RESEARCH ARTICLE | NOVEMBER 27 2013

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M. A. Roslani; M. A. Mustapha; T. Lihan; W. A. Wan Juliana

AIP Conf. Proc. 1571, 480–486 (2013)
https://doi.org/10.1063/1.4858701

Classification of Mangroves Vegetation Species Using Texture Analysis on RapidEye Satellite Imagery

M.A. Roslani, M. A. Mustapha, T. Lihan, and W. A. Wan Juliana

School of Environment and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor Darul Ehsan, Malaysia

Abstract. Mangroves are unique ecosystem structures that are typically made up of salt tolerant species of vegetation that can be found in tropical and subtropical climate country. Mangrove ecosystem plays important role and also is known as highly productive ecosystem with high diversity of flora and fauna. However, these ecosystems have been declining over time due to the various kinds of direct and indirect pressures. Thus, there is an increasing need to monitor and assess this ecosystem for better conservation and management efforts. The multispectral RapidEye satellite image was used to identify the mangrove vegetation species within the Matang Mangrove Forest Reserve in Perak, Malaysia using texture analysis. Classification was implemented using the maximum likelihood classifier (MLC) method. Total of eleven main mangrove species were found in the satellite image of the study site which includes *Rhizophora mucronata*, *Rhizophora apiculata*, *Bruguiera parviflora*, *Bruguiera cylindrica*, *Bruguiera gymnorrhiza*, *Avicennia alba*, *Avicennia officinalis*, *Sonneratia alba*, *Sonneratia caseolaris*, *Sonneratia ovata* and *Xylocarpus granatum*. The classification results showed that the textured image produced high overall classification assessment recorded at 84% and kappa statistic of 0.8016. Meanwhile, the non-textured image produces 80% of overall accuracy and kappa statistic of 0.7061. The classification result indicated the capability of high resolution satellite image to classify the mangrove species and inclusion of texture information in the classification increased the classification accuracy.

Keywords: Mangrove vegetation species; MLC; RapidEye satellite image; Matang Mangrove Forest Reserve.
PACS: 87.63.L-, 07.07.Df, 07.87.+v

INTRODUCTION

Mangroves are intertidal forests of salt tolerant tree species which is known as the only forests situated at the confluence of land and sea occurring along tropical and subtropical coasts [1-2]. Mangrove forests form a unique ecosystem along coastal shoreline. They can survive in brackish water, extreme tidal zones, harsh conditions of high salinity, muddy and oxygen depleted soils with their pneumatophores or well known as their special prop root system [3].

In the world, mangroves are known as the most productivity and biologically diverse ecosystem [4]. It provides habitat, food and breeding grounds for a variety of fauna [5]. It is important in shoreline stabilization, reduction of coastal erosion, sediment and nutrient retention, storm protection, flood and flow control and water quality and provides various forestry products such as timber, charcoal and firewood. They are also utilized as a source of fuel, wood and pole production that contributes to the countries income [3,6].

However, since the last decade decline of mangrove areas are at an alarming rate as these ecosystems were degrading and receding. This ecosystem is seriously threatened by coastal development projects, food production, wood extraction, pollution and irrational development [7-9]. There is an increased need to assess and monitor this ecosystem in order to gain a better understanding of their basic biology and also to help guide conservation and restoration efforts [7,10].

The use of remote sensing tools greatly assists in accurately mapping the mangrove species [7]. Remote sensing technology provides better alternative of mapping and it is also capable to obtain mangrove information in a wider range compared to ground survey [6,10]. Study the growth and loss of mangrove in over a period of two decades from 1980 to 2002 in Pacific Panama was implemented using aerial photography and Geographic Information Systems (GIS) [10]. Investigation of the capability of QuickBird satellite imagery was implemented for determination of mangrove species and stand mapping in Gazi Bay of Kenya [2]. Apart from getting the mangrove information in a wide range scale, the application of remote sensing in the study of mangrove forest will help to reduce time and human energy [6].

The 2013 UKM FST Postgraduate Colloquium
AIP Conf. Proc. 1571, 480-486 (2014); doi: 10.1063/1.4858701

In remote sensing data, application of texture analysis has been shown help in classification process. A previous research indicated that by inclusion texture into the classification process, it can improve the accuracy by 10 to 20% [11]. Texture is known as the frequency of tonal change in a photographic image [12]. There are many studies that include the texture information in the classification method in order to improve the accuracy of classification result. The results of mapping mangrove species using IKONOS and QuickBird satellite imageries on the Caribbean coast of Panama, shows that the inclusion of first order texture features improved the classification result while the adding of second order does not improve the classification accuracy [7].

The purpose of this present research is to evaluate the use of texture analysis in classification of mangrove vegetation species in Matang Mangrove Forest Reserve using high resolution satellite image of RapidEye.

MATERIALS AND METHODS

Study Site

Matang Mangrove Forest Reserve is situated on the west coast of Peninsular Malaysia which is located between latitude of 4º 15′ N - 5º 1′ N and longitude of 100º 2′ E - 100º 45′ E (FIGURE 1). This mangrove forest is divided from north to south including north Kuala Sepetang, south Kuala Sepetang, Kuala Trong and Sungai Kerang with total area of approximately 40,466 hectares excluding the major waterways [13]. It is located under the administration of Kerian district, Larut Matang and Manjung in the state of Perak, Malaysia [13]. Matang Mangrove Forest Reserve is well known as the best mangrove forest management in Malaysia and also amongst the world [3]. The conservation and systematic management process of this mangrove forest has begun since in 1904 [13].

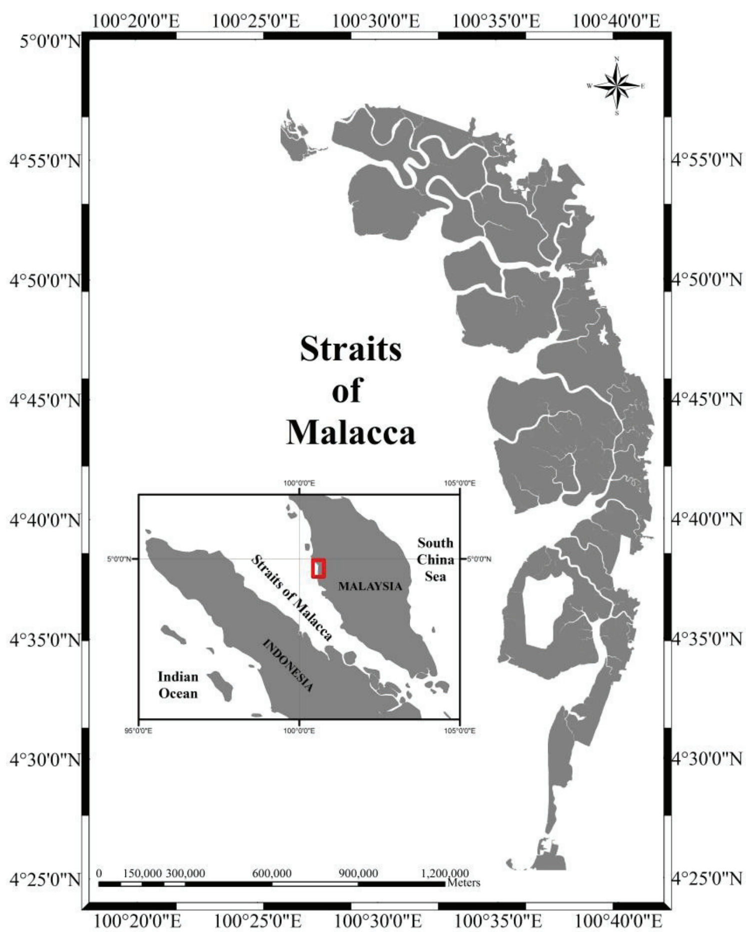

FIGURE 1. Study site of Matang Mangrove Forest Reserve in Perak, Malaysia.

Satellite Image Data

The remote sensing data used in this study is high resolution RapidEye 2011. It is a German satellite with five satellite constellation that was launched in August of 2008 [14]. The RapidEye satellite image consists of five multispectral bands including blue (440 – 510 nm), green (520 – 590 nm), red (630 – 685 nm), red edge (690 – 730 nm) and near-infrared (NIR) (760 – 850 nm) at 5m resolutions. It has the spacecraft lifetime of seven years while the ground sampling distance of this satellite is 6.5m.

Image Processing

The RapidEye standard image products of Level 3A are radiometrically, sensor, geometrically corrected and aligned to cartographic map. The image was projected and rectified to the world geodetic survey 1984 (WGS 1984) datum and featured in a Universal Transverse Mercator (UTM) which is UTM-47N. Five multispectral bands were stacked. The entire image undergoes masking and sub-setting processes to obtain the mangrove cover area. The whole digital image processing was carried out in ERDAS Imagine 2011 and ArcGIS 10 software.

Texture Analysis

Texture analysis was implemented using variance operator with a window of 9x9 pixel size as a statistical measure for the texture analysis. The equation used in the analysis is:

$$V = \frac{\sum (Xij - M)^2}{n-1} \tag{1}$$

Where: Xij: value of pixel (i,j); n: number of pixels in a window; M:mean value of all pixels in a window:

$$M = \frac{\sum Xij}{n} \tag{2}$$

Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) is one of the most widely used vegetation indexes and is utilized in satellite assessment and monitoring of global vegetation cover [15-16]. In this study, NDVI was used to differentiate the vegetation and non-vegetation area to enhance further classification process. NDVI value was computed as below:

$$NDVI = \frac{NIR - \mathrm{Re}\,d}{NIR + \mathrm{Re}\,d} \tag{3}$$

Where, NIR: band 5 and Red: band 3.

This formula is according to the fact that chlorophyll absorbs red whereas the mesophyll leaf structure scatters NIR [17].

Image Classification

Two types of image classification were used in this study, unsupervised classification and supervised classification Unsupervised is the process that is carried largely by the software with the user only defining the number of classification [18]. In this study, the unsupervised classification was applied to the 100 classes of unknown land covers using Iterative Self Organizing Data Analysis Technique (ISODATA) with 25 iterations and convergence threshold of 0.950. Meanwhile, supervised classification is a technique that allows the user to define certain signatures from which the image is classified [18]. In this technique, the RapidEye image was classified using the maximum likelihood classifier (MLC) in the ERDAS Imagine 2011 software.

Field Data Measurement

The field data measurement was obtained by collecting the leaves samples of main mangroves species within the study area in the natural mangrove forest which includes *Rhizophora mucronata, R. apiculata, Bruguiera parviflora, B. cylindrica, B. gymnorrhiza, Avicennia alba, A. officinalis, Sonneratia alba, S. caseolaris, S. ovata* and *Xylocarpus granatum*. The location of each species found was recorded using a Global Positioning System (GPS) in order to obtain the precise geographical locations in the field at the time the data were collected.

Accuracy Assessment

The accuracy assessment was defined as the accuracy of the location point in the satellite imagery classification with the reference to its location on the ground by using the GPS data from the field work. At each reference location, the respective mangrove vegetation species and GPS coordinates were recorded. The field data was then compared with the results of the classified image. The end of the accuracy assessment technique will give the descriptive statistics of accuracy in the mangrove vegetation species classification.

RESULTS AND DISCUSSION

The inclusion of NDVI method in this study was able to distinguish the vegetation and non-vegetation area (FIGURE 2). NDVI is a calculation of ratio difference between measured canopy reflectance in the red and near-infrared bands, respectively [19]. The NDVI results from both images were scale of from 0 to 255 and the value of the results varies between -1.0 and +1.0. From the results, the positive value of NDVI indicates the vegetation area while the negative values indicate non-vegetation area which includes water bodies, clouds and others (e.g: settlements / buildings).

There are differences in the NDVI result between the textured and the non-textured image (TABLE (1)). The result for the textured image recorded -0.777723 as the minimum value while 0.973689 as the maximum value. Meanwhile, the non-textured image recorded -1 as the minimum value while 0.685934 as the maximum value. By comparing the percentage of vegetation and non-vegetation area of the image, the textured image indicated 98.97% vegetation area and the non-vegetation area were recorded at 1.03%. Meanwhile, the non-textured indicated 99.16% of vegetation area and 0.84% of non-vegetation area. NDVI has been identified to have high association with green biomass, crown closure, and leaf area index (LAI) among other vegetation parameters [20].

TABLE (1). Total area and the percentage of vegetation and non-vegetation area of textured and non-textured images.

	Vegetation area		Non-vegetation area	
	Area (hectares)	Percentage of image (%)	Area (hectares)	Percentage of image (%)
Textured image	37030.41	98.97	384.64	1.03
Non-textured image	43495.86	99.16	369.03	0.84

The classification of the textured and non-textured images showed fifteen categories of classes including twelve classes of vegetation (FIGURE 3). Eleven species of mangrove plants were determined in the image including *R. apiculata*, *R. mucronata*, *S. alba*, *S. ovata*, *S. caseolaris*, *B. cylindrica*, *B. parviflora*, *B. gymnorrhiza*, *A. alba*, *A. officinalis* and *X. granatum*. From the result, *Rhizophora* species was indicated as dominant species. *Rhizophora* forest is the major forest type in Matang Mangroves which comprises about 85% of the total forested area and it is classified as productive and subjected to intensive management [13].

The result of classification accuracy assessment shows that, the textured image produced high overall accuracy at 84% while the non-textured image recorded of 80%. The overall accuracy is a measurement process which is calculated by dividing the total correct (i.e., the sum of the major diagonal) by the total number of pixels in the error matrix [21]. Meanwhile, the kappa statistic value of textured image produced at 0.8016 and the non-textured image recorded of 0.7061. The kappa statistics value indicates how accurate the classification output account for and it is measure based on the difference between the actual agreement and the chance agreement in the confusion matrix [22]. From the results, the overall accuracy of the textured image classification was being 4% higher than the non-textured image classification. The amount of improvement of the classification accuracy depends on the relationship between the size of the processing window and the nature of the texture [23].

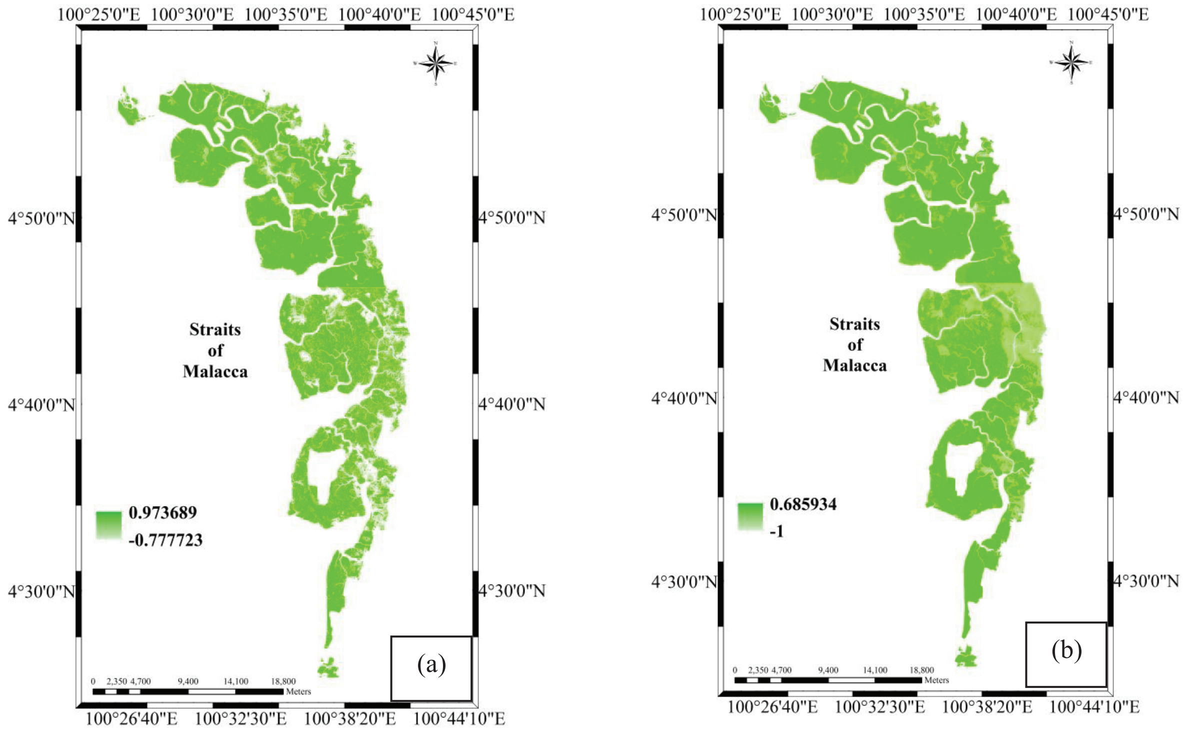

FIGURE 2. (a) NDVI result of textured image;(b) NDVI result of non-textured image.

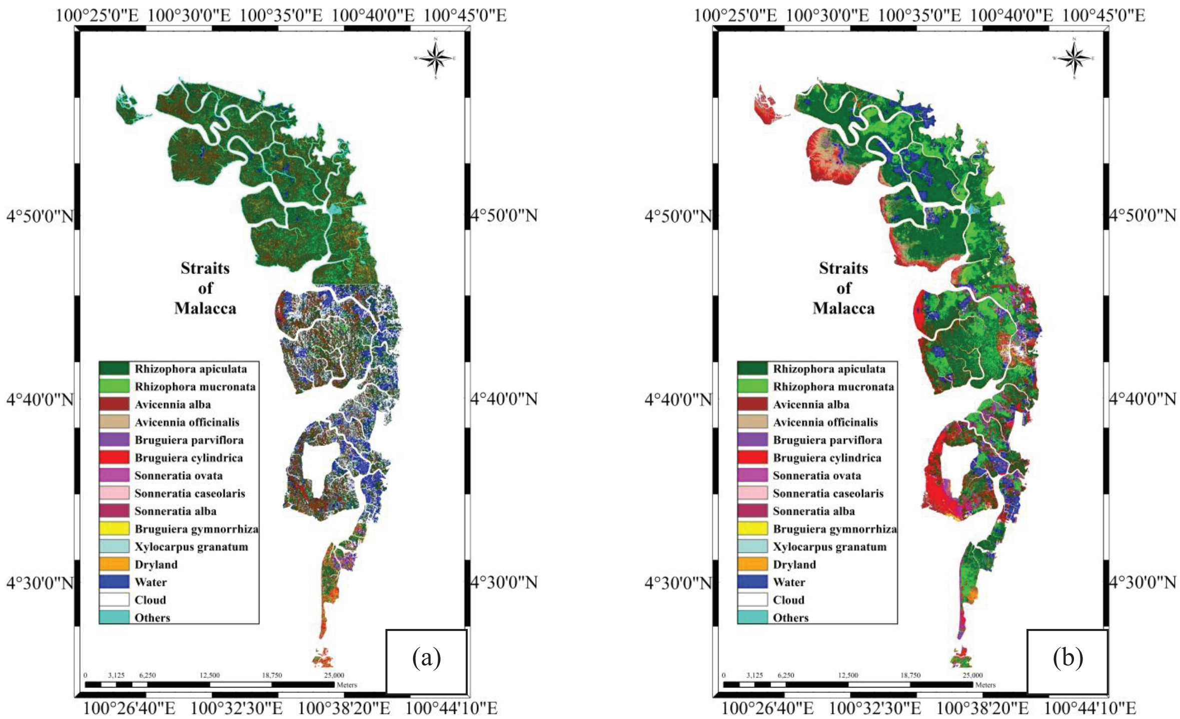

FIGURE 3. (a) Supervised classification of textured image; (b) Supervised classification of non-textured image.

The study indicated capability of mangrove vegetation species classification using remote sensing application to differentiate the mangrove species according to their unique spectral reflectance. In addition, the high resolution satellite of RapidEye imagery enhances the capability of species classification with the presence of red edge band. The red edge band has the ability to detect the presence of vegetation due to its sensitivity to the chlorophyll content of plants [24]. However, the classification of mangrove vegetation species might be limited due to the nature of the natural forest. The species of mangrove trees are closely located and they do not live in groups according to their own species.

CONCLUSION

This research demonstrated that the implementation of texture analysis on high resolution satellite imagery can increase the classification accuracy. Extraction of the texture features helps in the classification analysis as it is able to distinguish different classes of mangrove vegetation species.

ACKNOWLEDGMENTS

The authors would like to thank the Universiti Kebangsaan Malaysia (UKM), the Universiti Teknologi MARA (UiTM) and the Ministry of Higher Education of Malaysia. Appreciation is also extended to all the parties involved directly or indirectly for support and encouragement in accomplishing this research. This research was funded by the UKM Research University Grant (UKM-GUP-2011-194).

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