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Detecting and Quantifying Degraded Forest Land in Tanah Merah Forest District, Kelantan Using Spot-5 Image

Mohd. Hasmadi Ismail*, Ismail Adnan Abd. Malek and Suhana Bebakar
Department of Forest Production, Faculty of Forestry,
Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
**E-mail: mhasmadi@putra.upm.edu.my*

ABSTRACT

In sustainable forest management, information on the extent and types of degraded forest sites is essential and crucial. It enables planning of appropriate remedial strategies. This study was carried out to detect and quantify degraded forest land in Tanah Merah District, Kelantan using remotely sensed data. Spot-5 satellite data (Path/ Row: 269/339) was acquired from MACRES, which covered part of three forest reserves ie. Sungai Sator, Gunung Basor and Gunung Stong. The ERDAS IMAGINE software version 8.7 was used to enhance the image for better visualization using band combination and spatial filtering techniques. This was followed by "Supervised Classification" of the image using "Maximum Likelihood Classifier" to detect and classify degraded forest features into pre-determined classes. The four classes detected were primary forest, degraded forest, gap and water bodies. Results showed that the degraded forest class constituted the largest area (57,878 ha), followed by primary forest gap (20,686 ha) and gap (3,488 ha). Degraded forest types were represented by road, agriculture, plantation areas. Based on the accuracy assessment, the overall classification accuracy obtained was 89% and showed that the remote sensing technique was able to detect and map degraded forest sites.

Keywords: Remote sensing, degraded forest detection, quantifying

INTRODUCTION

Forestry is the scientific management of forests for the continuous production of goods and services, in particular the production of timber. At the end of 2002, Malaysia had an estimated 19.93 X 106 ha. of forest covering 60.7% (32.86 X 106 ha) of its total land area. Of this total, about 14.33 X 106 ha have been designated as Permanent Forest Estate (PFE) under sustainable management, while 2.12 X 106 ha are protected by legislation for conservation purposes. Currently, forest management practices in Peninsular Malaysia are based on the Selective Management System (SMS) with the main objective of optimizing timber harvest while maintaining the sustainability of forest production. In Kelantan, the total extent of forest is 629 687 hectares including virgin forest, the logged forest and the plantation forest. In the western part of Kelantan, there are 12 permanent reserve forests, as shown in Table 1.

Based on the study by John (1991), forest degradation problems include ecological damages, especially soil erosion, climate change and nutrient degradation. The implications of forest degradation are loss in forest structures, function, species compositions, and productivities which are normally low compared to natural forest types. Technology can assist in reducing forest degradation problems especially spatial data technology such as GIS, GPS and remote sensing (Henry *et al.*, 1997).

Remote sensing is the collection of data about objects, which are not in contact with the collecting device (Sabin, 1997). It can be used for providing information on recognizable features e.g. water, vegetation and soil due to their reflectance characteristics. Geographical Information System (GIS) involves the computer-organized grouping of activities and procedures covering the input, storage and manipulation, retrieval and presentation of spatially based

* Corresponding Author

TABLE 1
The 12 permanent reserve forests (PRF) in Tanah Merah District, Kelantan

No.	PRF	Types Forest	Areas (Hectare)	Date Gazetted
1.	Balah	Forest Land	56,010	1/3/1990
2.	Berangkat	Forest Land	21,409	9/9/1941
3.	Bukit Akar	Forest Land	1,072	11/5/1989
4.	Gunong Basor	Forest Land	40,613	11/5/1989
5.	Gunong Stong Selatan	Forest Land	28,134	11/5/1989
6.	Gunong Stong Tengah	Forest Land	21,950	11/5/1989
7.	Gunong Stong Utara	Forest Land	11,044	11/5/1989
8.	Jedok	Forest Land	4,382	1/1/1957
9.	Jeli	Forest Land	3,649	6/6/1991
10.	Jentiang	Forest Land	13,673	11/5/1989
11.	Sungai Sator	Forest Land	2,777	1/4/1962
12.	Sokortaku	Forest Land	21,825	10/10/1960

reference data (John, 1991). It can be used to complement remote sensing data especially for creating operation maps. GIS has two common methods of structuring geographic data, the raster data and vector data structure. The raster data that was used is a grid. However for the vector data, a point is represented as a single x,y coordinate pair and area represented by a closed line or set of line. This study was carried out to detect and quantify the degraded forest land in Tanah Merah District using SPOT-5 imagery. SPOT-5 imagery was used due to its 20 meter spatial resolution and was the only good images available during the period of this study. GIS was used to support satellite image data collected for quantifying and mapping degraded forest areas.

MATERIALS AND METHODS

Study Area

Kelantan is one of the 13 states in Malaysia, richly endowed with resources, covers a land area of about 15 000 km^2, northeast of Peninsular Malaysia facing the South China Sea and is occupied by almost 60% of forest. It is situated within latitudes of 101° 20' E to 102° 40' E and longitudes of 4° 30' N to 06° 15'' N. The total land area of Kelantan is approximately 1, 493, 181 ha, of this 894,276 ha are forested areas. A total of 626 372 ha of the total forested area are forest reserves and the rest is forest state land and the National Park (Iwan, 2001). The study area was conducted in the western part of Kelantan, consist of 12 permanent forest reserves in the Tanah Merah district. The total forest area is about 184,610 ha. *Fig. 1* shows the location of the study area.

Daily temperature ranges from 21° to 32°C. There is a marked dry season in February, March and April. The geological formations of the area are mainly sedimentary in origin, accompanied by folding and metamorphism (Haryono, 1995). The soil nutrients are depleted due to the continuous leaching associated with high rainfall of the humid tropics.

Data Acquisitiozn and Digital Image Analysis

The satellite image was acquired from the Malaysian Centre for Remote Sensing (MACRES) for path and row of 269/339 dated 13th March 2005. The geocorrected data with spatial resolution of 20 m has about 10 percent cloud cover. Secondary data used in this study are topographical map (scale 1: 50 000) from the Forestry Department Headquarters, Kuala Lumpur and digital compartment map from the Kelantan State Forestry Department.

ERDAS IMAGINE software version 8.9 was used for digital image processing such as remote sensing analysis, digital photogrammetry, data visualization, image analysis, GIS and Digital Terrain Model (DTM) analysis. ERDAS IMAGINE is an integration of remote sensing and GIS, which has the ability to digitize images, process images, generate maps and analyse remotely sensed data in raster and vector formats. In this study, overlaying maps of compartments and boundaries of forest reserves were undertaken to complement analysis satellite image.

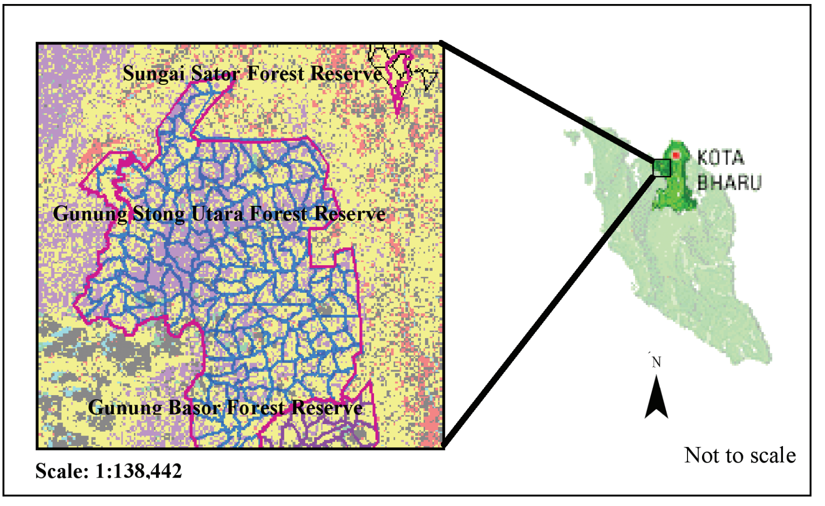

Fig. 1: A map of the Peninsular Malaysia showing a satellite image of forest compartments in the study area

Methods

Briefly, the procedure for the first step was data acquisition, digital image processing and analysis, ground verification, image classification, accuracy assessment and degraded forest land map derivation (*Fig. 2*). SPOT-5 data was corrected from geometric distortion. The image was enhanced through adjustment of the linear stretch line and increasing the image appearance by modifying the contrast level and then the image was filtered using a low pass type filter. False color composite, band 4-1-2 (R-G-B) was used since it showed much better information in land cover type discrimination (Mohd. Hasmadi and Kamaruzaman, 2004).

Classification of the land cover type and degraded forest land from SPOT-5 imagery involved both visual interpretation and computer assisted analysis (Maximum Likelihood supervised classification approach). For the purpose of this study, a total of six sample pixels for each class were selected, which are called training samples. Comparisons of spectral reflectance from these training samples were discriminate land cover features at the study area. The classes were forest, poor forest, opened areas of roads or plantation, river and water bodies.

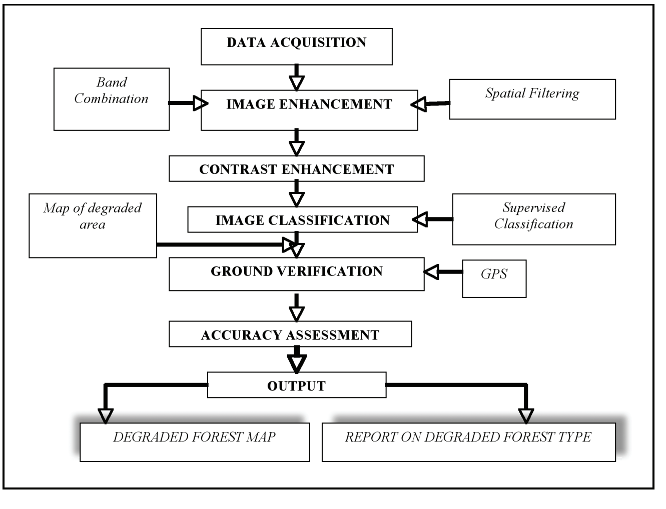

Fig. 2: Flowchart of the study

In a remote sensing study, ground verification is an essential component to evaluate accuracy of classified satellite imagery (Story and Congalton, 1986). In order to determine the accuracy of image classification, ground verification survey was carried out. A total of 61 training areas were selected randomly and visited with the support of satellite imagery, topographical map and land use map. For each visited site, photographs, locational data and type of land cover were observed and recorded in a form. The ground truth verification data were used in the maximum likelihood report as the independent data set from which the classification accuracy was compared (Kamaruzaman and Mohd.Hasmadi, 1999). The accuracy is essentially a measure of how many ground truth pixels were correctly classified.

RESULTS AND DISCUSSION

Band Combination and Image Enhancement

Selection of band combinations is one of the essential procedures for making enhanced color composite images and it is possible to visualize maximum information of the data. *Fig. 3* shows the study area image in band combinations of 4-1-2, (R-G-B). This image can clearly distinguish the pattern of land cover features in the study area such as water bodies, primary forest, secondary forest and cleared land. Low temperature areas such as the forest and water bodies were represented in the image as green for forest and dark blue for water respectively. Areas with high temperature such as logging area, opening land, road network and plantation areas were showed as light color.

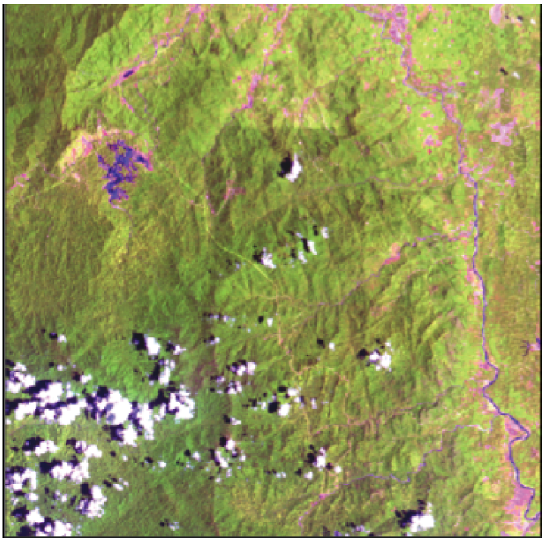

Fig. 3: False color composite of 4-1-2 (R-G-B) band using contrast stretching enhancement technique

Spatial Filtering

In spatial filtering, the results showed that median filter with a low pass filter (3x3) was found to be the most suitable filter to apply on Spot-5 satellite imagery. Using median filter enabled identification of features such as opened area because of their light color. *Fig. 4* showed that the image was filtered by low pass median filter (3 x 3) and enhanced using contrast stretching. For the entire filtered image, a composite image of band 4-1-2 (R-G-B) was later used in the image classification process for delineating forest and degraded areas.

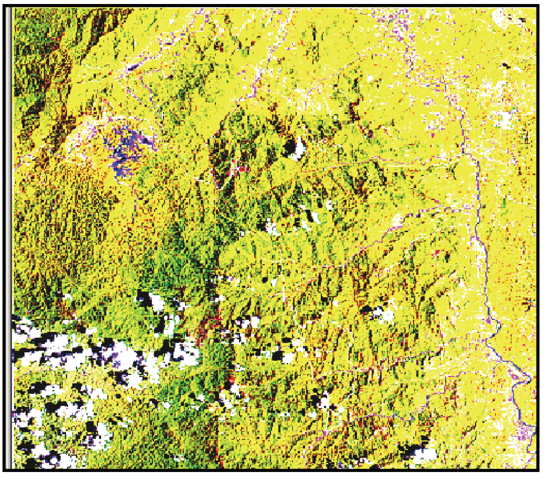

Fig. 4: Enhanced image of 4-1-2 (R-G-B) false color composite filtered using low pass median filter

Supervised Classification

Maximum Likelihood classifier (MLC) was used in the classification. This classifier produced the best results when 30 training sites were sampled, that is, each site has 50- 100 times as many pixel as there were bands in the data set which were closely homogeneous. However, this approach is slow compared to the Parallepiped Classifier and Minimum Distance classifier for image classification (Wan Zuraidi, 2000). Classification using prior information on the study site helped accuracy of classification. This implies that there are advantages for the interpreter to know the study area well before interpreting any satellite image. *Fig. 5* shows the results of supervised classification of the study area.

The supervised classification using MLC produced six classes and were identified as follows; forest (purple and green), gap (red), poor forest (yellow), water bodies (light blue), bamboo (light green), and plantation (pink).

Ground verification points were collected using Garmin hand held GPS (<10 m accuracy), which were marked initially on topographic and image maps. The area indicated by the GPS point represents different features on the scene. Most of the area visited on the ground can be identified and discriminated in the image. A total of 61 samples locations were chosen randomly and visited during ground verification work. During the verification process most of the verified points from Sungai Sator Forest Reserve areas represented degraded area and constituted areas of agriculture, plantations and shrubs. More than 80% of the degraded areas were within rubber plantations and roads.

Water bodies such as rivers were easily spotted due to its size and can be identified clearly in the map and image. Opened area such as road networks and human settlement can also be easily spotted in the image. Most of the bamboo areas were found in the forest, especially along the secondary roads in Gunung Basor Forest Reserve, where the site has been previously degraded by logging.

Accuracy Assessment

Final classification categorised the area into four classes namely forest, gap, poor forest (including bamboo and plantation), and water bodies. Table 2 shows the results of confusion matrix for the four classes in the study area. The average and overall accuracy of classification results were 85 % and 89 %, respectively. Water bodies showed the highest accuracy (100%) while gap or opened area showed the lowest accuracy (65%). The accuracy of other classes such as forest and poor forest were 92% and 100%. The presence of cloud in the image slightly affected the image classification results.

The overall accuracy indicates that the remotely sensed classified image was sufficiently accurate in mapping the types of degraded forest in the study site. The high accuracy achieved was due to the selection of dominant spectral response patterns and to the researcher's familiarity with the study site. The area for each class obtained from the final classification is shown in Table 3 which shows that the degraded forest area is the largest occupying 57,878 ha, and the primary forests of Gunung Stong Utara

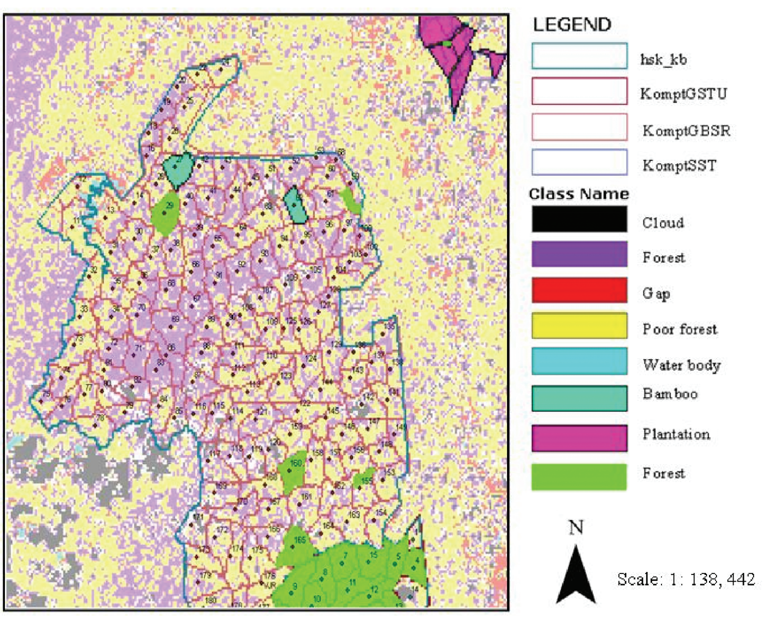

Fig. 5: Six cluster of land cover in the study area Ground Verification

TABLE 2
Confusion matrix for four classes of the study area

Referred code	Classified Data					Accuracy (%)
	1	2	3	4	Total	
1	13	1	0	0	14	66.5
2	8	15	0	0	23	92.86
3	0	0	13	0	13	100
4	0	0	0	11	11	100
Total	22	15	13	11	61	

1: Forest	*Average accuracy*	*= 85.02%*
2: Gap	*Overall accuracy*	*= 89.52%*
3: Poor forest	*Mean overall accuracy*	*= 0.21%*
4: Water bodies	*Kappa coefficient*	*= 0.81*

TABLE 3
Classification of degraded forest in Tanah Merah district, Kelantan

No.	Classes	Area (ha)
1	Forest (Gunung Stong Utara Forest Reserve, Gunung Basor Forest Reserve and Sungai Sator Forest Reserve)	20, 685.93
2	Gap	3488.68
3	Degraded forest (Poor forest, bamboo and plantation)	57, 878.4

Forest Reserve, Gunung Basor Forest Reserve and Sungai Sator Forest Reserve occupying 20, 685.93 ha.

CONCLUSIONS

From the results of this study, Spot-5 satellite data based on computed- assisted analysis could serve as a useful tool to identify degraded forest land in the study area. This identification was extracted from enhanced image of 4-1-2 (R-G-B) false color composite band, and filtered with low pass 3 x 3 window. The image classification supervised classification technique of Maximum Likelihood Classifier (MLC) was capable of classifying with an accuracy of about 89% of the land cover type in the study area. However, the presence of clouds (about 7%) in the image affected the results of the accuracy assessment. The total degraded forest area classified in the study area was about 57,878.4 ha. This comprises land cover such as poor forest, plantation and bamboo areas. The outputs in the form of maps or digital images are useful for better management and rehabilitation of degraded forest lands.

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