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Applicability of RapidEye Satellite Imagery in Mapping Mangrove Vegetation Species at Matang Mangrove Forest Reserve, Perak, Malaysia

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ABSTRACT

Mangroves are typically made up of salt tolerant species of vegetation with great diversity of flora and fauna which is mainly found in tropical and subtropical climate country. However, these forest ecosystems have been declining over time due to the various kinds of direct and indirect pressure. Thus, there is increasing need and efforts to monitor and assess this ecosystem for better conservation and management. In this study, multispectral RapidEye satellite image was analysed to identify the mangrove vegetation species within the Matang Mangrove Forest Reserve in Perak, Malaysia. The Maximum Likelihood Classifier (MLC) was used to classify the mangrove vegetation species with integration of Normalized Difference Vegetation Index (NDVI) using $NDVI_{Red}$ and $NDVI_{Red\ Edge}$ data. Eleven species of mangrove vegetation were found within the study area including from the genus of *Rhizophora, Avicennia, Bruguiera, Sonneratia* and *Xylocarpus*. The overall classification accuracy assessment of RapidEye multispectral image integrated with $NDVI_{Red\ Edge}$ was higher at 87.5% with overall kappa statistics recorded of 0.85 compared to with employment of $NDVI_{Red}$ at 85% and kappa statistics of 0.80. The results indicated the applicability of red edge band in the RapidEye satellite imagery in combination with ancillary and field data to classify the mangrove species within the study area. It also helps for better management and conservation process to ensure the sustainability of these valuable resources.

Key words: Classification, Normalized Difference Vegetation Index, red edge, RapidEye satellite imagery, Matang Mangrove Forest Reserve

INTRODUCTION

Mangroves are forest that form forest intertidal ecosystems represented by a variety of tree species which mainly occurs worldwide along tropical and subtropical coasts (Conchedda *et al*., 2008; Kovacs *et al*., 2011). Mangrove forests are essential for economic, ecological, scientific and also culture resources which make them as one of the most valuable coastal resources for current and upcoming generations (Jusoff, 2008a). They offer a habitat for a wide variety of species with some occurring in high densities (Nagelkerken *et al*., 2008). This ecosystem also functions as shelter and sanctuary for fauna and also provides spawning and breeding ground for marine life (Jusoff, 2008a). Furthermore, they also act as natural coastline protection such as protecting the coasts against erosion, tsunamis, typhoon damage, wave action, pollutant absorption and also water purification (Neukermans *et al*., 2008; Howari *et al*., 2009). Apart from that, various forestry products are also obtained from mangrove trees such as charcoal, firewood, timber and also the production of poles which contribute a lot of profit to the countries income (Chun *et al*., 2011; Jusoff, 2008b).

Though the mangrove ecosystem plays an important role in many aspects, unfortunately they are threatened by various anthropogenic activities for various purposes. They are being threatened and exploited due to the increasing coastal development projects, wood extraction, human populations and food production (Field, 1999) and also conversion to aquaculture and salt ponds (Vo *et al*., 2013). Therefore, monitoring and protection of mangroves ought to be given top priority (Liu *et al*., 2008). There is an increasing need to monitor and assess mangrove forest structure and dynamics in order to increase a better understanding of their basic biology and also help for guidance in conservation, restoration and management efforts of the ecosystem (Wang *et al*., 2004).

In order to implement a well-timed, effective and efficient monitoring and management process of mangrove forest resources thus, an accurate, cost reasonable and immediate mangrove forest cartography technique is needed (Liu *et al*., 2008). The ground inventory for mapping mangrove is tremendously difficult, time consuming and costly due to the remote location of some areas and the nature of the mangrove environment itself (Benfield *et al*., 2005). Thus, the remote sensing tools would greatly assist in this effort to accurately map mangrove species (Wang *et al*., 2004). Moreover, remote sensing technology is proficient in gathering the information of mangrove forests in wide range scale from the unwelcome environment of mangrove forests which is logistically, extremely difficult to survey (Liu *et al*., 2008; Vaiphasa *et al*., 2006). Other than that, it is an alternative method which provides better way of mapping as it does reduce time and human energy and also timely and economical alternative in order achieving this objective (Tsai *et al*., 2005; Kamaruzaman and Kasawani, 2007). Combination of remote sensing data with field survey provides an ideal method in monitoring and assessing the status of mangrove forests and their environment (Neukermans *et al*., 2008).

Nowadays, there are a large number of satellite remote sensing systems in use which are specifically designed to collect and gather information for the observation of various types of earth's surface such as forests, crops, land use, water bodies and others (Campbell, 2002). These remotely sensed images data are characterized by spatial and spectral resolution (Bhandari *et al*., 2012). Remotely sensed data used in mangrove forest study started with aerial photos which mainly depended on manual interpretation (Liu *et al*., 2008). Ibrahim and Hashim (1990) conducted a research to identify and classify the species groups of mangrove forest in order to delineate their distribution and also to quantify their coverage by using aerial photographs. More recently, multispectral remote sensing images are very efficient in obtaining and gaining a better understanding of the earth environment (Ahmadi and Nusrath, 2010). Kirui *et al*. (2013) conducted a research on mapping of mangrove forest land cover change along the Kenya coastline by exploring the usefulness of Landsat imagery.

With the recent launching of the "Very High Resolution" (VHR) satellite sensors IKONOS and QuickBird, it offers a new chance to map land cover types at a much higher spatial resolution compared to the previous available sensors (Wang *et al*., 2004). Neukermans *et al*. (2008) mapped four dominant mangrove species in Gazi Bay Kenya through per-pixel classification of multispectral QuickBird satellite image. Mangrove species mapping at the Caribbean coast of Panama demonstrated the ability of IKONOS and QuickBird images in classifying mangrove species

(Wang *et al*., 2004). Apart from that, Huang *et al*. (2009) applied IKONOS imagery to evaluate morphological texture features to distinguish the red (Rhizophora mangle), white (Laguncularia racemosa) and also black (Avicennia germinans) mangroves and rainforest regions for mangrove forest mapping and species discrimination in the Caribbean coast of Panama. Yang *et al*. (2011) in a study concluded that SPOT 5 multispectral imagery with conjunction of maximum likelihood and Support Vector Machine (SVM) classification techniques was able to identify crop types and also estimate crop areas. Shang *et al*. (2012) applied RapidEye satellite data to estimate crop ground cover and Leaf Area Index (LAI) at the Brunkild area in Southern Manitoba, Canada. Meanwhile, Tapsall *et al*. (2010) applied RapidEye imagery data for analysed annual land cover mapping aided to the European Union (EU) common agricultural policy.

In remote sensing studies, vegetation indices are popular approaches because of their simple mathematical expressions that combine satellite measurements at different spectral bands to estimate vegetation properties. NDVI being as the most widely used index for remote sensing of vegetation (Gao, 1996) and these technique is also commonly used in measurement of crop health in agricultural applications (Bhandari *et al*., 2012). It presents the amount of photosynthesizing vegetation which calculated using spectral reflectance measurement acquired in the red and near infrared regions (Jahari *et al*., 2011). RapidEye is a sensor with a spatial resolution of 5 m which is very suitable in agricultural applications (Vuolo *et al*., 2010). The sensors imagery has an additional spectral data available in the red edge band allowing users to extract more useful land information. Red edge NDVI is a way to assess the health of a plant that contains chlorophyll. Red edge NDVI has been proven to have higher correlations with field measurements. This is because, red edge is found to be the best remote sensing descriptors of chlorophyll concentration (Filella and Penuelas, 1994). Thus, this study aims to determine the applicability of the higher spatial resolution imagery of RapidEye in combination with ancillary data and field sampling to distinguish and discriminate the mangrove species distribution at Matang Mangrove Forest Reserve in Perak, Malaysia.

MATERIALS AND METHODS

Study area: Matang Mangrove Forest Reserve in Perak, Malaysia is located at the West Coast of Peninsular Malaysia which lies between the latitude of 4°15' N - 5°1' N and the longitude of 100°2' E-100°45' E (Fig. 1). The area is divided into north of Kuala Sepetang, south of Kuala Sepetang, Kuala Trong and Sungai Kerang, under the administration of the Kerian, Larut and Matang and Manjung district in the state of Perak while, the coastlines are stretch from Kuala Gula in the north to Bagan Panchor in the south (Muda and Mustafa, 2003). Total area of Matang Mangrove Forest Reserve is approximately 40,466 ha excluding the major waterways (Muda and Mustafa, 2003). This mangrove forest is also known as the best mangrove forest management in Malaysia and also amongst the world (Muda and Mustafa, 2003). The conservation and systematic management process of this mangrove forest has begun since 1904 (Muda and Mustafa, 2003).

Satellite image data: RapidEye is a German satellite of five satellite constellation that was launched in August of 2008 (Sandau, 2010). The imagery data was delivered as level 3A that were stored in GeoTIFF format and featured in a UTM map projection (UTM-47N, WGS-84). These satellites have a lifespan of 7 years with a sun-synchronous orbit of 630 km and a ground sampling distance of 6.5 m which was resampled to 5 m (RapidEye AG and RapidEye US LLC, 2012) (Table 1). RapidEye satellite was considered suitable in this study, as it was designed to be applied

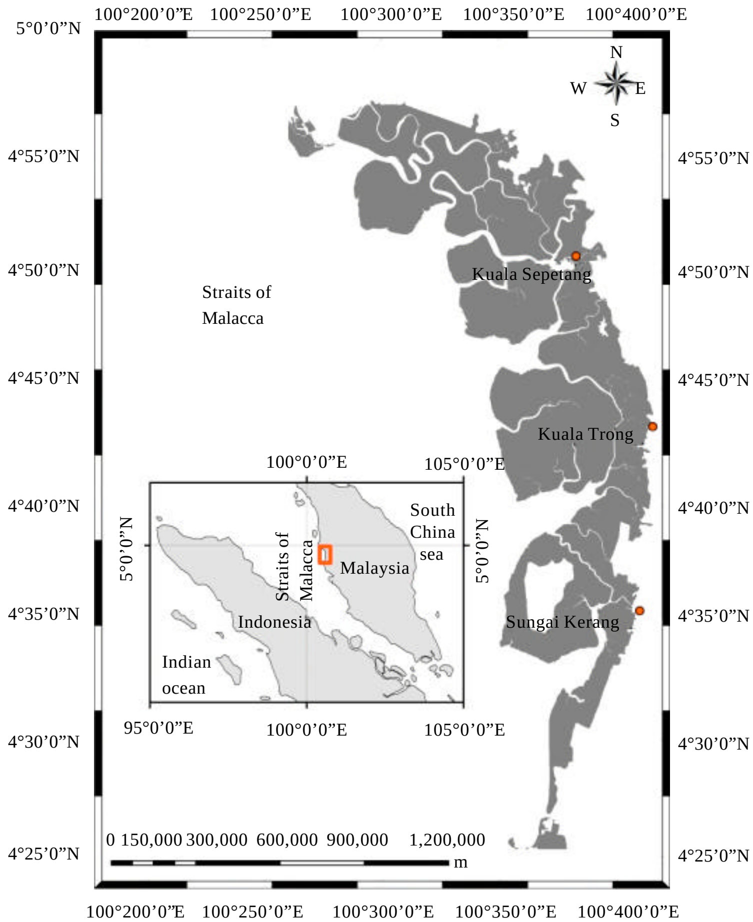

Fig. 1: Location of the study area in Matang Mangrove Forest Reserve, Perak which is located at the west coast of Peninsular Malaysia

Table 1: General specification characteristics of RapidEye satellite

Property	Information
No. of satellites	5
Space craft lifetime (years)	7
Orbit altitude	630 km in sun-synchronous orbit
Spectral bands (nm)	
Blue	440-510
Green	520-590
Red	630-685
Red edge	690-730
Near infrared	760-850
Ground sampling distance (m)	6.5
Pixel size (m)	5
Revisit time	Daily (off-nadir)/5.5 days (at nadir)
Dynamic range (bit)	Up to 12

mainly for monitoring and assessing of agricultural and natural resources at relatively large cartographic scale (Tapsall *et al*., 2010). RapidEye satellite imagery seems to be promising for

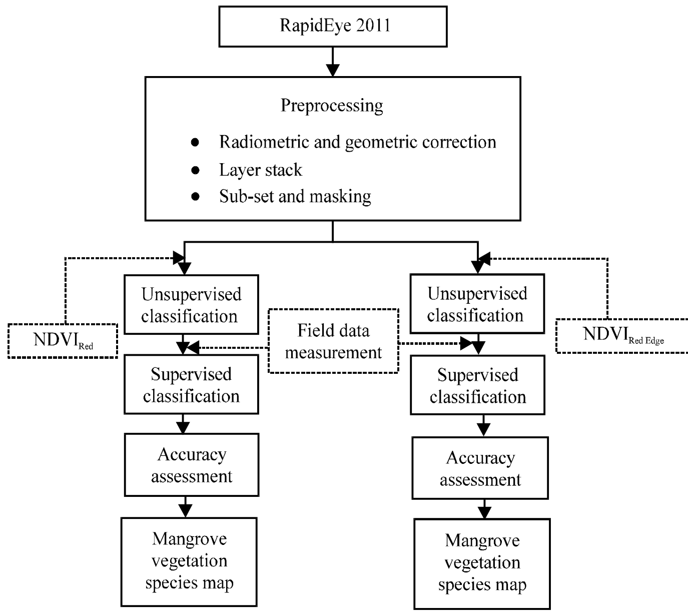

Fig. 2: Methodology applied in classification of mangrove vegetation species using RapidEye multispectral image with integration of $NDVI_{Red}$ and $NDVI_{Red\ Edge}$

mangrove forest area as it offers high spatial resolution at 5 m along with five multispectral bands including a new feature of the RapidEye sensor which is the red edge band. RapidEye is a high spatial resolution satellite with short revisit period and it is the first and currently the only satellite constellation able to repeatedly image larger areas in short intervals (Li *et al*., 2012).

Image processing: The RapidEye Standard Image Products of 3A level were radiometrically, sensor and geometrically corrected and aligned to cartographic map projection (Fig. 2). Layer stack process of the five multispectral bands was applied to the image. Masking and sub-setting processes were implemented to obtain the mangrove cover area. The image processing was carried out using ERDAS Imagine 2011 and ArcGIS 10 software.

Image classification: Two types of image classification were implemented in this study which includes unsupervised and supervised classification. Unsupervised is the process that is carried out largely by the software with the user only defining the number of classification (Long III and Srihann, 2004). Through this classification technique, it aims to get an idea of identifying elements that have the same pixel to be classified in the same class. In this study, the number of class was 100, the maximum iterations were 25 and the convergence threshold was set up to 0.950. Meanwhile, supervised classification is a process of clustering pixels in a data set into classes corresponding to user defined training classes (Wang and Tenhunen, 2004). This technique allows the user to define for certain signatures from which the image is classified (Long III and Srihann, 2004). In this study, supervised classification using the parametric analysis of “maximum likelihood” was implemented.

Normalized Difference Vegetation Index (NDVI): The Normalized Difference Vegetation Index (NDVI) was applied in this study to distinguish vegetation from other land cover classes.

NDVI is a common and widely used vegetation index which is widely applied in research on global environmental and climatic change (Gao, 1996). Its utility in satellite assessment and monitoring of global vegetation cover which has been well demonstrated and implemented over the past two decades (Huete and Liu, 1994; Leprieur *et al.*, 2000). In this study, the calculations of NDVI from the spectral channels of the RapidEye sensor were evaluated. It comprises the classic NDVI which was calculated using red channel and the $NDVI_{Red\ Edge}$ adapted the red edge channel. The calculation of $NDVI_{Red}$ (Tucker and Sellers, 1986) was derived using the equations below:

$$NDVI_{Red} = \frac{NIR - Red}{NIR + Red}$$

Where:
Near infrared (NIR) = band 5
Red = band 3

This equation is due to the fact that chlorophyll absorbs red while the mesophyll leaf structure scatters NIR (Pettorelli *et al.*, 2005). Meanwhile, the NDVI equation by adaptations of red edge channel of RapidEye is given as (Wu *et al.*, 2009):

$$NDVI_{Red\ Edge} = \frac{NIR - Red\ Edge}{NIR + Red\ Edge}$$

Where:
Near infrared (NIR) = band 5
Red edge = band 4

In this equation, the red channel of NDVI was substituted by the red edge channel. Red edge channel in NDVI calculations results in lesser saturation over highly vegetated regions (Haboudane *et al.*, 2002; Vina and Gitelson, 2005). Both NDVI equations produces values in the range of -1.0 to +1.0 which can be concluded that the more positive NDVI values indicates existence of more green vegetation within the pixel while the negative NDVI values were defined as non-vegetation areas such as water bodies and barren land.

Field data measurement: The leaf samples from each main mangroves vegetation species including *Rhizophora mucronata, Rhizophora apiculata, Bruguiera parviflora, Bruguiera cylindrica, Bruguiera gymnorrhiza, Avicennia alba, Avicennia officinalis, Sonneratia alba, Sonneratia caseolaris, Sonneratia ovata* and *Xylocarpus granatum* were collected for species identification during the field observation process. Apart from that, the locations of the species found were obtained using Global Positioning System (GPS) and the coordinate locations of each species were recorded. The spectral reflectance of the main mangrove species were measured using Jazz Ocean Optic spectrometer.

Accuracy assessment: Accuracy assessment is an important part in an image classification procedure. The field point data were used to assess the classification result. The accuracy assessment gives the descriptive statistics of overall accuracy for the mangrove vegetation species classification. The overall accuracy is calculated by dividing the total correct (the sum of the major diagonal) by the total number of pixels in the error matrix (Congalton, 1991). While, the kappa statistic value indicated how accurate the classification output accounts for and it is measured based on the difference between the actual agreement and the chance agreement in the confusion matrix (Zhou *et al*., 2011).

RESULTS AND DISCUSSION

The spectral reflectances of leaves are the most important factor in understanding the reflectance of the full plant canopy (Kamaruzaman and Kasawani, 2007). However, the spectral properties and characterization of vegetation canopies are one of the most important and crucial problems in remote sensing because the signal of the reflectance properties for the vegetation canopy detected at the sensor is influenced by many biochemical and biophysical canopy attributes as well as their external factors (Chuvieco and Huete, 2010).

According to Chuvieco and Huete (2010), the visible, the near infrared and the short wave infrared regions are namely the three main spectral domains that influence the optical properties of leaves. In this study, the spectral reflectance response for the mangrove vegetation species indicated reflectance within the visible regions in the blue, green and red wavelength regions produce similarity in overall shape and curve within these wavelength regions (Fig. 3). The typical spectral reflectance of leaf shows that, the absorbing effect of the leaf pigments is mostly affected by chlorophyll a, chlorophyll b, carotenoids and xantophylls which causes the low reflectance in the visible region which about 60-75% accounts for the energy absorbed (Chuvieco and Huete, 2010).

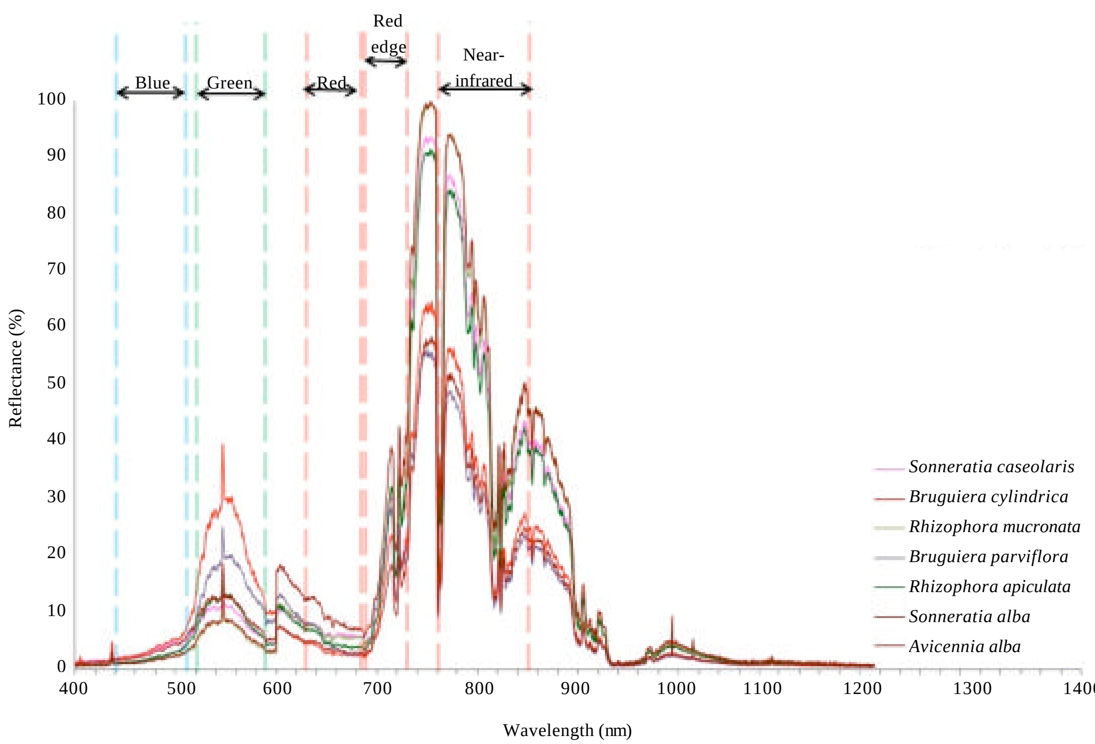

Fig. 3: Spectral reflectance characteristics of several main mangroves species at Matang Mangrove Forest Reserve, Perak, Malaysia

In the visible region, the blue and red light preferentially is absorbed by the chlorophyll molecules for use in the photosynthesis processes (Campbell, 2002). Meanwhile, in the green region much less of the green light is absorbed and more is reflected which is responsible for the green color appearance of healthy leaves and this shows the green light as the dominant reflection for the color of living vegetation (Campbell, 2002; Chuvieco and Huete, 2010). The graph indicates that each of the species did not show any obvious peak pattern within the blue wavelength region (440-510 nm) and red wavelength region (630-685 nm) because of the low reflectance and high absorption within this region. While, in the green wavelength region (520-590 nm) which is located between the blue and red wavelength region, the *Bruguiera cylindrica* recorded high reflectance at 39% while the lowest was recorded by *Rhizophora mucronata* with 12% of reflectance.

In the red edge wavelength region (690-730 nm), *Sonneratia alba* recorded highest reflectance at 42% while *Avicennia alba* recorded the lowest at 20%. Within this region, leaves have very low absorption, lower than 10% and their high reflectance can reach about 50% (Chuvieco and Huete, 2010).

For the near infrared (760-850 nm), the highest reflectance was recorded by *Sonneratia alba* at 94% while the lowest was recorded by *Bruguiera parviflora* at 48%. The reflectance curve within this region is high among the species. This is due to the strong influence of the leaf structural properties, in particularly the relative thickness of the mesophyll cell layer, where the internal air cavities in the spongy mesophyll layer scatter incident radiation (Chuvieco and Huete, 2010). Meanwhile, in the short wave infrared wavelength region, reflectance increases due to the decreases of water content in leaf (Chuvieco and Huete, 2010).

This generally shows that the spectral reflectance for all sampled species have similar characteristic of healthy green leaves with high absorption indicated in the visible wavelength region while the high reflectance is indicated in the near infrared wavelength region. In addition, Jahari *et al.* (2011) stated that, the growing healthy vegetation has low red light and high near infrared reflectance. Therefore, these unique characteristics of the spectral properties allow the vegetation to be easily identified and distinguished with remotely sensed data (Kamaruzaman and Kasawani, 2007). The variations of the unique spectral signature of each mangrove species also helps in discriminating species in the classification process.

NDVI is a technique that is commonly used in agricultural applications for crop health measurement and it is also widely used in examining the relation between the spectral variability and also the vegetation vigor or growth rate (Bhandari *et al.*, 2012). Determination of the $NDVI_{Red}$ in this study indicates the minimum value at -1.0 and the maximum value recorded at 0.74 (Fig. 4). Meanwhile, the $NDVI_{Red\ Edge}$ result recorded -0.34 as the minimum value while 0.53 as the maximum value. The mounting amount of the green vegetation is indicated by the increasing amount of the positive NDVI values (Jahari *et al.*, 2011). The high values of NDVI also indicated the strong photosynthetic activity of green vegetation (Houlie *et al.*, 2006). On the other hand, the negative NDVI values indicated non-vegetated areas such as water bodies, clouds, settlement areas and other buildings types.

Higher vegetation area at 43831.12 ha (99.92%) and lower non-vegetation area at 33.78 ha (0.08%) was detected using $NDVI_{Red\ Edge}$ (Table 2). On the other hand, $NDVI_{Red}$ indicated 43495.86 ha (99.16%) of vegetation area while, non-vegetation area covered an area of 369.03 ha (0.84%). The $NDVI_{Red\ Edge}$ detected higher vegetation area due to the presence of the red edge band of RapidEye satellite imagery which was able to detect the presence of the vegetation since it is sensitive to the chlorophyll content of the plants (De Sousa *et al.*, 2012).

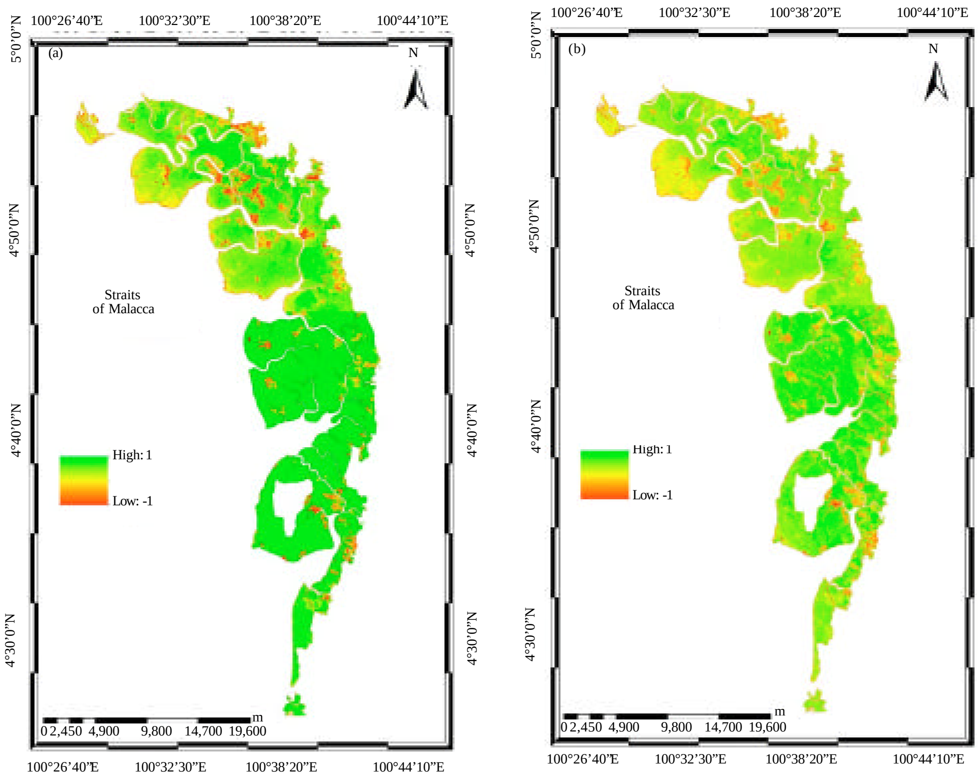

Fig. 4(a-b): Distribution of vegetation at the Matang Mangrove Forest Reserve, Perak, Malaysia determined by Normalized Difference Vegetation Index (NDVI) using (a) $NDVI_{Red}$ and (b) $NDVI_{Red\ Edge}$

Table 2: Total area of vegetation and non-vegetation area using $NDVI_{Red}$ and $NDVI_{Red\ Edge}$

	Vegetation area		Non-vegetation area	
	Area (ha)	Image (%)	Area (ha)	Image (%)
$NDVI_{Red}$	43495.86	99.16	369.03	0.84
$NDVI_{Red\ Edge}$	43831.12	99.92	33.78	0.08

The remotely sensed image provides a fundamental and essential mechanism in understanding feature due to the variations in reflectivity of the surface material across different spectral band (Bhandari *et al.*, 2012). Supervised classification results shows that there were fifteen classes of elements classified within the same pixel (Fig. 5). Long III and Srihann (2004) stated that, all pixels in an image is automatically categorize into land cover classes or themes in the image classification procedure. There were eleven classes identified as mangrove vegetation species including *Rhizophora apiculata*, *Rhizophora mucronata*, *Bruguiera cylindrica*, *Bruguiera parviflora*, *Bruguiera gymnorrhiza*, *Sonneratia alba*, *Sonneratia caseolaris*, *Sonneratia ovata*, *Avicennia alba*, *Avicennia officinalis* and *Xylocarpus granatum*. Meanwhile, the other classes were identified as dry land forest and the other three classes were indicated as non-vegetated classes which includes water bodies, clouds and

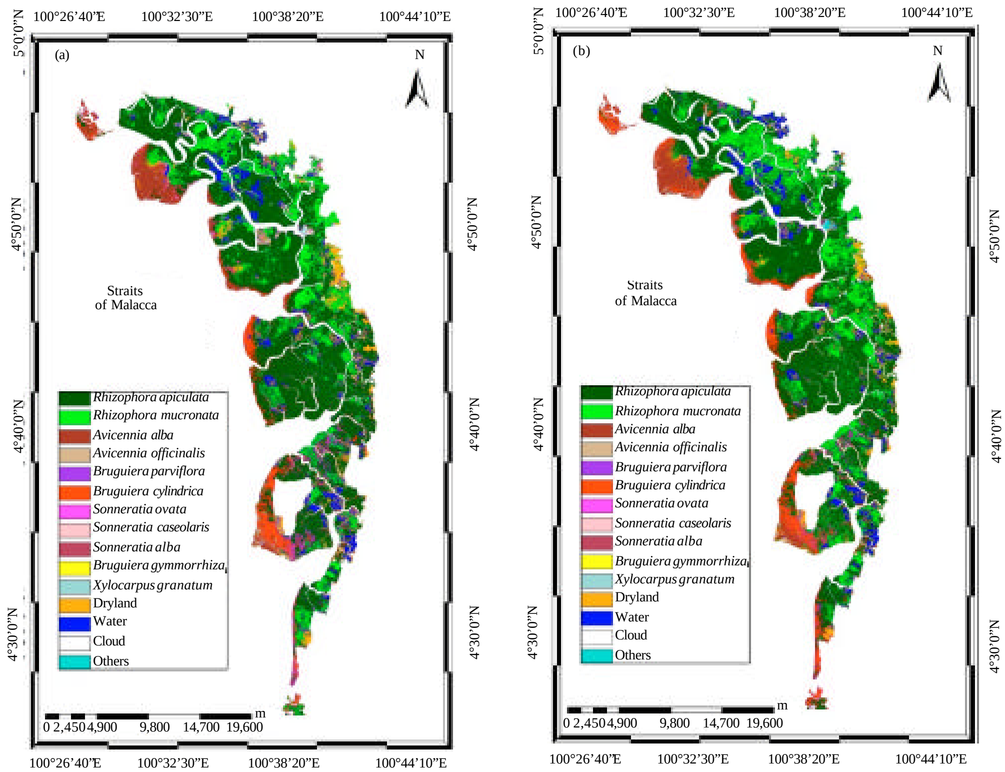

Fig. 5(a-b): Supervised classification results for RapidEye multispectral image with integration of (a) $NDVI_{Red}$ and (b) $NDVI_{Red\ Edge}$

settlement/buildings. Kairo *et al.* (2002) stated that, mapping mangroves at the species level is essential for a detailed understanding of mangrove biodiversity studies and mangrove management.

The study indicated the potential of RapidEye imagery to discriminate the mangrove vegetation species within the study area. The result of overall classification accuracy of RapidEye multispectral image with integration of $NDVI_{Red\ Edge}$ was 87.5% with kappa statistic at 0.85. Meanwhile, the result of overall classification accuracy of RapidEye multispectral image when the $NDVI_{Red}$ was employed was 85% with kappa statistic of 0.80. The results revealed that the classification result of RapidEye multispectral image with the integration of $NDVI_{Red\ Edge}$ was slightly higher compared to the classification results of RapidEye multispectral image with employment of $NDVI_{Red}$. This indicated that the integration of $NDVI_{Red\ Edge}$ in the classification of RapidEye multispectral image increases classification accuracy at about 2.5%. The increase of the overall accuracy refers to the additional information offered by the red edge channel in the NDVI equation.

The higher classification result with integration of $NDVI_{Red\ Edge}$ in differentiating the mangrove species vegetation was due to the inclusion of the red edge band which is suitable in measuring variances in vegetation, monitoring of vegetation health and discriminating of species (Cheng and Sustera, 2009). Apart from that, according to Filella and Penuelas (1994), the point of maximum slope in vegetation reflectance spectra has been found to be red edge where the reflectance changes from very low in the chlorophyll red absorption region to very high in the near-infrared due to the scattering of the leaf and canopy.

The spatial distribution of mangrove species classification at Matang Mangrove Forest Reserve indicated that *Rhizophora* species dominated the study area image. In Matang Mangroves, *Rhizophora* forest is a major forest type which comprises about 85% of the total forested area and it is also classified as productive and subjected to intensive management (Muda and Mustafa, 2003). In addition, *Rhizophora apiculata* and *Rhizophora mucronata* were the two main commercial species that led to the establishment of production forests in the management system (Muda and Mustafa, 2003).

Based on the supervised classification result, it shows a relatively clear zonation pattern of mangrove vegetation in the study area. *Rhizophora* species which consists of *Rhizophora apiculata* and *Rhizophora mucronata* were the dominant species in the study area image. While, *Avicennia* species dominated along the coasts. In Matang Mangroves, *Avicennia* forest species invade the mud flats of the estuaries and foreshores and they mainly occur towards the seafront bordering the Straits of Malacca (Muda and Mustafa, 2003).

Comparison of the classification results indicated that the classification maps provided good separations between the mangrove vegetation species and also other land cover classes. However, there could be incidents whereby some species which does not belongs in a certain class may be included together in the classification and considered as the group species. Moreover, the classification of mangrove vegetation species might be limited due to the nature of the natural forest because the trees are closely located to each other and the trees do not stand in a group in accordance to their own respective species. Several approaches can be implemented to enhance classification processes such as the integration of texture analysis. The application of texture analysis utilizes spatial and spectral information simultaneously and has shown effective classification in mapping land cover.

CONCLUSION

This study gives an overview of mapping the mangrove vegetation species in Matang Mangrove Forest Reserve in Perak, Malaysia using RapidEye 2011 imagery. The results of the accuracy assessment indicated it was possible to identify tree species from RapidEye 2011 data using maximum likelihood classifier. The classification resulted in eleven classes of mangrove vegetation species out of fifteen classes of land cover. However, the comparison of the classification result of RapidEye multispectral image with employment of $NDVI_{Red}$ and $NDVI_{Red\ Edge}$ reveals that the integration of $NDVI_{Red\ Edge}$ gave a slightly higher accuracy due to the inclusion of the red edge channel in the sensor. The ability to map mangrove vegetation at species level contributes in better management of the resources.

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