

MAPPING OF OIL PALM CULTIVATION ON PEATLAND IN MALAYSIA

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Oil palm (*Elaeis guineensis* Jacq.) is the main industrial crop in Malaysia. In the early years of its expansion, most of the oil palm was cultivated on suitable mineral soils. However, as available suitable land is diminishing, some of the oil palm is now being cultivated on marginal soils such as peat. There are 2.43 million hectares of peatland in Malaysia which are mostly located in Sarawak. Generally, peatland is formed in the lowlands, and only a small area occurs in the highlands. Lowland peat occurs in the coastal areas, in low lying and poorly drained depressions or basins.

A remote sensing (RS) survey in 2003 indicated that there were about 313 000 ha of oil palm cultivated on peatland in Malaysia (Wahid *et al.*, 2005). RS technologies using satellite data have been successfully adopted in various applications related to earth resource studies and environmental monitoring. These techniques are cost-effective and have wide coverage, provide near real-time data acquisition and have frequent revisit capability. RS has significant potential in assisting oil palm monitoring and detection efforts. Satellite data from Landsat Thematic Mapper (McMorrow, 1995; Wahid, 1998) and SPOT (Lukman and Poeloengan, 1996) have been successfully used to identify oil palm areas, and to map differences in palm age at the early stages of growth. In this study, peatland digital maps were created by digitizing the soil maps and oil palm land use in Peninsula Malaysia, Sabah and Sarawak using RS data.

OBJECTIVES

- To determine the extent of peatland in Malaysia.
- To set up an inventory of oil palm plantings on peat.
- To determine the latest area of oil palm on peat.

MATERIALS AND METHODS

Peatland Information

Peatland digital maps were created by digitizing the soil maps of Peninsula Malaysia, Sabah and Sarawak. The soil maps were obtained from the Department of Agriculture of the respective regions.

Satellite Data

Oil palm land use in Peninsula Malaysia, Sabah and Sarawak was determined and mapped using 2008-

2009 SPOT 5 (10 m) images (Table 1). Some 181 scenes of SPOT 5 images were used. Figure 1 shows the mosaicked SPOT 5 images of Sabah.

Image Processing

The ERDAS Imagine 9.3 software was used to process the images. Figure 2 shows the flow chart in developing an oil palm land use map from SPOT 5 (10 m) images.

Image enhancement. Enhancement of the images was carried out using the histogram equalization technique (Jensen, 1997). The enhancement provided more contrast stretch to enable better visualization of the images (Figure 3). Visual analyses of the enhanced images were carried out with the assistance of field and ancillary data, such as existing land use and topographic maps.

Classification. Object-oriented digital classification and visual classification approaches were used for land use classification. The enhanced images were segmented into polygons with built-in topology by supervised classifications using Nearest Neighbour Algorithm.

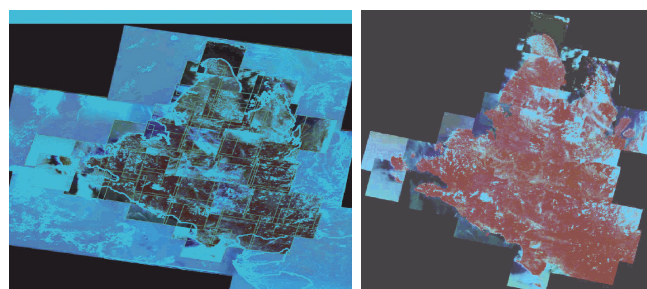


Figure 1. Individual (left) and mosaicked (right) SPOT 5 images of Sabah.

TABLE 1. SPOT 5 (10 m) IMAGE SPECIFICATIONS

Spatial resolution	10 m – green, red and near infra-red (NIR) and short wave infra-red (SWIR)
Radiometric resolution	8 bits
Spectral resolution (multi-spectral data set)	Green: 500-590 nm Red: 610-680 nm NIR: 780-890 nm SWIR: 1580-1750 nm
Scene size	60 x 60 km

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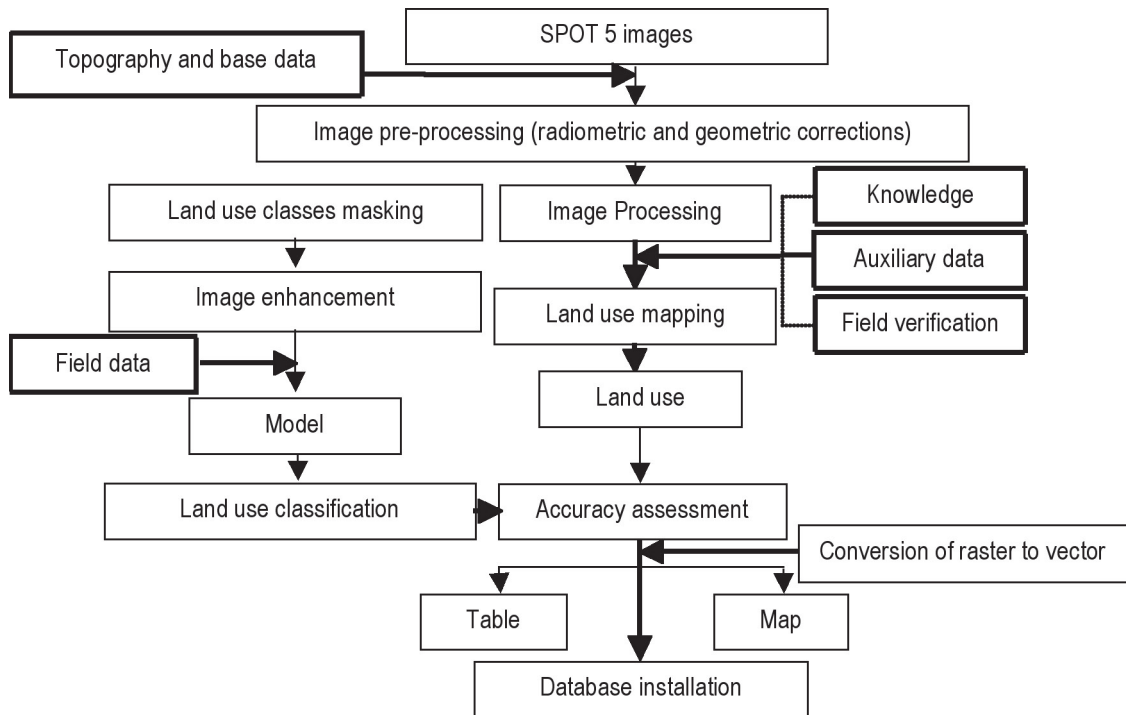


Figure 2. Methodology flow chart for developing an oil palm land use map.

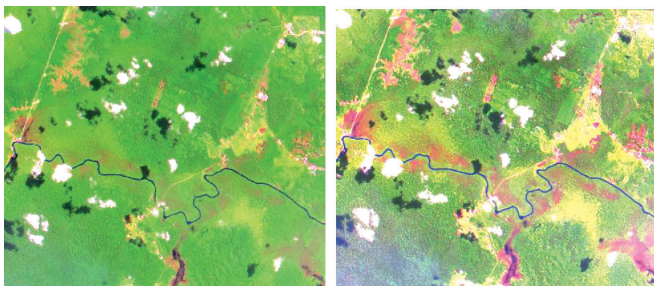


Figure 3. Comparison between unstretched (left) and stretched image (right) after histogram equalization.

The polygons were then assigned to different classes of land use. Factors such as colour, tone, texture and shape of the features in the image were used to interpret the features for the different types of land use classes (Figure 4). Prior to the delineation of land use and supervised classification, ground truthing was carried out to identify the heterogeneous, complex features and colour. Digital number and site position on the ground of known land use were used in a model to classify similar features in the image. The description and legends of the Department of Agriculture of Peninsula Malaysia were used for the land use classes.

Geographic Information System (GIS) Integration.

The classified land use polygons were exported to the Geographic Information System (GIS) environment for spatial integration and analysis. This process comprises (i) validating polygon attribute data, feature coding and land use nomenclature, and (ii) polygon editing to correct for node errors, dangles, pseudo polygons, gaps, overlapping and non-matching arcs. Upon completion of the validation and editing process, the digital vector files were merged and sectored into maps according to state boundaries on a 1:50 000 scale.

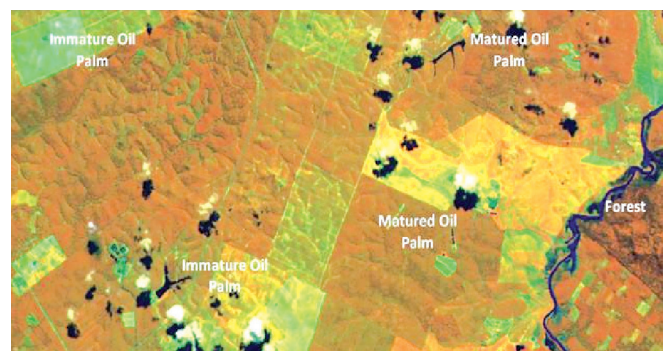


Figure 4. Features on a satellite image with different colour, tone, texture and shape used for creation of land use classes.

RESULTS AND DISCUSSION

Peatland

Digitization of the soil maps of Peninsula Malaysia, Sabah and Sarawak indicates that the area of peatland in Malaysia totals 2.43 million hectares (Figure 5 and Table 2). Sarawak has the largest area of peatland followed by Peninsula Malaysia and Sabah.

Oil Palm Cultivation Areas

The total area of oil palm detected from the SPOT 5 images was 5.01 million hectares (Table 3). The area detected was 6.8% more than the total oil palm registered area (4.69 million hectares) as reported by the Malaysian Palm Oil Board (MPOB) for 2009. The additional areas detected were the yet-to-be registered new oil palm areas and unplanted areas (roads, drain, quarters, etc.). Atmospheric noise and cloud covers also caused errors to the area estimations. However, these problems were solved using shadow-free images,

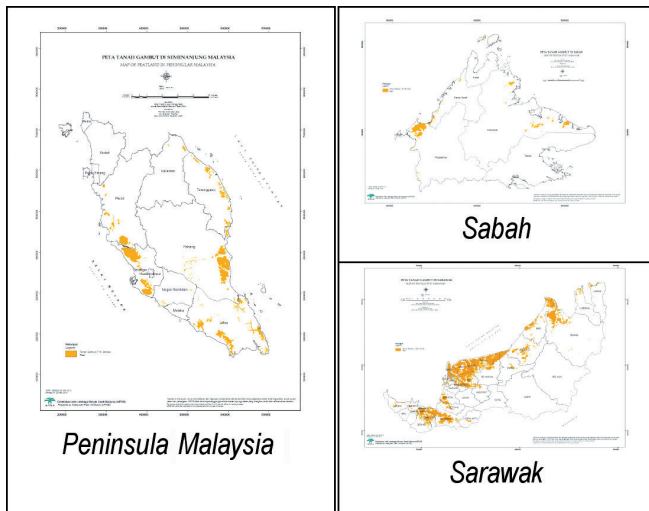


Figure 5. Location of peatland in Peninsular Malaysia, Sabah and Sarawak.

TABLE 2. PEATLAND AREAS ACCORDING TO REGIONS IN MALAYSIA

Region	Area (ha)
Peninsula Malaysia	716 944
Sabah	121 514
Sarawak	1 588 142
Total	2 426 600

TABLE 3. TOTAL OIL PALM ON PEAT IN 2009, MALAYSIA

Region	Oil palm (ha)	Oil palm on peat	
		(ha)	%
Peninsula Malaysia	2 503 682.02	207 458.01	8.29
Sabah	1 340 317.39	21 405.75	1.60
Sarawak	1 167 172.51	437 174.27	37.45
Total	5 011 171.92	666 038.03	13.29

ground truthing and the right image processing techniques.

Oil palm cultivated areas on peat in Malaysia in 2009 totalled 666 038 ha, which was 113% more than in 2003. Sarawak still has the largest area of oil palm cultivation on peat, followed by Peninsula Malaysia and Sabah (Figure 6). The percentage of Malaysian oil palm cultivation on peat in 2009 was 13.3%, compared to 8.2% in 2003. Up to 2009, some 27.4% of Malaysian peatland had been cultivated with oil palm.

Land Use Classification Accuracy

The results of the land use validation using 16x16 confusion matrixes are shown in Table 4. The results indicate that the user's accuracy for the oil palm land use classes was 94%. The overall land use classification accuracy (Kappa Coefficient) was 90%.

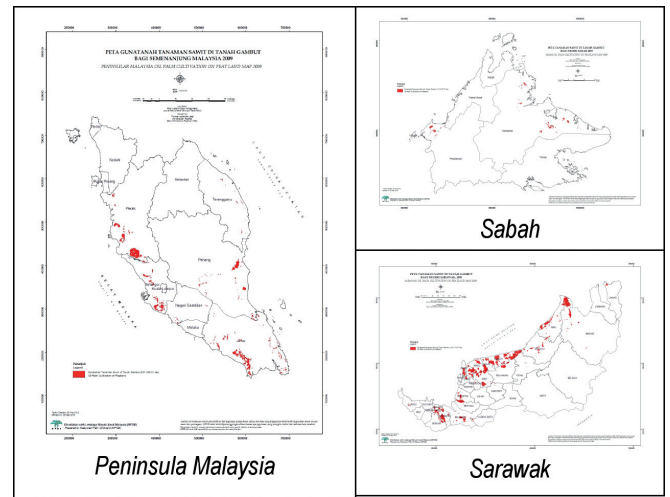


Figure 6. Maps of oil palm cultivation on peat in Peninsular Malaysia, Sabah and Sarawak in 2009.

CONCLUSION

Satellite images, e.g. from SPOT 5 (10 m), can be used to identify oil palm cultivated areas. Compared to the conventional land use survey, this RS technique is time-efficient, has wide coverage and is capable of frequent revisit and near real-time data acquisition. However, RS surveys are influenced by the quality of the image, image processing technique and ancillary data gathered during ground truthing. Integration of RS and GIS has allowed for a more accurate assessment of oil palm cultivation on peatland. In 2009, the total area of Malaysian oil palm cultivation was 5.01 million hectares, of which, 0.67 million hectares were planted on peat covering about 27.4% of the peatland in Malaysia.

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TABLE 4. CONFUSION MATRIX FOR ACCURACY ASSESSMENT

Land use class	1U	3O	3G	3S	3A	3P	4C	4P	6R	7S	7L	7F	8P	8O	9B	10W	Row total	User accuracy (%)	Commission error (%)
1U	26																26	100	0
3O		33								1	1						35	94.3	6
3G			3														3	100	0
3S				2													2	100	0
3A					1												1	100	0
3P						2											2	100	0
4C							3										3	100	0
4P								2									2	100	0
6R							1		43								44	97.7	2
7S									2	10	2						14	71.4	29
7L										2	46	3	3				54	85.2	15
7F										2	1	13	1				17	76.5	24
8P													11				11	100	0
8O														4			4	100	0
9B															2		2	100	0
10W																2	2	100	0
Column total	26	33	3	2	1	2	4	2	45	15	50	16	15	4	2	2	222		
Producer accuracy (%)	100	100	100	100	100	100	75	100	95.6	66.7	92.	81.3	73.3	100	100	100			
Omission error (%)	0	0	0	0	0	0	25	0	4	33	8	19	27	0	0	0			
Total: 222									K _{hat} Coef: ((N*PART A)-PART B)/(N ² -PART B)										
Diagonal: 203									PART A: Diagonal: 203										
Overall accuracy: 0.914414									PART B: 7216										
% Accuracy: 91.44144									K _{hat} Coef: 0.899734										
									% of K _{hat} Coef: 89.97%										

Note: 1U = urban land; 3O = oil palm; 3G = rubber; 3S = sago; 3A = cocoa; 3P = pepper; 4C = diversified crops; 4P = paddy; 6R = non-cultivated vegetative land; 7F = primary forest; 7L = logged over forest; 7S = secondary forest; 8P = peat swamp forest; 8O = other swamp forest; 9B = bare land; 10W = water bodies.

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