Assessment of Peat Swamp Forest Cover of Malaysia using Remote Sensing

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KEY WORDS: Tropical Forest, Optical Remote Sensing, Plotless Sampling

ABSTRACT: Concern over global problems induced by rising CO_2 has prompted attention on the role of forest as carbon 'storage' because forests store a large amount of carbon in vegetation biomass and soil. Monitoring techniques based on multispectral satellite-acquired data have demonstrated potential as a means to detect, identify, and map changes in forest cover. This study was focuses on the role of remote sensing and geographic information system (GIS) in assessment of changes in forest cover between 2005 and 2010, in the peat swamp forest of Malaysia. Peat swamp forests are tropical moist forests where waterlogged soils prevent dead leaves and wood from fully decomposing, which over time creates a thick layer of acidic peat. The importance of peat swamp forests in relation to maintaining the environmental stability includes flood mitigation, revitalizing the soil and providing a limited source of water during droughts, and as a carbon store and carbon sequestration. Forest's mapping is very significant for the estimation and evaluation of the forest resources, carbon sequestration, and to support sustainable forest management. Optical satellite remote sensing such as Landsat TM provides a cost-effective method to obtain current and reliable terrestrial information because of its widespread availability and frequency update. This information is useful to discover the driving forces of the forest changes and can provide policy decision supporting information to the local relevant government in Malaysia. Klias Peninsular peat swamp forest has been selected as a test site in this study to estimates biomass using plotless technique and it was found that the distribution of biomass within the plot is ranging from 96.06 to 213.10 tonne/ha with mean of 169.36 tonne/ha. The object oriented classification technique has been applied to remote sensing data to map the distribution of peat swamp forest cover of Malaysia. The trend of forest cover changes over the time span of 5 years was precisely analysed in this study. From the result, the extent of peat swamp forest of Malaysia in 2005 and 2010 is about 1,156,304.81ha and 744,557.06 ha respectively. It was noticed that the peat swamp forest cover in Malaysia has decrease about 35 % between 2005 and 2010. It is envisage that this project would prove the usefulness of remote sensing and geographic information system in forest resource management. The maps produced could serve as a platform for assessing and monitoring forest resources in Malaysia.

INTRODUCTION

Peat swamp forests are tropical moist forests where waterlogged soils prevent dead leaves and wood from fully decomposing, which over time creates a thick layer of acidic peat. Peat swamp forest constitute a significant component of Malaysia forest cover with an estimated about 1.54 million ha still remaining (UNDP, 2006). The importance of peat swamp forests in relation to maintaining the environmental stability includes flood mitigation, revitalizing the soil and providing a limited source of water during droughts, and as a carbon store and carbon sequestration. Recently, peat swamp forests are disappearing rapidly due to forest conversion and fires, which have contributed significantly to global carbon emissions. At current deforestation rates, these ecosystems in Southeast Asia may disappear by 2030 (Miettinen, et al., 2012). In Peninsular Malaysia, the peat swamp forests can be found in Pahang state which locating four production Forest Reserves, namely Pekan, Nenasi, Kedondong and Resak Forest Reserves. Another patch of peat swamp is in the North Selangor Peat Swamp Forest and the Southern Selangor Peat Swamp Forest which locating the Kuala Langat South Forest Reserve. In Sarawak, the peat swamp forest area covering about thirteen percent of the state's total land area. In the other East Malaysian state of Sabah, remaining peat swamp forest areas are relatively small. Information on the distribution of forests area is critical for decision-making and significant in climate stabilization, biodiversity conservation and social-related issues.

Forest's mapping is very significant for the estimation and evaluation of the forest resources, carbon sequestration, and to support sustainable forest management. It plays a key part in the concentrated effort on illegal logging, forest fire monitoring and early warning for forest degradation, the reduction of deforestation, and the improvement of forest quality. This will be achieved by making intensive use of the most recent satellite remote

sensing technology. Landsat TM is one of the optical satellite imagery that has proven an invaluable resource for mapping and monitoring in tropical forests ecosystem (Hansen, et al., 2010). Optical satellite remote sensing provides a cost-effective method to obtain current and reliable terrestrial information because of its widespread availability and frequency update.

MATERIALS AND METHODS

The study area covers the entire of Malaysia that consists of thirteen states with a total landmass about 32, 900.00 ha separated by the South China Sea into two similarly sized regions, Peninsular Malaysia and East Malaysia (Sabah and Sarawak). Figure 1 shows the location of this study area. The management of the forest reserve is undertaken by the state Forestry Department and complies with the Malaysian criteria and indicators for forest management certification requirements. Malaysia faces two monsoon winds seasons, the Southwest Monsoon from late May to September, and the Northeast Monsoon from November to March.

Figure 1 Location of study area

The primary data set of this study is Landsat 5 TM imagery acquired on various month in 2005 and 2010. The Thematic Mapper (TM) is an advanced, multispectral scanning, Earth resources sensor designed to achieve higher image resolution, sharper spectral separation, improved geometric fidelity and greater radiometric accuracy and resolution than the MSS sensor. TM data are sensed in seven spectral bands simultaneously. Landsat TM scene has an Instantaneous Field of View (IFOV) of 30m x 30m in bands 1-5 and 7 while band 6 has an IFOV of 120m x 120m on the ground. In theory, remote sensing technology is more economical for mapping over a large land area (Khali Aziz, et. al., 2011). However this satellite images have limitations in acquiring cloud-free imagery on regular basis. This study assesses the changes in forest cover between 2005 and 2010, in the peat swamp forest of Malaysia. Image classification of remotely sensed data is the process of categorizing all pixels in a digital image into one of several land cover classes. Image classification and analysis operations are used to digitally identify and classify pixels in the data. Three main forest classes can be differentiate by Landsat TM data as shown in Figure 2.Classification is usually performed on multi-channel data sets and this process assigns each pixel is an image to a particular class or theme based on statistical characteristics of the pixel brightness values. In this study, land cover classification was applied to the satellite images to identify and classify the extent of peat swamp forest in the study area.

The conventional methods of classification consist of supervised and unsupervised procedures, which rely strongly on a variety of statistical algorithms employed in geometric space. The development of classification methodologies has been enhanced by the advent of objects orientated analysis or segmentation. Segmentation is the first step in object-based classification and involves the delineation of areas of an image into separate objects. A scale parameter is used to control the average image object size. In this study, standard Nearest Neighbour segmentation technique was applied to the image variables to delineate and extract the land cover within the study area. In this data, the reference data implies the collection of land cover field information to control and help as a reference in remote sensing image interpretation. In this study, the reference data has been obtained through two

sources, by field GPS (Global Positioning System) data collection activity and data sampling from the existing land use map. In addition, interpretations of high resolution satellite image from Google Earth also assist to get a sample of land cover type in the study area. Some of this sample data information will be used as a reference in satellite data classification process and some of the data are being used for the assessment of classification results.

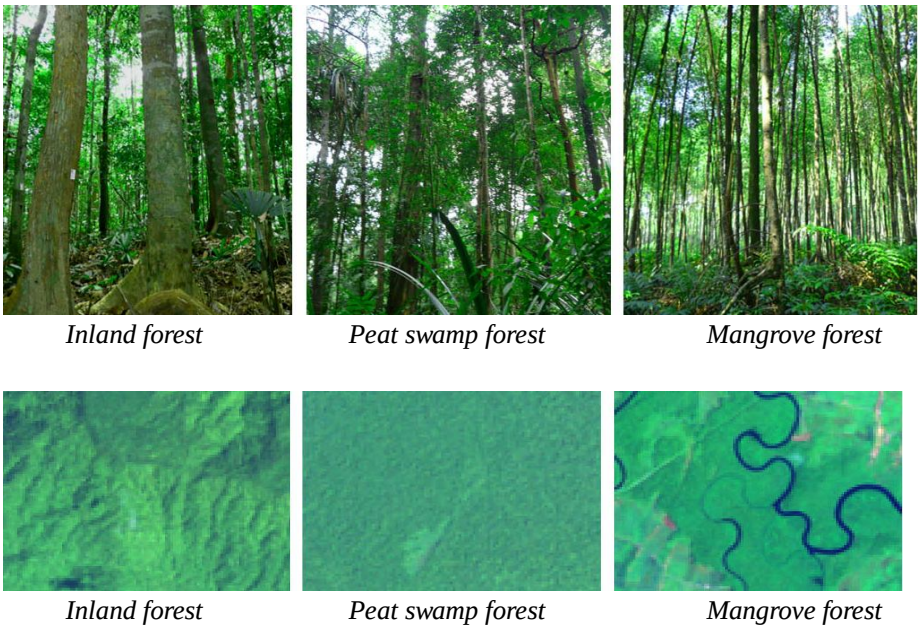

Figure 2 Main forest types in the study area

RESULTS AND DISCUSSION

Peat Swamp Forest Cover

Land cover classification was applied to the satellite images to identify and classify the extents of land cover classes in the study area. By using an Nearest Neighbour classification method to appropriate segmented satellite images, eleven major land cover classes namely; rubber, inland forest, mangrove forest, peat swamp forest, fresh water swamp forest, shrub land, grassland, crop land, urban and built-up, water, and other unclassified (clouds and cloud shadows) have been identified in the study area (Figure 3). These classes were determined based on the discriminating capability of the Landsat TM satellite data. Figure 3 shows the example of landuse classification result from segmentation method. From the classification result of 2005 and 2010, peat swamp forest classes has been extract for analysis. The peat swamp forest areas were spatially mapped as shown in Figure 4, 5, 6 and 7. The extent of each land cover category was quantified and shows in Table 1.

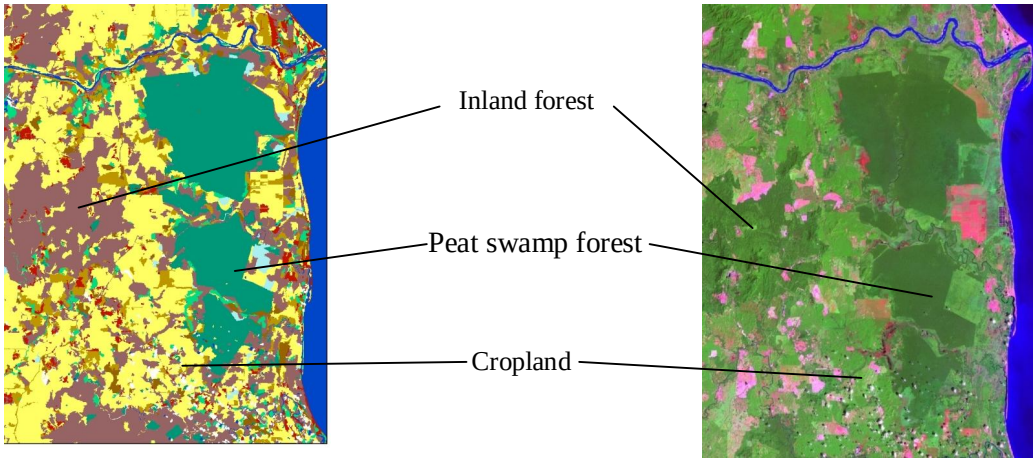

Figure 3 Landuse classification using Landsat TM data

From the result of peat swamp forest cover classification using Landsat TM data, its shows that the extent of peat swamp forest of Malaysia in 2005 and 2010 is about 1,156,304.81ha and 744,557.06 ha respectively. Where, 29.45% of the Malaysia peat swamp forest can be found in Peninsular Malaysia, 62.76% in Sarawak and 7.79 % in Sabah in 2010.

Table 1 Peat swamp forest cover extent in the study area

Study area	**2005**		**2010**	
	Area (Hectare)	**Percent (%)**	**Area (Hectare)**	**Percent (%)**
Peninsular Malaysia	257,221.91	22.25	219,263.50	29.45
Sabah	102,166.56	8.84	57,975.28	7.79
Sarawak	796,916.34	68.92	467,318.28	62.76
Total	1,156,304.81	100	744,557.06	100

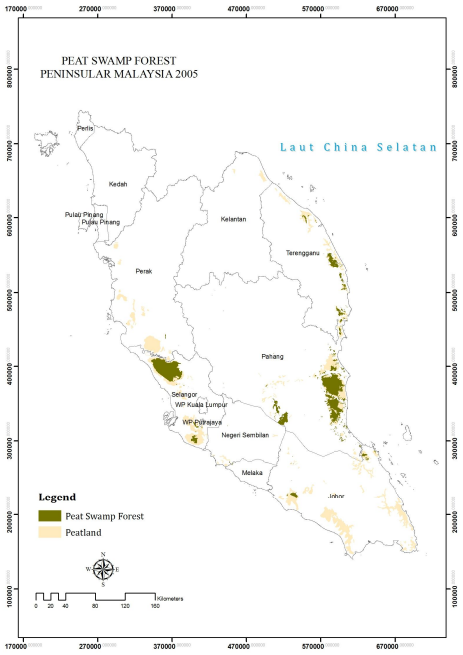

Figure 4 Peat Swamp Forest of Peninsular Malaysia 2005

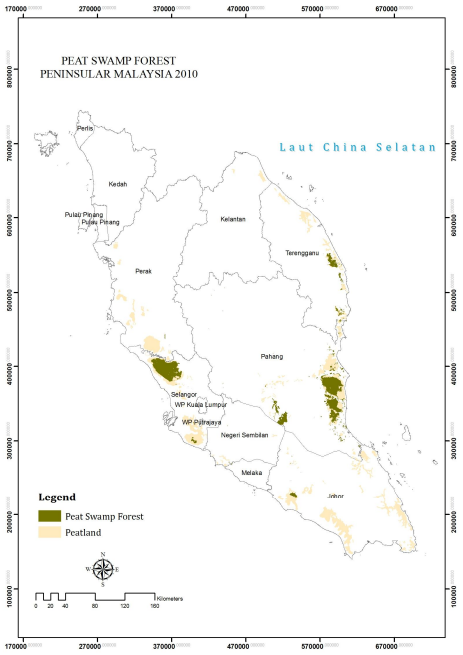

Figure 5 Peat Swamp Forest of Peninsular Malaysia 2010

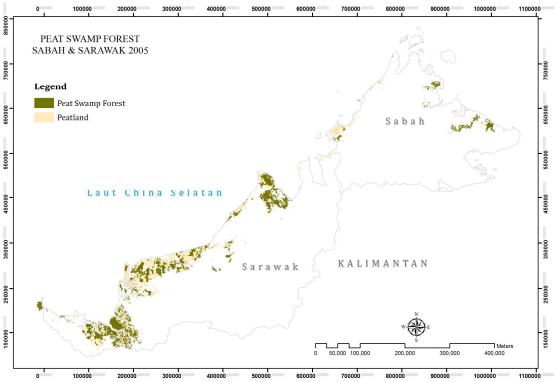

Figure 6 Peat Swamp Forest of Sabah and Sarawak 2005

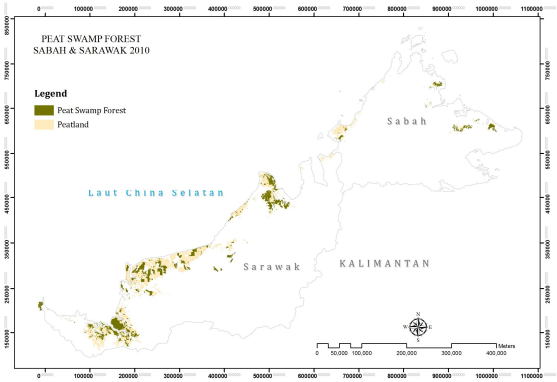

Figure 7 Peat Swamp Forest of Sabah and Sarawak 2010

Peat Swamp Forest Changes

From the classification result of peat swamp forest in the study area, the assessment of peat swamp forest cover changes has been done between 2005 and 2010. From the result, it has been found that the peat swamp forest cover in Malaysia has decrease about 35 % as shown in the details in Table 2. In the earlier stage of this study, the ground sampling has been done including the activity of ground truthing and forest biomass inventory. Klias Peninsular peat swamp forest has been selected as a test site to estimates biomass using plotless technique and it was found that the distribution of biomass within the plot is ranging from 96.06 to 213.10 tonne/ha with mean of 169.36 tonne/ha. From the result of biomass that has been produced from field inventory, the total amount of peat swamp forest biomass has been estimated as shows in Table 2

Table 2 Peat swamp forest cover and carbon stock changes from 2005 to 2010

Study area	**Area Decrease**		**Biomass Decrease**
	Hectare	**Percent Decrease**	**Tonne/ha**
Peninsular Malaysia	37,958.41	14.76	6,428,454.78
Sabah	44,191.28	43.25	7,484,023.84
Sarawak	329,598.06	41.36	55,819,151.14
Total	411,747.75		69,731,629.76

Accuracy Assessment

Typically the resulting classification is compared with reference data to assess the overall and class accuracy. In this study, points for verification of land cover classification result are determined based on a systematic sampling point method within the Landsat TM data. Total about 1829 verification points were generated to cover the entire Landsat TM scene with a distance between each point are consistent between 4 km. Existing land use map of 2008 has been used to quantify the accuracy of 11 land cover class that has been produced in this study namely; bare land, cropland, dipterocarp forest, fresh water swamp forest, grassland, mangrove, peat swamp forest, rubber, shrub land, urban and built up, and water. Table 4 shows the error matrix and the accuracy results. The overall accuracy is 67% which can be accepted for Landsat TM satellite based forest mapping.

Table 4 Accuracy assessment of land cover classification result

		Reference											
Result	Bareland	Cropland	Inland Forest	Fresh Water Swamp Forest	Grassland	Mangrove	Peat Swamp Forest	Rubber	Shrub land	Urban and Built Up	Water	Total	User Accuracy
Bareland	24	7	13	0	4	0	3	13	0	6	0	70	0.34
Cropland	3	430	59	0	7	0	20	51	0	9	0	579	0.74
Inland Forest	4	74	460	0	4	0	33	36	0	5	5	621	0.74
Fresh Water Swamp Forest	0	5	11	8	2	0	0	4	0	1	1	32	0.25
Grassland	0	2	0	0	7	0	2	0	0	0	0	11	0.63
Mangrove	0	2	0	0	0	5	2	0	0	0	0	9	0.55
Peat Swamp Forest	0	1	8	0	1	0	55	0	0	0	0	65	0.84
Rubber	3	64	26	0	10	0	12	162	0	4	0	281	0.57
Shrub land	0	17	8	0	0	0	4	3	14	0	0	46	0.30
Urban and Built Up	2	15	11	0	6	0	3	12	0	48	0	97	0.49
Water	3	0	1	0	0	0	0	1	0	0	13	18	0.72
Total	39	617	597	8	41	5	134	282	14	73	19	1829	
Procedure Accuracy	0.61	0.69	0.77	1.00	0.17	1	0.41	0.57	1.00	0.65	0.68		

Overall Accuracy : **0.67**

Kappa Coefficient : **67%**

CONCLUSION

In this study, a multi spectral image segmentation method combining spectral and shape features is proposed for land cover classification. Using Landsat TM satellite data, the study has successfully classified the images into eleven land cover classes namely; bare land, cropland, dipterocarp forest, fresh water swamp forest, grassland, mangrove, peat swamp forest, rubber, shrub land, urban and built up, and water with acceptable accuracy. From the result, the extent of peat swamp forest of Malaysia in 2005 and 2010 is about 1,156,304.81ha and 744,557.06 ha respectively. It has been found that the peat swamp forest cover in Malaysia has decrease about 35 % between 2005 and 2010. The distributions of peat swamp forest area can further be used to plan the restoration program and management activity. These results show that using medium resolution satellite images, which are widely available free of charge, can be used to distinguish peat swamp forests based on their spectral signature and segmentation method. The classification result could be refined further by increasing the number of sites for ground truthing. High resolution satellite data would provide even higher differentiation of vegetation units, but these must be purchased commercially and are very expensive.

ACKNOWLEDGEMENTS

This work was made possible by a grant from the Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet) under its collaborative project of Forest Cover and Carbon Mapping in the Greater Mekong Sub-region and Malaysia. The roles played by the Ministry of Natural Resources and Environment, Malaysia (NRE) as the executing agency, as well as FRIM and the forestry department in Malaysia are also greatly appreciated.

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