UNIVERSITI PUTRA MALAYSIA

SATELLITE REMOTE SENSING TECHNOLOGY FOR FOREST TYPE CLASSIFICATION AND INVENTORY IN GUNUNG STONG FOREST RESERVE, KELANTAN, MALAYSIA

ZAILANI KHUZAIMAH

FH 2000 10

SATELLITE REMOTE SENSING TECHNOLOGY FOR FOREST TYPE CLASSIFICATION AND INVENTORY IN GUNUNG STONG FOREST RESERVE, KELANTAN, MALAYSIA

By

ZAILANI KHUZAIMAH

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Faculty of Forestry Universiti Putra Malaysia

November 2000

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science.

SATELLITE REMOTE SENSING TECHNOLOGY FOR FOREST TYPE CLASSIFICATION AND INVENTORY IN GUNUNG STONG FOREST RESERVE, KELANTAN, MALAYSIA

By

ZAILANI KHUZAIMAH

November 2000

Chairman : Professor Capt. Kamaruzaman Jusoff, Ph.D.

Faculty : Forestry

In Malaysia and other developing countries access to the forest area is often difficult and forest information is inadequate. Remote sensing in forestry is very valuable and it has become important due to its capability to collect data from large areas and its capability to generate information. In other words, remote sensing technology offers reliable information essential for forest management and inventory.

The objective of this study is to develop a technique for preliminary estimation of timber volume using satellite remote sensing imagery. Based on data analysis of the Landsat TM imagery, six classes of land cover were classified such as Primary Forest, Logged-Over Forest, Degraded Forest/Plantation, Shrub, Barren Land/Cloud and Water Bodies/Shadow. Using a forest canopy density technique, three volume intensity categories can be mapped out such as High Density (>35 m^3 –

100 m^3/ha), Medium Density (20 m^3 – 35 m^3/ha) and Low Density (below 20 m^3/ha) with an overall accuracy assessment of about 97.30 percent. The results of these studies imply that Malaysian loggers can now utilize these maps to have a preliminary estimate of the timber volume in the concession areas without really "flying over" the inaccessible sites. Consequently from the government's point of view, preliminary estimate of the concession fees can now be imposed on the loggers.

It can be concluded that satellite remote sensing (i.e. Landsat TM) can be successfully used in forest type classification and inventory for macro-forest planning in Malaysia. However, high resolution satellite remote sensing data such as IKONOS-1 or THEMAP airborne data taken from aircraft should be further investigated for micro-planning in forest management due to its high resolution capability for individual tree counting and mapping.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk mendapatkan ijazah Master Sains.

TEKNOLOGI SATELIT PENDERIAAN JARAK JAUH UNTUK PENGKELASAN HUTAN DAN INENTORI DI HUTAN SIMPAN GUNUNG STONG, KELANTAN, MALAYSIA

Oleh

ZAILANI KHUZAIMAH

November 2000

Pengerusi :Profesor Kapt. Kamaruzaman Jusoff, Ph.D.

Fakulti :Perhutanan

Di Malaysia dan negara membangun yang lain, untuk masuk ke dalam kawasan hutan adalah sukar dan kurangnya maklumat mengenai hutan. Penggunaan penderiaan jarak jauh dalam perhutanan sangat berkesan dan akan menjadi penting disebabkan oleh keupayaan untuk mengumpul data dari kawasan yang luas dan berupaya untuk menghasilkan maklumat. Dengan kata lain teknologi penderiaan jarak jauh dapat menghasilkan maklumat yang diperlukan dengan lebih tepat untuk pengurusan dan iventori hutan.

Objektif kajian ini adalah untuk membangunkan teknik awal bagi mengira isipadu balak dengan menggunakan imaj satelit penderiaan jarak jauh. Berpandukan kepada analisa data dari imej Landsat TM, enam kelas litupan tanah dapat dikelaskan dalam kawasan kajian iaitu

Hutan Prima, Hutan Lepas-Tebangan, Hutan Miskin/Kawasan Pertanian, Semak, Tanah Terbuka/Awan dan Jasad Air/Bayang. Dengan menggunakan teknik kepadatan silara hutan, tiga jenis kepadatan isipadu dapat di petakan iaitu Kepadatan Tinggi (>35 m^3 – 100 m^3/ha), Kepadatan Sederhana (20 m^3 – 35 m^3/ha), dan Kepadatan Rendah (dibawah 20 m^3/ha) dengan ketepatan keseluruhan lebih kurang 97.26%. Daripada keputusan kajian ini kini pembalak di Malaysia dapat menggunakan peta ini untuk membuat anggaran kasar nilai balak dalam kawasan konsesi tanpa memasuki kekawasan yang sukar untuk dimasuki. Bagi pihak kerajaan pula, dapat penganggaran jumlah cukai konsesi boleh di perkenalkan kepada pembalak.

Pada kesimpulanya, satelit penderiaan jarak jauh boleh dengan jayanya digunakan untuk pengkelasan hutan dan iventori di peringkat makro dalam perancangan hutan di Malaysia. Walaubagaimanapun penggunaan data satelit penderiaan jarak jauh yang beresolusi tinggi seperti data IKONOS-1 atau THEMAP yang diambil dari pesawat udara perlu dikaji dalam penyelidikan dimasa hadapan untuk pengurusan hutan di perigkat mikro kerana data yang beresolusi tinggi berkeupayaan untuk pengiraan isipadu setiap pokok dan pemetaanya.

ACKNOWLEDGEMENTS

Bismillahirahmanirahim,

Praise to the Allah Almighty for His blessings, which enables me to complete this thesis. I would like to express my deepest appreciation to my Supervisor, Prof. Capt. Dr. Kamaruzaman Jusoff for his invaluable guidance and constructive criticisms throughout this study.

My gratitude is also expressed to Prof. Dato' Dr. Nik Muhamad Majid and Assoc. Prof. Dr. Faridah Hanum Ibrahim for their useful comments.

Special appreciation goes to the staff of the Center for Precision Agriculture and Bioresource Remote Sensing, Institute of Bioscience for invaluable comments and ideas on writing this thesis.

Last but not least, special appreciation is also dedicated to my beloved family and Asmidawati Ashari for her support.

TABLE OF CONTENT

		Page
DEDICATION		ii
ABSTRACT		iii
ABSTRAK		v
ACKNOWLEDGEMENTS		vii
APPROVAL SHEETS		viii
DECLARATION FORM		x
LIST OF TABLE		xiii
LIST OF FIGURE		xiv
LIST OF ABBREVIATION		xv
CHAPTER		
I	**INTRODUCTION**	1
	General	1
	Justification	4
	Objective	7
II	**LITERATURE REVIEW**	8
	Status of Forest Inventory in Malaysia	8
	Definition of Satellite Remote Sensing	13
	Landsat MSS and TM System	19
	Multispectral Scanner (MSS)	19
	Thematic Mapper (TM)	21
	Thematic Mapping Bands and Combination	23
	Application of Remote Sensing in Forest Type Classification and Inventory	29
III	**MATERIALS AND METHODS**	50
	Description of Study Area	50
	Topography and Climate	52
	Materials	53
	Data Acquisition	53
	Image Processing System	54
	Global Positioning System (GPS)	55
	Methods	56
	Digital Image Analysis	58
	Pre-Processing	58
	Image Enhancement Technique	60
	Contrast Enhancement	63
	Spatial Filtering	64
	Thematic Mapping Bands and Combination	65
	Development of Forest Canopy Density (FCD)	67

	Image Classification	70
	Unsupervised Classification	72
	Supervised Classification	76
	Ground Truth	79
	Accuracy Assessment	82
IV	**RESULTS AND DISCUSSIONS**	84
	Band Combination and Image Enhancement	84
	Forest Canopy Density	86
	Image Classification	93
	Unsupervised Classification	93
	Supervised Classification	96
	Ground Truthing	100
	Timber Volume Estimation	102
	Accuracy Assessment	105
V	**CONCLUSIONS AND RECOMMENDATIONS**	107
	Conclusions	107
	Recommendations	108
	REFERENCE	109
	APPENDICES	117
	BIODATA OF AUTHORS	139

LIST OF TABLE

Table		Page
1	The Conventional Method of Forest Inventory Design in Malaysia	10
2	Landsat Sensor MSS	20
3	Landsat Sensor TM	21
4	Colour Combinations for Thematic Mapper Images	24
5	Single-Band Description of TM Sensor	25
6	Statistical Result of Six Classes by MLC of Landsat TM Image	98
7	Statistical Result of Six Classes by MLC of Forest Canopy Density Image (FCD)	98
8	Average Timber Volume (m^3/ha) by Species Group	104
9	Confusion Matrix of MLC Landsat TM Image	105
10	Confusion Matrix of MLC Forest Canopy Density Image (FCD)	106

LIST OF FIGURES

Figure		Page
1	Diagram of Landsat Image Map Processing	15
2	Data Collection by Remote Sensing	17
3	Spectral Signature of Various Natural Surface Features	18
4a	Band 1 Landsat TM	25
4b	Band 2 Landsat TM	26
4c	Band 3 Landsat TM	26
4d	Band 4 Landsat TM	27
4e	Band 5 Landsat TM	27
4f	Band 6 Landsat TM	28
4g	Band 7 Landsat TM	28
5	A Map of Kelantan Showing the Study Area	51
6	Trimble GeoExplorer II	55
7	Flowchart of the Study	57
8a	Average Filter	66
8b	Laplacian Filter	66
8c	Median Filter	66
8d	Edge Sharpening Filter	66
9	Relation between Forest Condition and Each Index	69
10	Flowchart of FCD Development	
11	Sampling Plot Design for Ground Truthing	80
12	The Location of Training Sites	80
13	False Color Composite of Band 453 of Landsat TM Image	85
14	Advance Vegetation Index (AVI) of the Study Area	87
15	Bare Soil Index (BI) of the Study Area	89
16	Shadow Index (SI) of the Study Area	90
17	Forest Canopy Density Image of the Study Area	92
18	Five Classes of Unsupervised Classification of Landsat TM Image of the Study Area	94
19	Three Classes of Unsupervised Classification of Forest Canopy Density Image of the Study Area	95
20	Six Classes of Land Cover Type of MLC on Landsat TM Image	97
21	Four Classes of Supervised Classification of Forest Canopy Density Image of Gunung Stong Forest Reserve	99
22	Timber Volume Estimation of Gunung Stong Forest Image	103

LIST OF ABBREVIATION

AVI	Advance Vegetation Index
BI	Bare Soil Index
CCT	Computer Compatible Tape
FCC	False Colour Composite
FCD	Forest Canopy Density
F.R.	Forest Reserve
GCP	Ground Control Point
GIS	Geographic Information System
GPS	Global Positioning System
ITTO	International Timber Trade Organization
MACRES	Malaysia Center for Remote Sensing
MLC	Maximum Likelihood Classification
MSS	Multispectral Scanner
PC	Principal Component
SI	Shadow Index
SPOT	Satellite Probatoire d'Observation de la Terre
TM	Thematic Mapper

CHAPTER I

INTRODUCTION

General

Forest plays a major role in supporting the life of mankind. For example, supplying timber, storing water, preventing landslides or debris flows, providing protection from strong winds and purifying the atmosphere. Recently, people have come to appreciate forests not only as a source a timber, but also as a place where contact with nature can be enjoyed.

Malaysian tropical rainforest is one of the most complex ecosystems in the world. Its unique natural heritage, which has evolved millions of years, and is rich and varied in plant and animal life. The remarkably rich flora of Malaysia is estimated to include at least 8,000 species of flowering plants, of which 2,500 are tree species. Therefore, there are many different rain forest formations, depending on factors such as edaphic conditions, drainage, and altitude. At an elevation of about 750m, there are species rich lowland and hill dipterocarp dominated forests in dryland areas and in the wetland areas mangrove, peat-swamp thrive. The upper montane rainforest formations grows

between 750m and 1,500m, respectively. The upper dipterocarps are replaced by oak and laurel dominated forest above about 12,000m.

The total land area of Peninsular Malaysia is approximately 13.2 mill. ha, of which 5.97 mil. ha or 45.3% is forested. This area comprises 5.67 mill. ha of Diptrocarp forest, 0.2 mil. ha mangrove forest (Anon, 1992). Of the forested area, 5.25 mil. ha have been designated Permanent Forest estate (PFE) and the balance in State land Forest. Although forest stand growth models have become increasingly important for updates inventory information and projecting future forest conditions, such updating are limited because of cropland abandonment, harvesting, and urban development. Such changes are extremely difficult to models and that is the major reason why satellite remote sensing data need to be fully utilized. Since the mean characteristics of forest strata change relatively little, the major inventory problem is to estimate the amount and location of such strata.

Conventional ground surveys, even though more reliable and accurate in forest inventory and mapping are not cost and time effective. This method cannot be used for updating the desire information at any short period of time. The study of growth and depletion of forest resources and damage areas, which require constant monitoring, is very slow with these methods. This is why it becomes imperative to resort to

the use of advanced and sophisticated technique of remote sensing for data collection and monitoring the changes (Tomar 1976).

New methods of mapping vegetation must be considered to meet the demand for timely and accurate information about ecosystems. This method must consider the entire landscape, including adjacent land under separate ownership, land designated as wilderness, and other land often excluded from inventories and analyses. Remote sensing and GIS are providing new tools for advancing ecosystem management. Satellite imagery is only one of the many remote sensing tools available to resources managers, yet it offers the most comprehensive perspectives of all. It allows users to view and manipulate large areas of land, such as an entire forest or region.

Remote sensing is a particularly useful tool for forestry applications. The spectral resolution of the sensors, and the repetitive coverage and digital nature of data allow detecting forest conditions which cannot be recognized by the human eye. Different techniques exist for differentiating and mapping forest units. For studying large area, data can be processed in an automated way; for thematic mapping, images are visually interpreted, enabling the forestry experts to use their knowledge and experience.

Justification

The area of tropical forest decreases and the ecosystem become poorer at an alarming rate due to shifting cultivation, uncontrolled logging and unplanned land uses. The most serious problems occur in the zones of tropical rain forest. Data collection is difficult and ground measurements are expensive due to poor infrastructure (Mikael *et al.* 1995).

In Malaysia and other developing countries access to the forest area is often lacking and forest information is inadequate. Remote sensing in forestry is very valuable and it has become important due to the capability of collecting data for large areas and transforming information without wasting a lot of time and cost (Kamaruzaman, 1992). In other words, remote sensing technology offers reliable information essential for forest management.

However, in recent years, tropical forest resources have contributed significantly to socio-economic development of this country. Consequently, there is growing awareness of its importance and prudent measures have been undertaken to ensure the conservation and management of the tropical forest as renewable resources.

During the last decade a number of studies have been conducted to determine the possible contributions of Landsat imagery for forest mapping, inventory and other uses using both visual as well as computer-aided techniques. However, much remain to be learned about the spectral characteristics of much different vegetation and the factors that influence the spectral response patterns that are measured by remote sensing systems.

In Malaysia, limited research has been done on forest typing. Most researcher emphasize on classification and mapping of degraded forestlands. For example, Wan Yusoff (1988) reported that by using Landsat MSS and SPOT data, recent logged-over forest compartments that have been intensively harvested were easily detected and mapped. The needs for research on the potential of remote sensing for forest typing are therefore deemed necessary.

Management of various economic aspects of forest is characterized by long production intervals. Consequently sound long-term planning is required, for which detailed forest maps and inventories are vital. In the course of preparation of forest maps and inventories, forested areas are divided into homogenous units (strata). Recent forest conditions in the strata are described in detail, and future management activities planned.

In countries where forest management is less extensive, the inventories are often based on surveys of randomly sampled areas resulting in accurate statistics of tree species distribution, timber volume and quality. This practice, however, is time-consuming and costly, and does not support the production of adequate forest maps. Satellite remote sensing helps by providing a synoptic view of large region and by displaying forest patterns. Forest mapping by remote sensing methods can be complemented by detailed ground survey; thus both accurate statistics and thematic maps can be obtained.

By applying remote sensing techniques, timber volume and forest stand structure data can be successfully analyzed with combination of additional ground data. The final output of remote sensing supported inventories is image maps and statistics, reliably documenting up-to-date documentation of forest conditions.

Objectives

The general objective of this study is therefore to assess the usefulness of satellite remote sensing technology in forest type classification and timber inventory. The specific objective is to estimate of the timber volume in Gunung Stong Forest Reserve, Kelantan, Malaysia using satellite remote sensing imagery.

CHAPTER II

LITERATURE REVIEW

Status of Forest Inventory in Malaysia

In Malaysia, forest inventories are carried out at the macro and operational level. The procedure used in each of the inventory differs in terms of sampling design, types of information being collected and the frequency of inventory being carried out (Masran and Samsudin, 1994).

In general, forest inventory at the macro level aims to collect and generate the following information on the forest resource base:-

a. to determine the acreage and location of forest areas according to the forest type stratification;
b. to assess changes in forest resources with respect to distribution, composition, forest stocking, forest stand and total tree volume according to its quality and productivity;
c. to determine the standing volume of forest areas in accordance with the forest type stratification;

d. to estimate the net and gross standing volumes of specific diameter classes according to species group/types and areas with potentials for exploitation; and
e. to determine the location and asses both the quality and quantity of rattan, bamboo, palm and padanut resources.

As an example, in Peninsular Malaysia the third national forest inventory was recently carried out from 1991 to 1993. As a follow-up to the first two national forest inventories, this inventory collected the most recent and up-to-date data on the forest resources in P. Malaysia, for use in the present and future planning, management and development of the forest resources. The mode of implementation and inventory design under the third national forest inventory had been formulated through a joint project between the United Nations Development Program and the Food and Agriculture Organization of the United Nations. The design formulated was to accommodate the current conditions as well as the expected future conditions.

Currently, at the operational level, two types of forest inventory are being carried out for the inland forest especially in P. Malaysia, which are as follows:-

a. pre-felling (pre-F) forest inventory; and
b. post-felling (post-F) forest inventory.

The pre-felling forest inventory is carried out to determine the stand structure of the forest before harvesting commences in order to determine appropriate management (felling regimes which will be equitable to the logger and forest owner as well as to ensure ecological balance and environmental quality. The inventory is carried out using systematic line plots of 50m x 20m with four sub-plots of 25m x 20m, 10m x 10m, 5m x 5m, 2m x 2m.

The size classes of trees to be enumerated within the principal and four sub-plots and their sampling intensity are shown in Table 1.

Table 1: The Conventional Method of Forest Inventory Design in Malaysia

Sample plot	Size Class	Sampling Intensity (%)	Description
50m x 20m	>45cm dbh >30cm – 45 cm dbh	10.00	Big trees Small trees
25m x 20m	>15cm – 30cm dbh	5.00	Big poles
10m x 10m	>5cm – 15cm dbh	1.00	Small poles
5m x 5m	>1.5m ht. – 5cm dbh	0.25	Saplings
2m x 2m	15cm ht. – 1.5cm ht	0.04	Seedlings

The present of rattans, bamboo's, *Eugeissona triste* (bertam), palm and fens are also being enumerated in the principle plot of 50m x 20m,