengganu, Malaysia. 190p

29. Sulong, I.; Mohd-Lokman, H.; Mohd Tarmizi, K.; Ismail, A., (2002). Mangrove mapping using Landsat imagery and aerial photographs: Kemaman District, Terengganu. Malaysia. *Environment, Development and Sustainability*, 4: 135-152

30. Twilley, R.R., (1998). Mangrove wetlands In: M.G. Messina and W.H. Corner (Eds). Southern Forested Wetlands: Ecology and Management. Lewis Publishers, Boca Raton, Florida, 490p.

31. Wang, L.; Wayne, P.S.; Gong, P.; Gregory, S.B., (2004). Comparison of Ikonos and Quickbird Images for Mapping Mangrove Species on the Caribbean Coast of Panama. *Remote Sensing of Environment*, 91: 432-440.

Table 1: Mean and range of DN reflectance of mangrove species based on VI's model from Landsat TM.

VI's Model	Species	Mean	Range (DN value)
NDVI	*Avicennia*	36.7	30.1-39.9
	Avicennia-Sonneratia	44.2	41.0-48.2
	Acanthus-Sonneratia	51.0	48.9-54.6
	Mixed *Sonneratia*	39.2	37.4-40.2
	Mixed *Acrostichum*	46.0	40.5-48.8
RVI	*Avicennia*	95.6	80.4-113.2
	Avicennia Sonneratia	123.1	113.8-130.8
	Acanthus Sonneratia	204.9	171.9-233.2
	Mixed *Sonneratia*	97.5	81.9-113.1
	Mixed *Acrostichum*	145.9	130.9-171.5
PVI	*Avicennia*	22.32	17.38-26.75
	Avicennia Sonneratia	-12.80	-24.02-4.69
	Acanthus Sonneratia	2.71	-2.75-11.61
	Mixed *Sonneratia*	6.77	2.00-10.74
	Mixed *Acrostichum*	-9.83	-13.73-3.15
SAVI	*Avicennia*	239.64	230.24-249.39
	Avicennia Sonneratia	177.05	167.05-187.75
	Acanthus Sonneratia	217.08	200.45-228.82
	Mixed *Sonneratia*	213.87	203.68-227.31
	Mixed *Acrostichum*	194.27	191.18-199.13
MSAVI	*Avicennia*	0.76	0.38-0.99
	Avicennia Sonneratia	5.39	4.11-6.87
	Acanthus Sonneratia	2.47	1.33-3.89
	Mixed *Sonneratia*	2.91	2.03-3.93
	Mixed *Acrostichum*	3.70	3.05-3.99

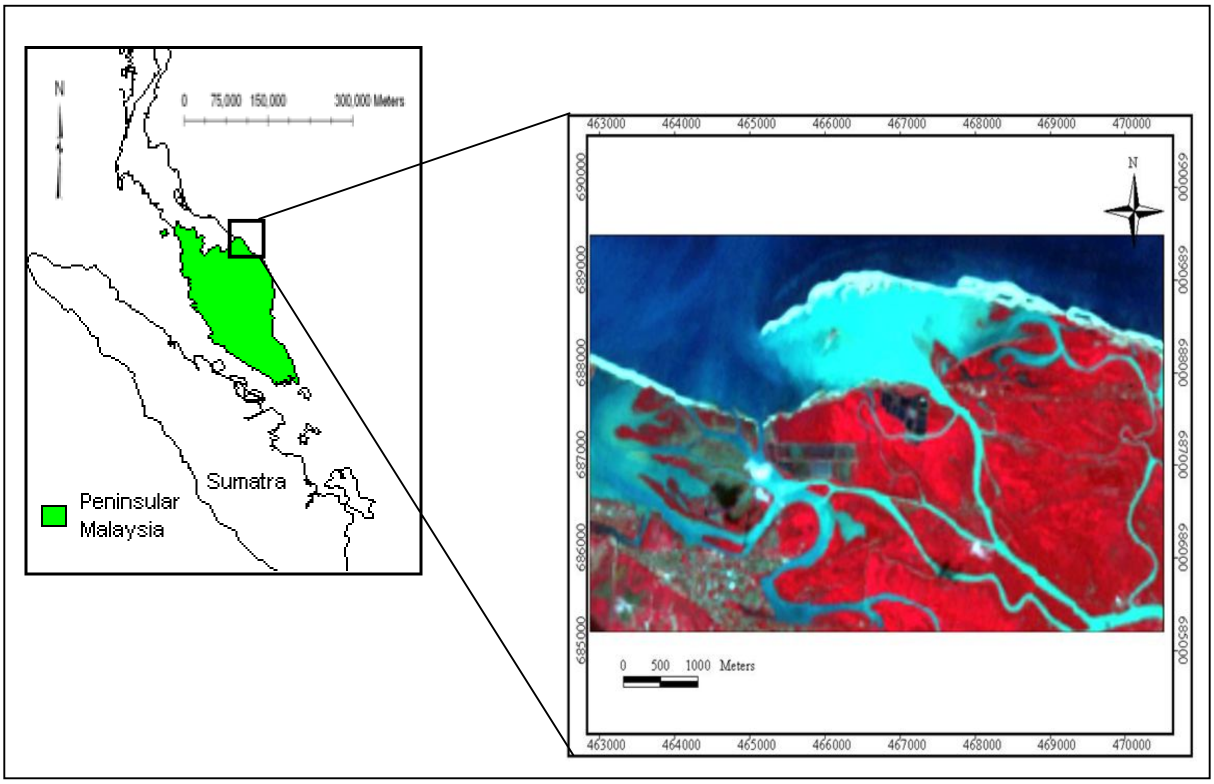

Figure 1: Map showing the location and satellite image of study area

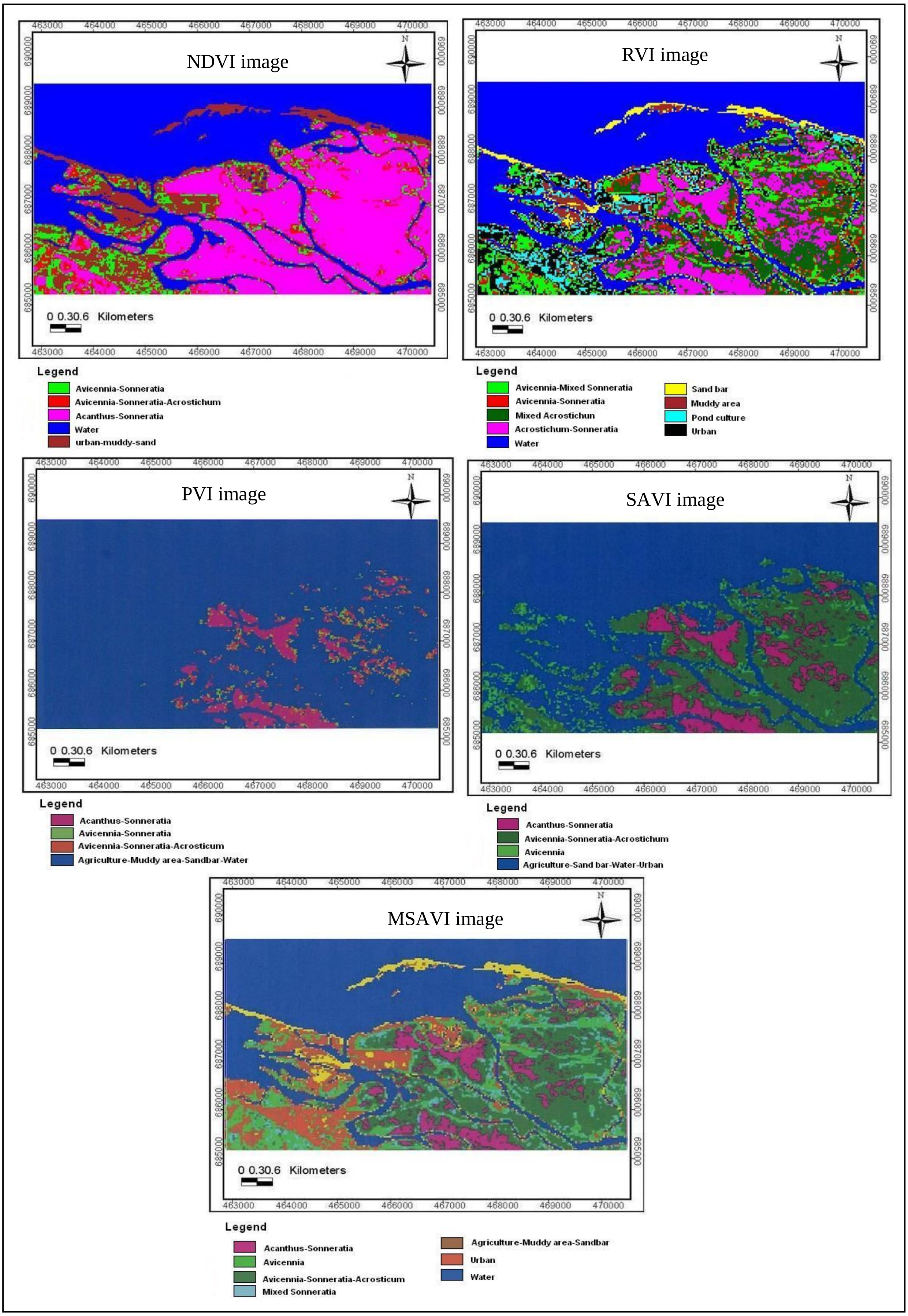

Figure 2: The classified mangrove classes in Kelantan Delta by each VI’s model.

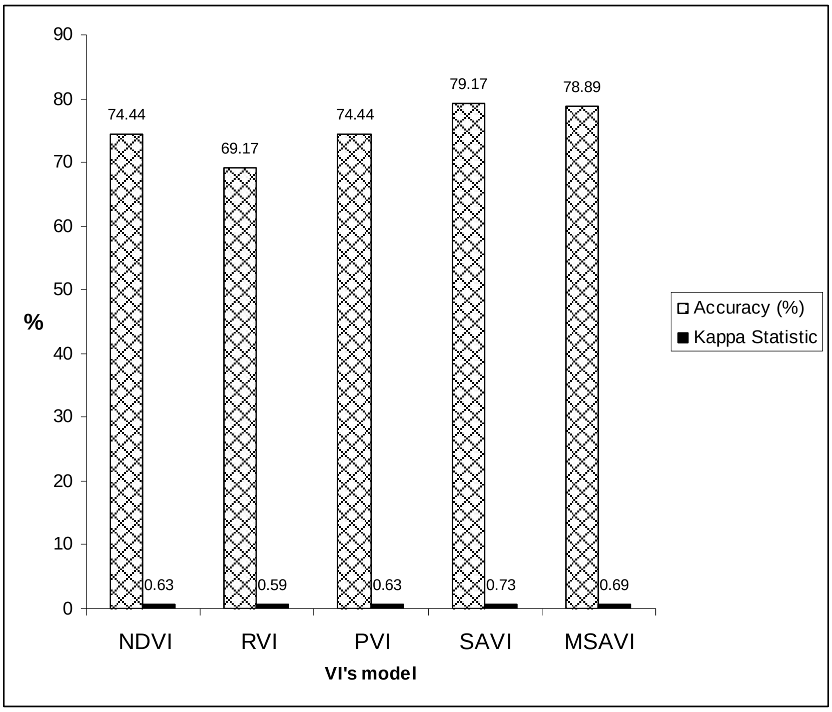

Figure 3: The performance of different VI's model, classification accuracies and kappa statistic for mangrove mapping in Kelantan Delta.