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MAPPING OF SECOND GROWTH FOREST USING FOREST CANOPY DENSITY MODEL TECHNIQUE – A CASE STUDY

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ABSTRACT

Forest Management practices can be improved through the use of current technologies including remote sensing, Geographic Information System (GIS) and Global Positioning System (GPS). One approach where remote sensing data can be used effectively to map forest conditions is by using Forest Canopy Density model (FCD Mapper). FCD Mapper is a semi-expert system developed by the International Tropical Timber Organisation (ITTO). The model utilises forest canopy density as an essential parameter for characterisation of the forest conditions. Hence it is possible to monitor forest conditions over time using multi-temporal satellite images base on this model. Landsat TM data is the main input to the model and the analysis focuses on four indices namely the Advanced Vegetation Index (AVI), Bare Soil index (BI), Shadow Index or Scaled Shadow Index (SI, SSI) and Thermal Index (TI). These four indices have direct relationship with the forest conditions. The model produces forest canopy density map, which may indicates the intensity of rehabilitation treatment needed in the particular area. This is very useful in planning and implementation of any forest rehabilitation programmes. This paper highlights the usefulness of this technique in mapping logged-over forest for resource assessment purposes.

Keywords: Remote Sensing, Second Growth Forest, Forest Canopy Density Model.

INTRODUCTION

In 1999 the total forested areas in Malaysia is about 19.01 million ha (about 60%) of which about 14.33 million ha is the Permanent Reserved Forest (PRF). The PRF is classified into two basic management categories – production and protection forests. Of that total about 10.84 million ha of the PRF is a production forest where as about 3.49 million ha is a protection forest. The production forests are commercially logged and managed for sustainable timber production where as there is no logging in the protection forest area.

The production forest in Malaysia is managed under sustainable forest management (SFM) concept. For Dipterocarp forest in Peninsular Malaysia, trees are selectively felled in accordance with either the Selective Management System (SMS, 30-year cutting cycle) or the Modified Malayan Uniform System (MUS, 55-year cutting cycle) (Thang, 2000). In Peninsular Malaysia most of the production forest in the PRF has been logged. However, there is no comprehensive report on the status and condition of the logged-over forest. Much information needs to be collected to know whether the trees in the logged-over forest are able to regenerate and ready for the second cut.

The forest conditions after logging can be evaluated and assessed using remote sensing technique, which has the capability to map the whole forested area at a landscape level. One approach where remote sensing data can be used effectively to map forest conditions is by using Forest Canopy Density model (FCD Mapper). The model produces forest canopy density map, which may indicates the degree of forest recovery after logging. Following that forest rehabilitation programme can be planned and implemented appropriately. This paper highlights the usefulness of this technique in mapping logged-over forest for resource assessment purposes.

MATERIAL AND METHODS

Study area

The study was conducted in Tekam Forest Reserve, Pahang located between Longitudes 3° 50' to 4° 15' North and Latitude 102° 20' to 102° 45' East (Figure 1). The area covers about 15,000 ha of logged over hill dipterocarp forest. For resources management purposes, the forest areas were divided into 35 compartments and the boundaries are well demarcated in the map. The earliest logging was carried out in 1975 in Compartments 92, 93 and 138 and in 1986 most of the forest in the study areas have been logged.

Data

Landsat TM image acquired in 1998 was used. Other ancillary data including topographic maps and forest compartment maps were also used.

The FCD Model

FCD Mapper is a semi-expert system developed by the International Tropical Timber Organisation (ITTO). The model utilises forest canopy density as an essential parameter for characterisation of the forest conditions. Hence it is possible to monitor forest conditions over time using multi-temporal satellite images base on this model. Landsat TM data is the main input to the model and the analysis focuses on four indices namely the Advanced Vegetation Index (AVI), Bare Soil index (BI), Shadow Index or Scaled Shadow Index (SI, SSI) and Thermal Index (TI). These four indices have direct relationship with the forest conditions. The model produces forest canopy density map, which may indicates the intensity of rehabilitation treatment needed in the particular area. This is very useful in planning and implementation of any forest rehabilitation programmes. In this study the usefulness of the FCD model in mapping of second growth forest area is tested. Detail explanation on the theoretical aspect of the FCD model is given in Rikimaru, (1999). Briefly the flow of the process is shown in Figure 2.

Field Inventory

Field inventory was conducted to verify the different forest classes produced based on the FCD classification technique. Global Positioning System (GPS) was used to accurately locate field sample points in the forest. A circular plot design (0.1 ha) was used in which all trees with diameter of 10 cm and greater were enumerated. Data recorded include information on the site conditions and vegetation parameters (tree species, diameter at breast height (dbh), tree height, and crown size,). A total of twelve samples point covering the different forest classes in the study areas were enumerated.

RESULTS AND DISCUSSION

Forest classes

The Meranti-Keruing Hill Dipterocarp and the Seraya Ridge Forests, comprising valuable timber species of the meranti group dominate the Sungai Tekam Forest Reserve. Historically the forest, which is divided into 35 compartments, has been logged as early as in 1975. Then, logging was carried out based on the MUS. Due to the extraction of commercially adequate size trees, the originally closed canopy primary forest to some extent has now become more opened. The degree of the canopy opening varies, depending on various factors including number of trees felled and felling damaged created at the time trees were felled and extracted out. Hence this resulted in the creation of various classes of canopy opening in the logged-over forest which indirectly related to the stand density of the forest.

Despite the fact that the forest has been logged, from visual assessment of the original Landsat TM image, it is quite difficult to segregate the different forest classes resulting from the logging activities. This is expected since the raw data of 30 m resolution Landsat TM image could not detect the felled areas due to the selective cutting practices during timber harvesting. However, one can easily tells that the forest areas have been logged based on the availability of ex-logging road as seen in the raw satellite image.

Forest Canopy Density Classes

By applying FCD analysis to the Landsat TM image, encouraging results were observed. The technique was able to classify the logged over forest into various classes of canopy density based on various indices information (vegetation, bare soil, shadow, and thermal). The vegetation index response to all vegetation items and reacts sensitively for the vegetation quantity. The Advance Vegetation Index examines the characteristics of chlorophyll-*a*. The shadow index increases as the forest density increases. The soil index increases as the bare soil exposure on the ground increases. For the thermal index it will increases as the vegetation quantity increases.

Initial automatic computer processing result shows that the canopy density ranges from 0 to 100% (theoretically from bare land up to intact/close canopy forest). However, base on ground survey information, refinement of the forest classes was done by regrouping them into four classes. The four classes were Class 1, 2, 3 and 4 with canopy densities of < 30%, 30 – 50%, 51 – 70% and >70% respectively. Figure 3 shows the map produced based on the FCD classification technique.

Class 1 as classified in the FCD is a forest area with the lowest canopy density (< 30%) and from field inventory, stand density (estimated base on total tree volume for all trees with dbh > 10 cm) in this class is about 98 m3/ha (Table 1). About 34 % of the study area fall under this class. Class 2 is an area with canopy density from 30 – 50 %. With an area of approximately 6,611 ha (42%), this category dominates the forest in the study area. The stand density for this class is about 187 m3/ha. Class 3 with an area of about 2,722 ha has a stand density of about 276 m3/ha. The highest stand density was observed in the Class 4 (> 70% canopy density) with density of about 482 m3/ha. The stand density is considered too high for this class apparently due to the presence of trees with dbh of 154 cm and 140 cm in the sample plots. Hence, this might be true for this specific site only and does not necessary reflect the true picture of other logged-over forests. Most of areas in this class are located at a very steep and difficult terrain which prevent logging activities from being carried out. Hence, there are still numbers of big trees left unfelled, which influence the canopy density. This area accounts for about 7% of the total area.

Species composition and Stand density

Information collected during field inventory in each of the forest classes explained the differences in the stand conditions. In term of species composition the plant biological diversity in the study area considered high. From the field survey about 54 species were recorded from the twelve sample plots. Table 2 shows a list of tree species found in the study areas. It shows that the family of Dipterocarpaceae dominates the tree group in the study areas. Common species in this family include *Shores leprosula, S. resinosa, S. custisii, S ovalis, Dipterocarpus kerrii*, and *D. cornutus.*

Trees recorded from the field survey can be grouped into three main diameter classes as shown in Table 3. Inventory results show that most of trees in the study areas fall in the group diameter class range from 31 – 60 cm (about 46 %), indicating that the forest is a regenerating or second growth forest (Table 3). Trees with diameter size between 10 – 30cm and > 60cm are relatively few and accounted for about 27% and 28% respectively.

Results also show that most trees in Class 1 are in the group diameter range of 10 – 30 cm (about 44%) suggesting that most of the big trees have been extracted out during the first logging. Appropriate

silviculture treatment need to be carried out in this area in order to make sure the residual stand can regenerate back for the second cut.

For Class 2 most of the trees are in the diameter range of 31 – 60 cm (about 54%). For this class tree with diameter class 10 – 30 cm and >60 cm accounted for about 19% and 27% respectively. This suggest that the area is well stocked with trees for the second cut, and silviculture activities should focus on improving the growth of trees in the lower diameter range. Most of trees in Classes 3 and 4 are also fall in the diameter class of 31 – 60 cm. However, Class 4 with the highest canopy density, generally contains more trees in the diameter range of >60 cm (about 38%) compared with the Class 3 forest (about 20%). The reason might be due to the presence of big size trees which were left unfelled during the first logging in the rather steep terrain condition of the forest in Class 4.

The pattern shows in term of tree size composition and stand density is in line with the forest canopy density classes produced from the Landsat TM image. It shows that the low canopy density forest (FCD) contains relatively small size diameter trees and low tree stand density. This indicates the usefulness of the FCD technique in classifying the second growth forest. However, further testing of the FCD technique in other logged-over forest area should be carried out in order to get more information on it reliability.

CONCLUSION

The study indicates that the FCD technique can be used to classify logged-over forest into different forest canopy density classes. The classes indirectly related to the stand density. By performing this type of classification, map showing the different degree of forest densities can be produced and areas, which need rehabilitation can be identified and quantified. This will help in preparing necessary forest rehabilitation program in the logged-over forest area.

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Table 1. Forest classes in Tekam Study Area based on FCD classification technique.

Forest Class	Canopy density (%)	Area		Tree Density (m3/ha)*
Class 1	< 30	5,311 ha	34 %	98
Class 2	30 – 50	6,611 ha	42 %	187
Class 3	51 - 70	2,722 ha	17 %	276
Class 4	> 70	1,018 ha	7 %	482

(* estimated based on total tree volume for all trees with dbh > 10 cm).

Table 2. List of tree species recorded from sample plots in Tekam Forest Reserve.

No.	Local Name	Scientific Name	No.	Local Name	Scientific Name
1	Meranti Belang	*Shorea resinosa*	38	Merpauh	*Swintonia sp.*
2	Meranti Paang	*Shorea bracteolata*	39	Petaling	*Ochanostachys sp.*
3	Meranti Tembaga	*Shorea leprosula*	40	Sesenduk	*Endospermum sp.*
4	Meranti Seraya	*Shorea curtisii*	41	Bintangor	*Callophyllum sp.*
5	Meranti Kepong	*Shorea ovalis*	42	Hampas Tebu	*Gironniera*
6	Damar Hitam	*Shorea sp*	43	Kekatong	*Cynometra malaccensis sp.*
7	Meranti Melantai	*Shorea macroptera*	44	Nipis Kulit	*Memecylon sp.*
8	Keruing Gondol	*Dipterocarpus kerrii*	45	Minyak Berok	*Xanthophyllum sp.*
9	Keruing Gombang	*Dipterocarpus cornutus*	46	Setambun	*Baccaurea sp.*
10	Merawan	*Hopea sp.*	47	Sial Menahong	*Pternandra sp.*
11	Keranji	*Dialium sp.*	48	Sepetir licin	*Sindora coriacea*
12	Kempas	*Koompassia malaccensis*	49	Pulai	*Alstonia sp.*
13	Tualang	*Koompassia excelsa*	50	Karas	*Aqularia malaccensis*
14	Penarahan	*Myristicaceae*	51	Jelutong	*Dyera costulata*
15	Keledang	*Artocarpus*	52	Mempening	*Lithocarpus sp.*
16	Kedondong	*Bursaraceae*	53	Rengas	*Anacardiaceae*
17	Rambutan Pacat	*Xerospermum sp.*	54	Merbau	*Instia palembanica*
18	Langsat Hutan	*Lansium sp.*			
19	Putat	*Barringtonia sp.*			
20	Kelat	*Syzygium sp.*			
21	Terap Nasi	*Artocarpus elasticus*			
22	Melembu	*Pterocymbium javanicum*			
23	Kelampaian	*Neolamarkia cadamba*			
24	Kerdas	*Archidendron bubalinum*			
25	Medang	*Lauraceae*			
26	Petai	*Parkia sp.*			
27	Kasai Daun Besar	*Pometia sp.*			
28	Jelawai	*Terminalia sp.*			
29	Mempisang	*Annonaceae*			
30	Tinjau Belukar	*Porterandia anisophylla*			
31	Gapis	*Saraca sp.*			
32	Nyatoh	*Palaquium sp.*			
33	Membuloh	*Pellacalyx sp.*			
34	Simpoh	*Dillenia sp.*			
35	Kubin	*Macaranga sp.*			
36	Mahang	*Macaranga sp.*			
37	Jangkang	*Xylopia sp.*			

Table 3. Number of trees in each of the forest classes in the sample plots.

Forest class	**Diameter size (cm)**		
	10 - 30	**31 - 60**	**> 60**
Class 1 (FCD < 30%)	11	9	5
Class 2 (FCD 30 – 50 %)	5	14	7
Class 3 (FCD 51 – 70%)	9	15	6
Class 4 (FCD > 70%)	7	17	15

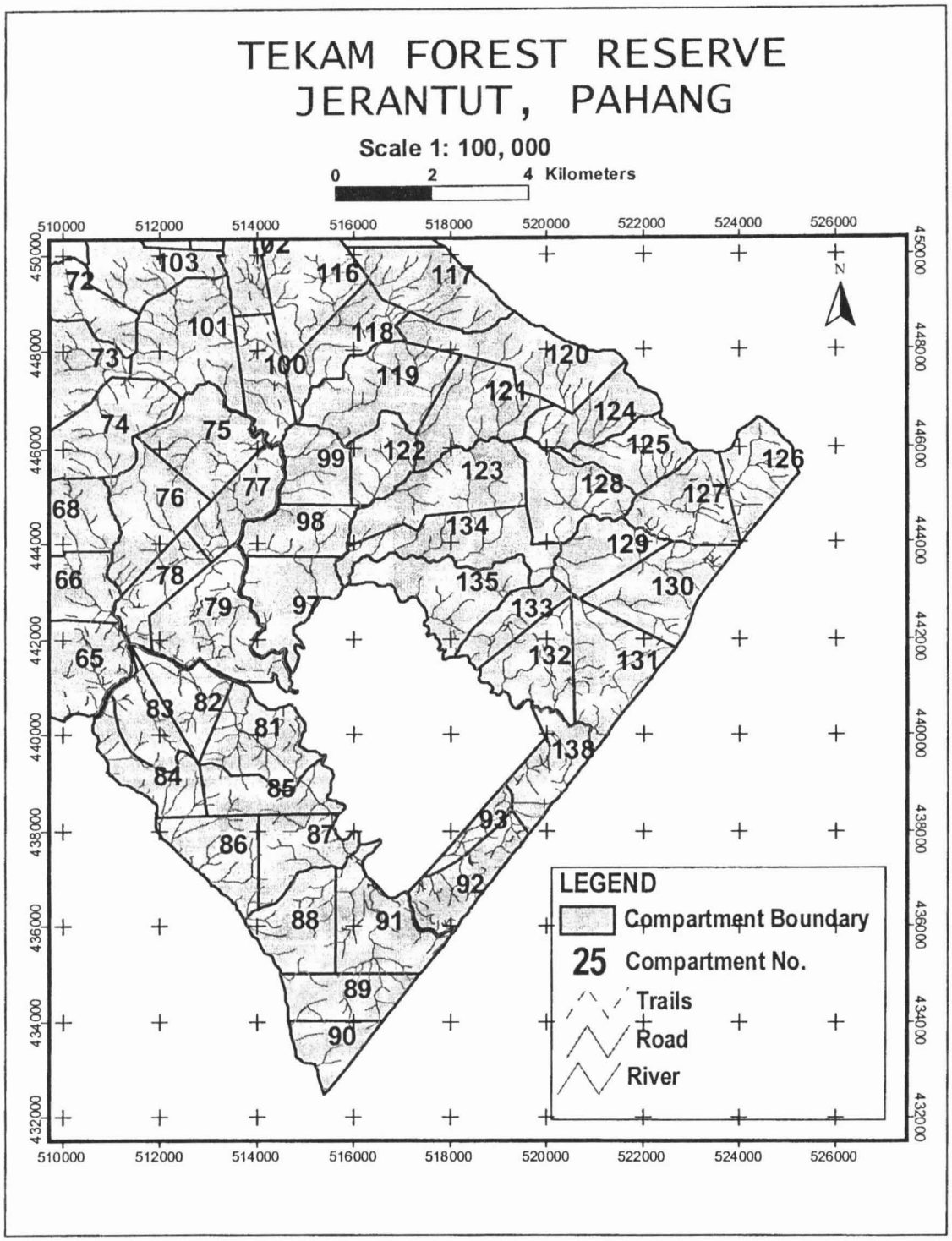
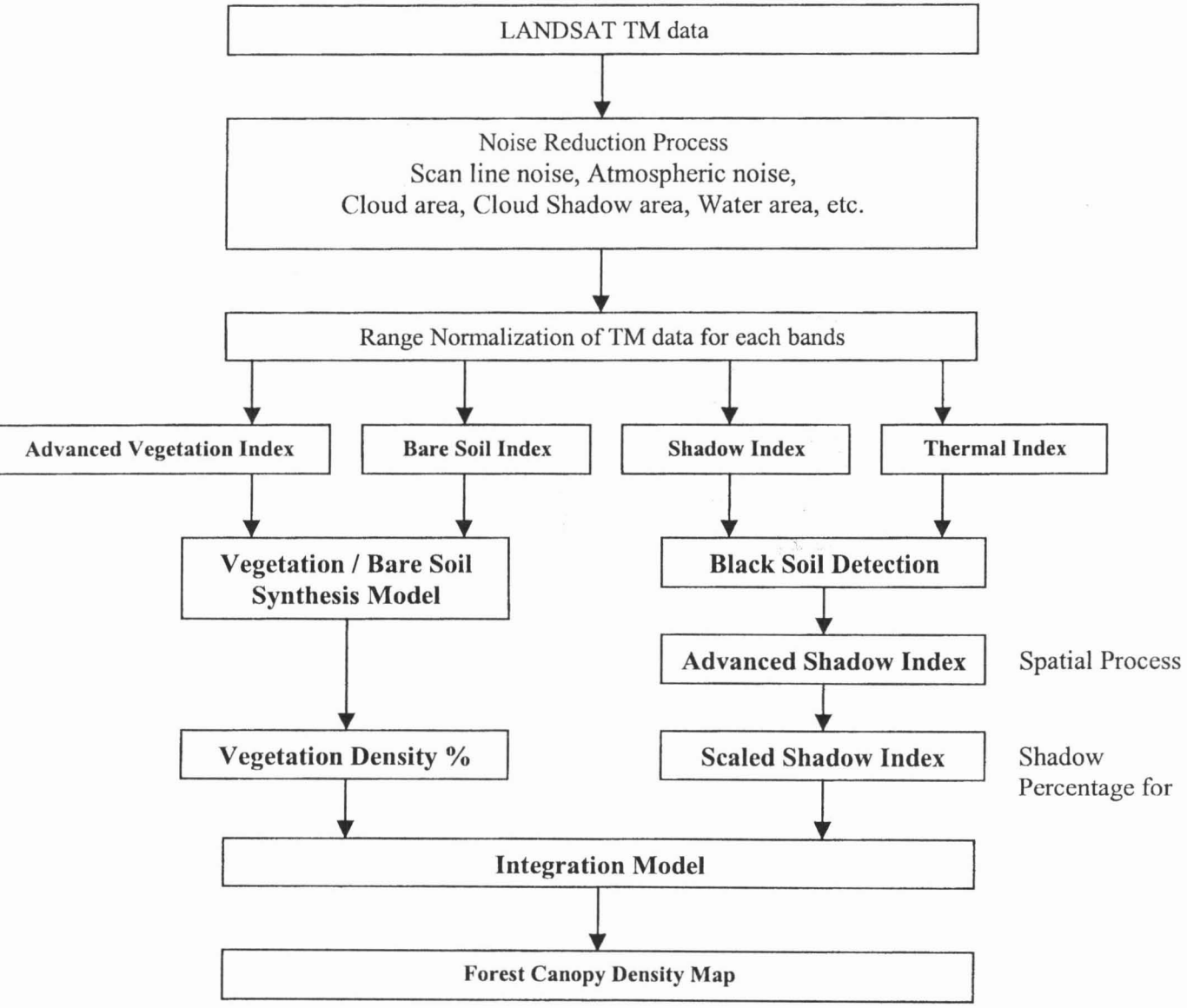


Figure 1. Location of the study area in Tekam Forest Reserve, Pahang

Figure 2: Flow diagram of the FCD analysis.



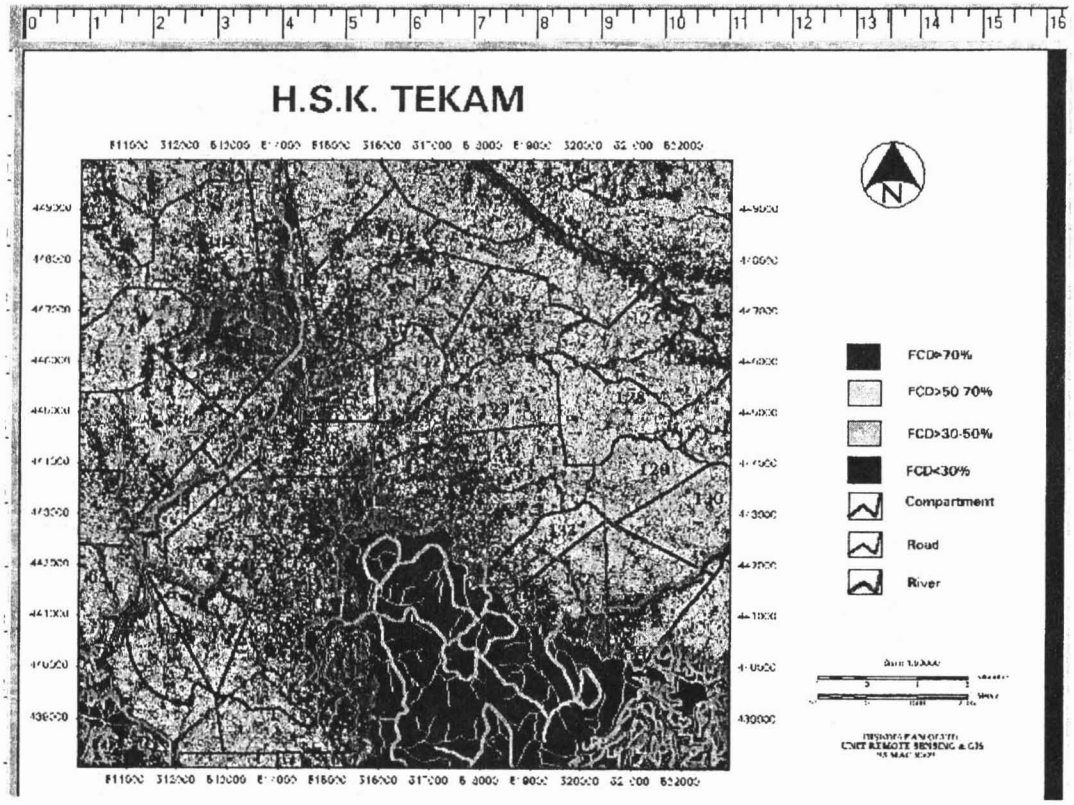


Figure 3. Map of Sungai Tekam Forest Reserve classified using FCD technique.