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Vegetation Assessment of Peat Swamp Forest Using Remote Sensing

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Abstract: Problem statement: Peat covers 1.6 million ha (13%) of the 12.4 million ha land area of Sarawak and some of peat swamp forests have been logged. The objective of this study was to assess the impact of logging operation on peat swamp forest in this area. **Approach:** The study used a remote sensing technique to assess vegetation cover in a peat swamp forest areas in Sarawak as result of logging practice and land clearing activities for oil palm plantation. Vegetation Index was used to assess impact of timber harvesting system and land clearing activities on remaining peat swamp forest in two sites which were logged previously and the possible relationship of change in hydrology. **Results:** The timber harvesting system was a combination of rail system for log transportation and excavator crawler for log skidding. Drainage work was probably carried out prior to logging activities which was followed up by land preparation for the establishment of the oil palm plantations. There was a general decrease in the level of greenness from 2002-2007. Between the two sites, the level of greenness was relatively lower in the West Site. The high green level of both sites was reduced remarkably in 2007 especially for the West Site and this corresponded to increase in the percentage of medium green level. The changed in the level of greenness in the remnant peat swamp forest could suggest that soil and other conditions such as vegetation structure and floristic composition are unfavorable for the expected rate of forest regeneration. **Conclusion:** The remnant logged peat swamp forest of the area declined due to a poor state of growth as shown by the dramatically decrease in the level of greenness. The peat swamp forest types strongly related to the hydrological conditions and the associated flow of nutrients and mineral elements. The surrounding hydrology was presumed to have influence the physical and chemical characteristics of the peat.

Key words: Peat swamp forest, remote sensing, logging, land clearing, environmental impacts

INTRODUCTION

Remote sensing has been widely applied for monitoring of the earth surface to determine changes in land use and land cover[12]. Multi-spectral satellite imagery is a cost effective, accurate and timely method of acquiring information on land use and land cover because they provide data more frequently and at lower cost compared to traditional methods of ground survey and aerial photography[4].

There are a number of approaches used in detecting changes in land cover[5]. One approach is the use of vegetation indices. Vegetation Indices are mathematical combinations of the spectral bands and have been found to be sensitive indicators of the presence and condition of green vegetation[7]. In this study changes in normalized difference vegetation index was used to assess impact of timber harvesting system and land clearing activities on remaining peat swamp forest in two sites-East which were logged previously. The vegetation assessment is based assessment on quantifying change of greenness level of vegetation cover change from 2002-2007.

The peat swamp forest is located in an area bound by Btg. Lebaan, Btg. Igan and Btg. Rejang, adjacent to Sibu town was selected for study. The area lies approximately between 111°35’-111°47’ E and 2°19’-2°24’ N. Location of the area is shown in Fig. 1.

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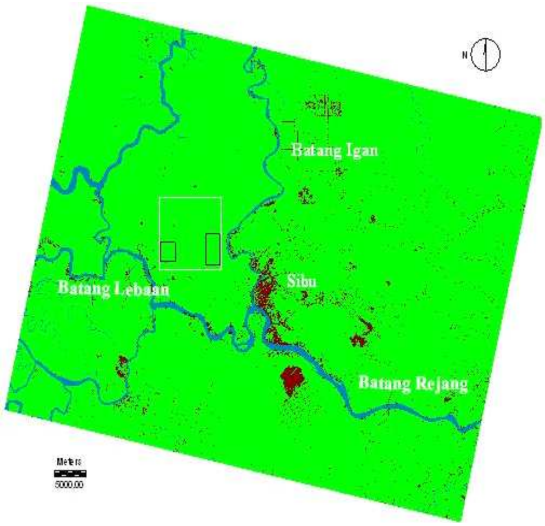


Fig. 1: Location of the peat swamp forest and area studied (white box)

Peat covers some 1.6 million ha or (13%) of the 12.4 million ha land area of Sarawak. It is a very important soil resource for the state as land suitable for conventional commercial agriculture is limited to only (26%) of the land area[13]. Peat swamp forest types with commercially valuable tree species are the Mixed Swamp, Alan Bunga and Alan Batu. Most of these forest types have been logged over in the past. Possibly only the Padang Alan forest type, consisting of few commercial timber species remains relatively undisturbed. Possibly about (1.5%) of peat swamp forest in Sarawak remain as natural forested original peat swamp forests[14].

Biodiversity is often studied in the light of increased human activities, In peat swamp forests the level of interest is at the ecosystem level that enables assessment of the potential suitability of the PSF for the species and habitat in question Wijdeven *et al*.[14]. The carbon stock of peat swamp forests is also becoming increasingly important in the light of global environmental issues. An assessment of the amount stored and the dynamics are very valuable assisting policy planners in assessing the importance of peat swamp forest. This includes biomass in dead wood which is an important aspect in the role of peat as a sink[14].

The study used remote a sensing technique to assess vegetation cover in a peat swamp forest areas in Sarawak to determine changes occurring and the possible relationship of change to the hydrology as result of logging practice and land clearing activities for oil palm plantation. The study is part of the multi-disciplinary studies on environmental impact of timber harvesting system on peat swamp forest in Sarawak.

MATERIALS AND METHODS

Two sets of SPOT 5 digital data from 291/345 path row^{-1} dated 1 August 2002 and 2 October 2007 with 20 m and 10 m pixel^{-1} ground resolution respectively were used in this study. The data sets with the lowest cloud contamination scenes available were acquired from the Malaysian Center for Remote Sensing (MACRES). Four spectral bands were included in both sets of data, Band 1-Green, Band 2-Red, Band 3-Near Infra-red (NIR) and Band 4-Short Wave Infra-Red (SWIR).

As the ground verification, the peat swamp forest studied lies on deep peat classified as Anderson 3 soil series and it is covered by logged and re-logged Alan Batu forest type. The structure of Alan Batu forest type in its primary condition is similar to that of mixed swamp forest type, except that the forest is dominated by large tree of Alan (*Shorea albida*). The total number of species is only slightly less than in Mixed Swamp Forest. The widely spaced dominant Alan trees are usually more than 45m tall with diameters frequently exceeding 117 cm. These large Alan trees are nearly all hollow and many are dead topped[6].

Melling *et al*.[9] reported that in comparison to the mixed swamp forest type which is generally mostly decomposed peat, the Alan forest types are woody. The Alan Batu forest type is generally found on a more stressful environment of the peat swamp. This may have led to physiological adaptation of the tree whereby it has a bigger buttress and are almost invariably hollow, whereby the shell of the timber remaining is very dense. Due to its harsh environment, the roots of the Alan Batu forest type are also more extensive creating the existence of a vacant layer in the peat profile which is about 20-30 cm within the top 100 cm of the peat profile. The inorganic nutrient of Alan forest type is significantly lower than the mixed swamp forest type. These present an extreme limiting conditions for plant growth as shown by the yield of oil palm planted on such peat.

The harvesting system used in the peat swamp forest was a combination of rail transportation and excavator crawler for timber skidding. For such timber harvesting system to be possible in a water logged peat swamp forest, extensive drainage is necessary carried. Drainage work was probably carried out initially to prepare the land for clearing, pulverizing and compaction of peat and plant biomass by excavator crawler prior to the establishment of the oil palm plantation. Casual check with a wooden stick at a recently logged site indicated that the water table might have dropped more than 50 cm. The dry condition of the peat probably enables the excavator crawler to move around freely during the timber extraction.

As logging and land clearing detection, the unsupervised classification method was first conducted on NIR Composite image, Bands 1-3 (BGR) to produce cluster images for both years. To detect and quantify temporal change in areas fell and cleared cluster labeling was used. The technique of image clustering and cluster labeling is a GIS-based image spatial reclassification procedure to deal with classification errors due to spectral confusion[14].

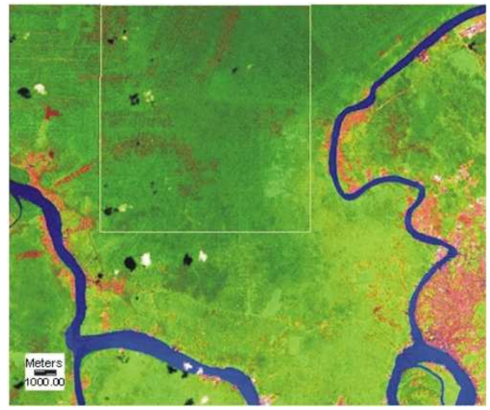
Because of the high level of cloud contamination in the 2007 image, the result of the spatial analysis is just indicative due to similarity of cloud spectral signature with fell and cleared area. The analysis was confine to white box (Fig. 1.) which is about 10,700 ha.

According to vegetation index, in order to detect level of greenness of remnant peat swamp forest due to the harvesting system and land clearing activities, two sites-East and West as illustrated by black boxes in Fig. 1 were used for the Vegetation Index analysis. Lillesand and Kiefer[4] noted that the use of Normalized Difference Vegetation Index (NDVI) has been much favored for studying many vegetation phenomena. Bands 3 (Red) and 4 (Near Infra-red) were used to compute the NDVI. The NDVI results generated were reclassified into the four level greenness categorized into non-green, low green, medium green and high green. The Vegetation Index scale ranges from-1 through 0 to +1 with negative values to zero value represent no vegetation.

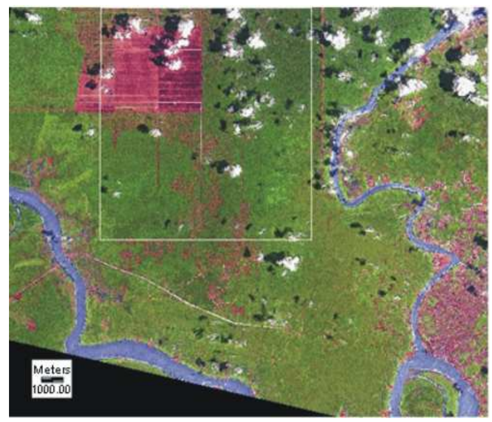
The sites analyzed, East and West Sites were areas of remnant of peat swamp forest which were not re-logged or affected by land clearing activities as visualized in the 2007 imagery. The sizes of the East and West Sites are about 1,060 and 650 ha respectively. As mentioned earlier the 2007 image has extensive cloud contamination and thus, cloud and shadow masks were applied to both the 2002 and 2007 imageries. Areas masked out were excluded from the Vegetation Index analysis.

RESULTS

The temporal trend of the vegetation cover from 2002-2007 of the logged peat swamp forest area is shown using NIR composite image (Fig. 2).



(a)



(b)

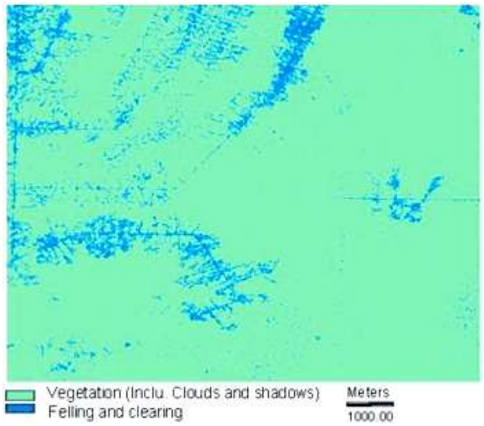
Fig. 2: NIR Composite image indicating felling and clearing activities: (a): 2002 and (b): 2007

Table 1: Relative sizes of area fell and cleared

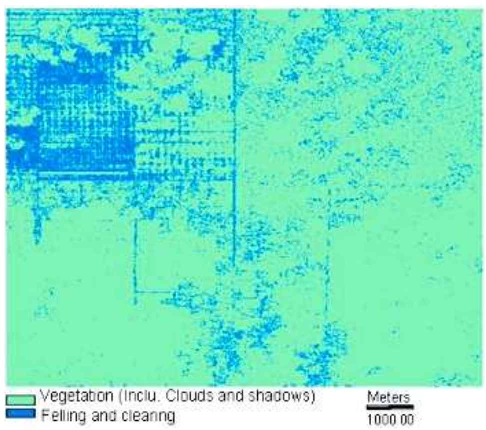
Cover	2002 Ha	(%)	2007 Ha (%)
Vegetation (including clouds shadows)	9,890	92	9,004 84
Felling and clearing	820	8	1,700 16
Total	10,710	100	10,700 100

The 2007 imagery clearly shows that felling as indicated by rail line features. Rail was used for log transportation and crawler excavator was used for log skidding. As seen in the left top corner of the area studied (white box), logging activities were succeeded by clearing of area for oil palm as the timber extraction areas widen.

The areas quantified in the white boxes for both years are shown in Table 1 and illustrated in Fig. 3. Fell and cleared areas have increased relatively by two folds from 2002-2007.



(a)



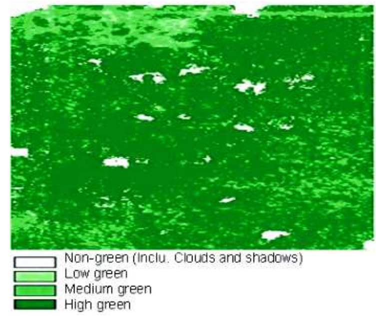
(b)

Fig. 3: Temporal changes of felling and clearing of area studied: (a): 2002 and (b): 2007

Table 2: Classes of vegetation indices and greenness levels

Plot	Greenness level	VI (2002)	VI (2007)
East	Non-green	-0.40-0.00	-0.71-0.00
	Low green	0.01-0.14	0.01-0.21
	Medium green	0.15-0.28	0.22-0.42
	High green	0.29-0.43	0.43-0.64
West	Non-green	-0.12-0.00	-1.00-0.00
	Low green	0.01-0.13	0.01-0.22
	Medium green	0.14-0.26	0.23-0.44
	High green	0.27-0.40	0.45-0.67

The vegetation indices generated for the East and West Site were sorted out into three classes and were categorized into relative levels of greenness for both years as shown in Table 2. The categorized level of greenness of both sites is then typified in the level of greenness thematic maps shown in Fig. 4 and 5.



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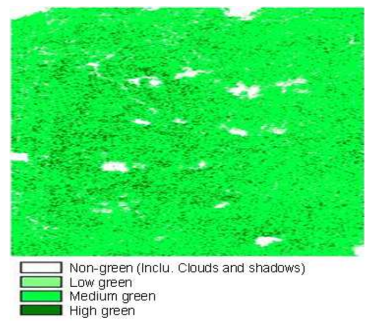
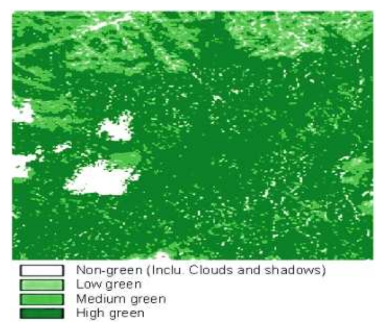
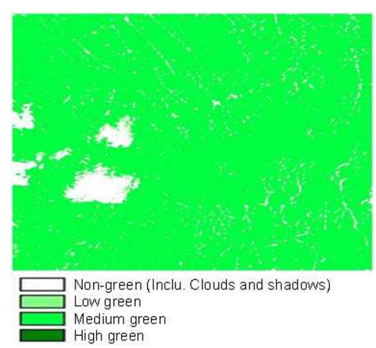


(b)

Fig. 4: Level of greenness of the East Site: (a): 2002 and (b): 2007



(a)



(b)

Fig. 5: Level of greenness of the West Site: (a): 2002 and (b): 2007

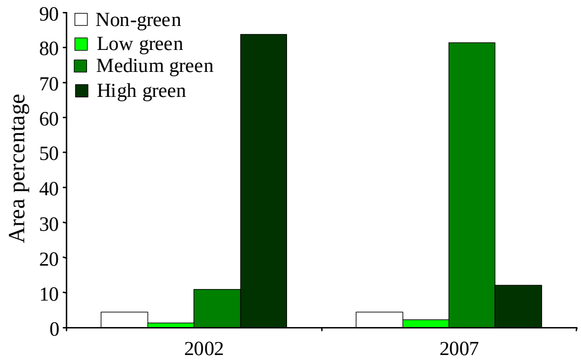


Fig. 6: Temporal change in the level of greenness for East site

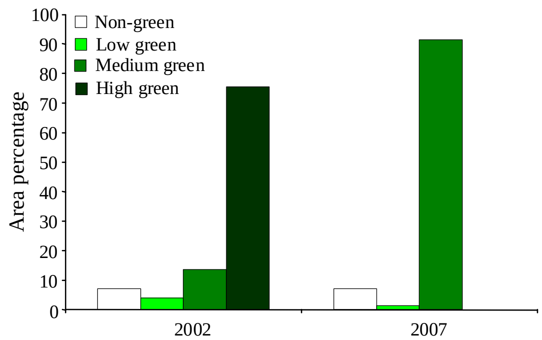


Fig. 7: Temporal change in the level of greenness for West site

The level of greenness thematic maps clearly typified that there was a general decrease in the level of greenness from 2002-2007. Between the two sites, the level of greenness was relatively lower in the West Site. The high green level of both sites was reduced remarkably in 2007 especially for the West Site and this corresponded to increase in the percentage of medium green level (Fig. 6 and 7).

DISCUSSION

Lee[6] reported that the logged-over mixed swamp forest regenerated well naturally with adequate to heavy stocking of desirable species which are well-distributed. In Alan forest type, although a high percentage of Alan (*Shorea albida*) seedlings are present after logging, they are quickly submerged by competing vegetation and those that survive have very slow growth rate. Similarly, slower growing species like Keruntum (*Combretocarpus rotundus*), Rengas (*Melanorrhoea* spp.). Nyatoh (*Palaquium* spp.) and Ramin (*Gonystylus bancanus*) decreased in distribution by (30%). However, fast growing species like Ako (*Xylopia coriifolia*), Medang (*Litsea* spp.) and Geronggang (*Cratoxylum* spp.) make large gains after logging. Species like Jongkong (*Dactylocladus stenostachys*), Ketiau (*Gabua* spp.) and Semayur (*Shorea inaequilateralis*) with medium rates of growth showed about 20% in gain in distribution.

The changed in the level of greenness in the remnant peat swamp forest could suggest that soil and other conditions such as vegetation structure and floristic composition are unfavorable for the expected rate of forest regeneration. However, Gibson and Power[1] pointed out that results of the Vegetation Index should be used with care as they are many factors external to plant morphology and growth that could alter the visible red band and near infra-red band ratio. Vegetation index is also sensitive to atmospheric degradation especially visible bands, which could alters the value of the band ratio.

The natural regeneration of sustainable logged forest should prevail except when sites are deforested and permanently converted to other land use such as clearing for oil palm plantations. Analysis of Vegetation Index indicated that the remnant logged peat swamp forest of the area studied may have decline into poor state of growth as shown by the dramatically decrease in the level of greenness. Uyo[9] reported that when peat is drained, it results in number of reactions such compaction and consolidation due to reduced in buoyancy and hydraulic conductivity, increase in decomposition and mineralization and subsidence and irreversible drying due to over drainage.

The peat swamp forest types are strongly related to the hydrological conditions and the associated flow of nutrients and mineral elements. It is observed that the surface topography and peat thickness does not influence the forest type directly but is actually more influence by the surrounding hydrology and the physical and chemical characteristics of the peat which are closely related[9,10] reported that peat is considered unsuitable for agricultural use because of some very serious limitations to crop growth. Oil palm estates on deep peat soils of Sarawak have not been yielding equally well as in other part of the country. The presence of vacant layer in the top 40-60 cm of some peat soils and the existence of difference morphological, physical and chemical properties could also have a direct bearing on the suitability, utilization and management of the soils for agricultural development but for the regeneration of the remnant logged peat swamp forest.

Apart from its commercially valuable tree species, diverse biodiversity and its role as carbon stock and sink, one of the benefits derivable from undisturbed peat swamp is the regulation of its hydrology[11]. Undisturbed peat swamp prevents flooding and droughts of adjacent populated or agricultural areas. The effects of the declining state and the reduction in size of the peat swamp forest may ultimately result in the reduction of dry season flow and worsening storm flow especially during the wet season. Drastic land cover changes will not only affect flood regime but also disruptions in water supply. Makino *et al*.[8] reported that forest clearing affected long-term water budget of a river basin in the western part of Japan based on a study using multi-temporal satellite and hydrological data. Review by Harding[2] of results from tropical forestry experiments concluded that deforestation increases water yields in most circumstances, resulting in increasing frequency of flooding(often on a local scale), as well as increases in erosion and sedimentation rates.

CONCLUSION

Remnant logged peat swamp forest of the area may be declining to a poor state of growth as shown by the dramatically decrease in the level of greenness. The peat swamp forest types are strongly related to the hydrological conditions and the associated flow of nutrients and mineral elements. The surrounding hydrology is presumed to have influence the physical and chemical characteristics of the peat.

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