UNIVERSITI PUTRA MALAYSIA

FOREST CLASSIFICATION AND MAPPING FOR RESOURCE MANAGEMENT AT THE GUNUNG STONG FOREST RESERVE, PENINSULAR MALAYSIA

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BY

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chair : Pakhriazad bin Hassan Zaki, PhD

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Forest is the main natural resources and heritage of the country. Apart from functioning to maintain biological diversity, forest is also a country economic generator, i.e., as the major supplier of world timber. Geographical structure of hills and tropical climate in Peninsular Malaysia create a critical phenomenon on mobilizing human resources for identification of forest species biogeography. The most suitable technique to overcome this problem is to apply remote sensing technology for inventory, classifying and mapping of forest resources. By classifying and mapping forest tree species it will be useful to develop and manage forest resource in sustainable manner. The main objective of this study is to investigate the capabilities of hyperspectral data on managing tropical forest information in Gunung Stong Forest Reserve, Kelantan, Peninsular Malaysia. Field spectroradiometer instrument is used in the field to develop the spectral curve. Hyperspectral with spectral reflection data (288 bands, 500-850nm) is obtained based on the existing tree canopy which stands out from the image. Analysis is performed on the study plot with size of five (5) hectares. Spectral properties of each species were taken. Classification of species was carried out based on Spectral Angle Mapper (SAM) classification technique. Eight species of forest trees have been identified, i.e., Chengal (*Neobalanocarpus hemii*), Kembang Semangkok (*Scaphium macropodum*), Kekatong (*Cynometra malaccensis*), Gerutu (*Parashorea spp*.), Meranti Kepong (*Shorea ovalis*), Kasai (*Pometia pinnata*), Merpauh (*Swintonia spp.*), and Merawan (*Hopea spp*.). The mapping accuracy was 79%. The distribution of Kekatong species is the greatest, i.e. 45.61%. The analysis of tree canopy and volume shows an estimated of 16,236.00m^2 trees canopies. A total of 318.37m^3 is the volume of trees. The study concluded that by applying remote sensing technology and the use of high resolution hyperspectral for classification of forest species and mapping, it can help towards implementing sustainable forest management through the implementation of Malaysian Criteria and Indicator (MC&I).

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

KLASIFIKASI DAN PEMETAAN HUTAN UNTUK PENGURUSAN SUMBER DI HUTAN SIMPAN GUNUNG STONG, SEMENANJUNG MALAYSIA

Oleh

RUHASMIZAN BINTI MAT ZAIN

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Hutan merupakan sumber asli utama dan khazanah warisan negara. Selain berfungsi untuk mengekalkan kepelbagaian biologi, hutan juga penjana ekonomi negara sebagai pembekal utama kayu-kayan dunia. Struktur geografi Semenanjung Malaysia yang berbukit bukau dan beriklim tropika menwujudkan fenomena yang kritikal untuk menggerakan sumber tenaga manusia bagi tujuan mengenalpasti biogeografi spesis hutan. Teknik yang paling sesuai untuk mengatasi permasalahan ini ialah dengan mengaplikasikan teknologi penderiaan jauh atau remote sensing secara global bagi tujuan pengkelasan dan pemetaan hutan. Dengan mengklasifikasikan dan pemetaan hutan, spesis pokok akan dapat di kenal pasti. Maklumat ini dapat membantu kearah pengurusan hutan secara mapan. Objektif utama kajian ini adalah untuk mengetahui keupayaan data hiperspektral dalam menguruskan maklumat hutan tropika di Hutan Simpan Gunung Stong, Kelantan, Semenanjung Malaysia. Alat spectroradiometer lapangan digunakan untuk membangunkan keluk spektral. Data hyperspektral dengan

spektral refleksi (288 jalur, 500-850nm) diperolehi berdasarkan silara pokok yang wujud menonjol dari imej. Analisa dilakukan pada plot kajian yang bersaiz lima (5) hektar. Sifat spektral setiap spesis diambil. Pengkelasan berasaskan spesis menggunakan teknik pengkelasan SAM. Lapan spesis pokok hutan telah dikenalpasti iaitu Chengal (*Neobalanocarpus hemii*), Kembang Semangkok (*Scaphium macropodum*), Kekatong (*Cynometra malaccensis*), Gerutu (*Parashorea spp*.), Meranti Kepong (*Shorea ovalis*), Kasai (*Pometia pinnata*), Merpauh (*Swintonia spp*.), dan Merawan (*Hopea spp*.). Ketepatan pemetaan adalah 79%. Taburan spesis Kekatong merupakan yang terbanyak iaitu 45.61%. Analisis silara dan isipadu pokok menunjukkan 16,236.00m^2 keluasan silara pokok dianggarkan. Sejumlah 318.37m^3 adalah isipadu pokok. Ini adalah hasil dari 588 pokok yang direkodkan diatas peta. Data menunjukkan komposisi spesies yang tinggi di kawasan kajian. Kajian merumuskan bahawa dengan mengaplikasikan teknologi penderiaan jarak jauh dan penggunaan data hyperspektral resolusi tinggi untuk mengklasifikasi spesis hutan dan pemetaan dapat membantu kearah melaksanakan pengurusan hutan secara mapan melalui pelaksanaan kriteria dan penunjuk Malaysia (MC&I).

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I certify that an Examination Committee has met on 9th November 2012 to conduct the final examination of Ruhasmizan Binti Mat Zain on her thesis entitled **"Forest Species Classification and Mapping Using Hyperspectral Imagery in Gunung Stong Forest Reserve, Kelantan, Peninsular Malaysia"** in accordance with Universities University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

RUHASMIZAN BINTI MAT ZAIN

Date: 9th November 2012

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LIST OF ABBREVIATIONS

AISA	Airborne Imaging Spectrometer for applications
ANN	Artificial Neural Network
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible/Infrared Imaging Spectrometer
CASI	Compact Airborne Spectrographic Imager
DBH	Diameter at Breast Height
EMR	Electromagnetic Radiation
ENVI	Environment for Visualizing Images
FAO	Food and Agriculture Organization of the United Nations
FCC	False Color Composite
FDPM	Forest Department of Peninsular Malaysia
FRIM	Forest Research Institute of Malaysia
GIS	Geographic Information System
GPS	Global Positioning System
ITTO	International Tropical Timber Organization
Landsat TM	Landsat Thematic Mapper
MCPFE	Ministerial Conference on the Protection of Forests in Europe
MNF	Minimum Noise Fraction
MC&I	Malaysia Criteria & Indicators
MTCC	Malaysian Timber Certification Council
MUS	Malayan Uniform System
NFC	National Forestry Council
NLC	National Land Council
NFI	National Forest Inventory
NTFPs	Non-Timber Forest Products
PRF	Permanent Reserve Forest
RIL	Reduced Impact Logging
SAR	Synthetic Aperture Radar
SAM	Spectral Angle Mapper
SFM	Sustainable Forest Management
SMS	Selective Management System
SPOT	Systeme Pour d' Observation de la Terre
UNFF	United Nations Forum on Forests

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Natural tropical forests were continued to provide multiple contribution to the economic, social and environmental benefits and also emphasizing that sustainable forest management can contributes significantly to sustainable development and poverty eradication. Forest support vast biodiversity and are a source of wonderment, scientific curiosity, enormous complexity and basic foundation for human welfare (Tilman, 2000). Forests help to conserve wildlife, genetic resources and provide natural eco-habitats for both flora and fauna. It provides food and shelter for a great variety of mammals, reptiles, amphibians, fishes, birds and insects, many of which are indigenous (UNFF, 2007). Malaysian forests play a major role in balancing of the climatic and physical conditions of the country, safeguarding water supplies and ensuring environmental stability.

Tropical forests are located in the 'tropics'. It lies between the Tropic of Cancer and Capricorn, approximately between 23° N and 23° S latitudes (Thomas and Baltzer, 2002).

Major forest types in Malaysia are lowland dipterocarp forest, hill dipterocarp forest, upper hill dipterocarp forest, oak-laurel forest, montane ericaceous forest, peat swamp forest and mangrove forest. In addition, there also smaller areas of freshwater swamp forest, heath forest, forest on limestone and forest on quartz ridges.

The forests in Malaysia are mostly dominated by trees from the Dipterocarpaceae family, hence the term 'dipterocarp forests'. The dipterocarp forest occurs on dry land just above sea level to an altitude of about 900m. This type of forest can be classified according to altitude into lowland dipterocarp forest (LDF), up to 300m above sea level, and hill dipterocarp forest (HDF) found in elevation of between 300m and 750m above sea level, and the upper dipterocarp forests, from 750m to 1,200m above sea level. However in Sarawak both the lowland and hill dipterocarp forests are known as mixed-dipterocarp forest (MDF).

Most of the dipterocarp forest left in Malaysia is HDF because HDF terrain is usually hilly and rugged – making it unsuitable for agriculture or large-scale settlements, as well as being difficult to access and clear. Timber extraction from these areas is also more difficult, but improving technology may change this situation (http://www.wwf.org.my).

Tropical Malaysian forests comprised of primarily rich species of lowland and hill dipterocarp forests, which is ecological vital and economic importance. The others are the mangrove and peat swamp forests, montane oak forests and ericaceous forests. Apart from economically important in producing poles and charcoal, the mangrove forests play a vital role in the protection and conservation of the natural coastal ecosystem, fishery and other marine life. The peat swamp forests found in the inland swampy regions yield several species of high quality timber, which improves the socioeconomic and welfare of the local community.

In managing especially to estimate forest resources and for future development of forests planners have several mechanism and options. The most recently is by means of remote sensing data. The use of remote sensing in forestry is becoming very important in which immense accumulation of data is unavoidable (Khali, 2001). Digital remote sensing images of forests can be acquired from field-based, airborne and satellite platforms (Steven, 2001). The logical extension of commercial forestry is logging, and the nature of the industry requires long-term planning for cutting and regenerated. The accurate data from aerial photography and satellite images are used for planning and monitoring of these activities. The Remote Sensing (RS), Geographic Information System (GIS) and Global Positioning System (GPS) are precise and efficient than any other resource assessment technology. These technologies provide a visual impression of the landscape and make quick decision in forests resource management. These technologies are enabling formation of local spatial context and the global spatial referencing issues related to the compatibility and uniformity of the geographic data produced. An extension of recent technologies allowed frontiers of data dissemination and distribution to be more effective and convenient way i.e., digital data using web technologies. Thus, the management authorities have the common place of data sharing system. Such development will benefit end user having access over data or metadata of the geographic products (Steven, 2001).

The GIS technology offers different tools to produce maps for managing the forests. GIS has the advantageous in capturing, storing, analyzing, displaying geographically information and data identified according to location. Forest resource management practitioners also define GIS as procedures, operating personnel, and spatial data that fix into the system. The key advantage to GIS is the ability to share maps. State and federal agencies, along with utility companies, which create their own respective maps, can share maps with each other. The GIS assessments of forest ecosystems are performed to assess the impact of logging, which usually uses Satellite Pour l Observation de la Terra (SPOT) or Advanced Very High Resolution Radiometer (AVHRR) satellite data to map regions where tree species and habitats are located. A remotely sensed tree species inventory can be used to identify rare or endangered plant species, as well as the habitats of animal species, based on the type of surrounding land cover. Once the distribution of species is known, it can be incorporated into detailed and extensive maps, which are used to plan for several activities (Khali, 2001).

By using remote sensing data, foresters can make optimally informed decisions. Foresters can be aware of the species distribution in a forest, the projected yields from logging, which areas contain habitats that cannot be disturbed, and how much land is needed for growth of settlements. After sections of forest are cut down, GIS and aerial photography techniques can be used to assess the speed and success of re-growth. Later, the data had to extrapolate and apply the findings to the entire forest. Using remote sensing, foresters can get more accurate and cost-effective information, and can directly observe as large an area as necessary. Due to the versatility and scale of remote sensing, it is invaluable in all stages of forest management. The forester's task begins with growing healthy forests. Remote sensing is a useful tool for assessment of environmental conditions, either in an existing forest or prior to planting.

Remote sensing instruments and techniques in forestry have continued to improve. For classification and mapping, most forest ecosystem models have been driven entirely with high resolution satellite and airborne-derived information. As commonly applied in forestry, the term "remote sensing" relates to the collection from a space platform of data about objects on or near the earth's surface (Parker, 1962), but it is increasingly extended to include the analyses of the data collected. Typical input variables relevant to processes with forestry models include land cover type, leaf area index (L), the fraction of incoming photo-synthetically active radiation that is absorbed by the canopy, and other leaf structural and chemical attributes such as specific leaf area and percent of nitrogen (Smith and Curran, 1995).

Satellite remote sensing has proved effective for the purpose of mapping cover types, using either classification of multispectral data at a single point in time for relatively small areas at fine spatial resolution (Woodcock *et al.,* 1994) or multi-temporal data for large areas at a relatively coarse spatial resolution. Since 1970's, multispectral imagery has been used widely in forestry (Marmo, 1996). The trend in the development of remote sensing in forestry has been increase from the panchromatic multispectral to the hyperspectral sensing technology. However, hyperspectral imagery is relatively new and gradually popular for commercial use. Hyperspectral imaging system differ from multispectral sensors because they collect information in many contiguous narrow bands (5 to 10 nm) while hyperspectral images generally contain dozens to hundred of bands. Multispectral systems do not cover the spectrum contiguously and their bands are generally wide (70 to 400 nm). These systems usually have a dozen or fewer bands. In hyperspectral image, a single pixel will contain information about reflectance across the entire spectral range of the sensor producing what is called spectral signature. The spectrum obtain from one image pixel will resemble a spectrum of the same material obtain through laboratory spectroscopy permitting detail identification of materials. Therefore, hyperspectral imageries can provide a very high data resolution where it can be to generate discreet signatures of object under investigation.

Unlike multispectral classifiers, hyperspectral classifiers are used to identify objects using spectral end-members in spectral libraries. Many attempts have been made to classify hyperspectral data using the traditional multispectral classifiers such as maximum likelihood and minimum distance classification to land use and land cover mapping (Buddenbaun *et al.,* 2005, Goodenough *et al.,* 2003, and Martin and Aber, 1997). However, the application to tree mapping is not yet being explored.

Forest surveying is a paramount task in order to manage forest land for sustainable forestry. In 1970, National Forest Inventory (NFI) was developed by the Forestry Department of Peninsular Malaysia (FDPM). The inventory program is an important instrument for forest resource management through the use of satellite imageries and geographic information system (GIS). A GIS is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The classification of forest area was based on established criteria of forest stratification and supported by ground information of sample locations from the GPS. These data were regularly updated through short term inventory (pre- and post-felling) and incorporated into digital maps produced in GIS. This system would enhance the capability of the Forest Department Peninsular Malaysia (FDPM) in capturing forest information and contribute towards better sustainable forest management at macro level.

Some legal consideration about remote sensing was the legal implications of using remote sensing technology for treaty verification, within the context of international laws, policies and remote sensing treaties (e.g., UN Principles Relating to Remote Sensing of the Earth from Outer Space and international Space Law Treaties including the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies). International air law was examined as well, citing the Chicago Convention of 1944. However, the UN Principles Relating to Remote Sensing of the Earth from Outer Space, which is not a binding Treaty, but a Statement from the United Nations to which many countries agree, that: remote sensing activities should be carried out for the benefit and in the interests of all countries taking into particular consideration the needs of the developing countries (Principle II) (Ake, *et al.*, 1999). In addition, FAO (1998) stated that: "It is evident that countries can no longer develop forestry policy isolations. The forest legislative and policies on forest resources management will determine the future forests and forestry in the respective government. The key challenges are to achieve balance among the multiple roles of forests to deliver the most economical benefits and to adopt measures that keep the forestry sector responsive to changing needs without compromising the sustainability of forest resources".

1.2 Problem Statement

Remote sensing provides a means of quick data capture for forest management, planning and development, a task that would be difficult and time consuming using traditional ground surveys. Remotely sensed data was available at various scales, space and resolutions to satisfy local or regional demands. Monitoring and mapping natural resources such as forests is critical for successful management. This means not only identifying and quantifying the amount of resources, but also details classification of forest species by high resolution of remote sensing or airborne data. Information on the distribution of individual tree species is needed for maintaining biodiversity.

However, it is difficult to archive because of the vast expanse of tropical rainforest in many regions and high diversity of species, many of which occur in the sub-canopy. The spatial resolution of currently operating space-borne hyperspectral sensor such as Hyperion is also limited and excessive cloud cover and haze in many tropical regions further restrict the utility of these data. Therefore, the most studies revert to airborne hyperspectral data but their used is often prohibited by the high cost of flying and the availability of the sensors. Nevertheless, the use of the sensors can be targeted such that areas with high biodiversity or vulnerability to change and tree species that are of particular importance are discriminated and mapped.

Traditional remote sensing classify broad forest type but hyperspectral much detail to individual tree species. This is because hyperspectral remote sensing's sensor record the large part of the electromagnetic spectrum simultaneously in a large number of a small bands, providing us a contiguous part of the electromagnetic spectrum with unique absorption features (Goetz *et al.,* 1985). Using this technique, it is possible to create a spectral profile plot or spectral signature for each pixel and tree species in the image. Technique have been developed to used this additional information for improving the classification of hyperspectral images such as cross correlogram spectral matching (Van der Meer and Bakker, 1997), spectral angle mapper (Kruse *et al.,* 1993) and the tricorder algorithm (Crosta *et al.,* 1996).

High resolution airborne remote sensing contains substantially more information than satellite data, and such imagery has greater potential to reduce expense of research cost. In this study, airborne hyperspectral remote sensing data with high resolution 2 meter will be use to distinguish forest tree species and to conduct forest inventory planning. Hyperspectral data can reliably distinguish a detail of forest cover condition like tree species and their distribution, tree diseases, tree mortality and stand density. In addition, interpretation of high resolution imagery provides measurement correlated with much field observation which can improve the accuracy of forest inventory.

Hyperspectral data has been proven had the highest accuracy compared to multispectral data for forest classification application by Czaplewski and Patterson (2003) obtained (92%), Goodenough *et al.* (2003) about (90%), Martin and Aber (1997) at least (75%) and Foster and Townsend (2004) between (60% and 80%) accuracy respectively.

1.3 Objectives of Study

The main objective of this study is to investigate the capabilities of hyperspectral data for managing in Gunung Stong Forest Reserve, Kelantan, Peninsular Malaysia. The specific objectives are:

1. To identify forest species classification for resources management in Gunung Stong Forest Reserve.
2. To develop spectral library of tree species in Gunung Stong Forest Reserve.
3. To estimate timber volume in Gunung Stong Forest Reserve.

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