UNIVERSITI PUTRA MALAYSIA

APPLICATION OF REMOTE SENSING TECHNIQUE TO ESTIMATE LEAF AREA INDEX IN AYER HITAM FOREST RESERVE, PUCHONG, SELANGOR, MALAYSIA

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Leaf Area Index (LAI), quantifies the total foliage per unit ground surface area. It is the "driving" biophysical variable and is therefore an important input parameter to many hydrological, ecological and climate models. In this study, we develop LAI estimation model for obtaining LAI value using LANDSAT TM data image analysis. The use of vegetation indices acquired from remotely sensed data considered as mean of estimating LAI. A study was carried out to estimate LAI using Normalised Difference Vegetation Index (NDVI) using Landsat TM data. The objective of this study was to estimate LAI in Air Hitam Forest Reserve (AHFR) using NDVI, in which, the empirical relationship between LAI (NDVI) and measured LAI (LICOR 2000) was developed.

The AHFR, located in Puchong, Selangor, Malaysia was chosen for this study. Landsat TM was digitally processed and enhanced using ERDAS IMAGINE 8.4 which produced the NDVI map. Based on this NDVI values, 12 sample plots of 20 m × 40 m were established to measure the LAI (using LICOR 2000) along with six stand parameters namely the dbh, height, crown volume, stand density, basal area and light intensity. The measurements were analysed to determine the descriptive statistic of each plot using SPSS Software. LAI was later regressed against the stand variables as well as the NDVI value, derived earlier from the Landsat TM image, to establish the regression fit. Once the regression fit model between NDVI and LAI was obtained, the NDVI image data was converted to the mapping of LAI. The accuracy of LAI was evaluated using the accuracy assessment in ERDAS IMAGINE 8.4.

Stand characteristic variables such as dbh, height, crown volume, basal area and light intensity showed correlation with LAI except stand density. It also produced correlation with the NDVI which was derived from Landsat TM. Linear relationship described the relationship between LAI and NDVI with the regression equation of $LAI = 7.0861 \times NDVI + 1.0929$ with high R^2 of 0.81 with significance level of 0.05. The range of LAI observed (LICOR 2000) was similar to the overall range in LAI from the NDVI. Through the models of LAI value estimation, LAI mapping on AHFR can be done with each pixel holding its own LAI value. This study suggests that remote sensing can be used to estimate LAI in forest stands and produce LAI map in AHFR subsequently provide predictive models of LAI specific for forest stands.

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

APPLIKASI TEKNIK PENDERIAAN JAUH BAGI MENGANGGAR INDEX KELUASAN DAUN DI HUTAN SIMPAN AYER HITAM, PUCHONG, SELANGOR, MALAYSIA

Oleh

WONG ZEE YENG

Mei 2005

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Index Keluasan Daun (LAI) mengukur jumlah daun per unit keluasan permukaan atas tanah. Ia merupakan pengerak pembolehubah biofizikal maka adalah input parameter yang penting bagi model seperti hidrologi, ekologi dan model-model iklim. Kajian ini merupakan pembentukkan model anggaran nilai LAI dengan menggunakan imej Landsat TM data. Bagi menganggar LAI, adalah perlu untuk membina kaedah untuk menepati nilainya. Penggunaan *vegetation indices* yang diperolehi dari data penderiaan jauh dianggap sebagai cara untuk menganggar LAI secara tepat. Oleh itu, satu kajian telah dijalankan bagi menganngar LAI menggunakan *Normalised Difference Vegetation Index* (NDVI) dari data Landsat TM. Objektif kajian ini adalah bertujuan untuk menganggar LAI di Hutan Simpan Ayer Hitam (HSAH), Puchong dengan menggunakan NDVI di mana hubungan empirical antara LAI (NDVI) dan LAI diukur (LICOR 2000) dibina.

Hutan Simpan Ayer Hitam (HSAH) yang terletak di Puchong, Selangor, Malaysia telah dipilih untuk kajian ini. Landsat TM telah diproses secara digital dan proses peninggian dengan menggunakan ERDAS IMAGINE 8.4 yang menghasilkan peta

NDVI. Berasaskan nilai-nilai NDVI, 12 sampel plot berukuran 20 m × 40 m telah disediakan untuk mengukur LAI (menggunakan LICOR 2000) serta enam pembolehubah dirian iaitu dbh, height, isipadu silara, kepadatan dirian, keluasan perempang dan intensity cahaya. Pengukuran dianalisis dengan Perisian SPSS bagi menentukan statistic deskriptif bagi setiap plot. Kemudian LAI diplot dengan menggunakan pembolehubah dirian serta nilai NDVI yang didapati terlebih dahulu dari imej Landsat TM. Setelah itu, menggunakan model regresi, nilai-nilai NDVI telah ditukar ke LAI bagi pemetaannya. Ketepatan LAI telah dirujuk dengan kaedah *accuracy assessment* dalam ERDAS IMAGINE 8.4.

Pmbolehubah ciri-ciri dirian seperti dbh, ketinggian, isipadu silara, keluasan perempang dan intensiti cahaya menunjukkan kolerasi dengan LAI kecuali kepadatan dirian. Kajian ini juga menghasilkan korelasi di antara LAI and NDVI yang diperolehi dari Landsat TM. Hubungan linear yang tinggi antara LAI dan NDVI digambarkan menerusi persamaaan LAI = 7.0861×NDVI + 1.0929 dengan R^2 of 0.81 dengan tahap signifikan 0.05. Julat LAI yang diperhati (LICOR 2000) adalah sama dengan julat keseluruhan LAI dari imej NDVI. Menerusi model penganggaran nilai LAI, pemetaan LAI di HSAH boleh dijalankan dengan setiap pixel memegang nilai LAI yang tersendiri.

Kajian ini menunjukkan penderiaan jauh boleh digunakan bagi menganggar LAI di hutan dirian dan menghasilkan peta LAI yang memberi model penganggaran spesifik LAI di hutan dirian.

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LIST OF ABBREVIATIONS

AHFR	Ayer Hitam Forest Reserve
DVI	Difference Vegetation Index
ERDAS	Earth Resource Data Analysis System
GEMI	Global Environmental Modified Index
GPS	Global Positioning System
IR	Infrared
Landsat TM	Landsat Thematic
LAI	Leaf Area Index
MACRES	Malaysia Centre for Remote Sensing
MSAVI	Modifies Soil Adjusted Vegetation Index
NDVI	Normalised Difference Vegetation Index
NIR	Near Infrared
PVI	Perpendicular Vegetation Index
R^2	Root Square
RS	Remote Sensing
RSO	Rectified Skewed Orthomorphic
RVI	Ratio Vegetation Index
SAVI	Soil Adjusted Vegetation Index
SE	Standard Error
TSAVI	Transformed Soil Adjusted Vegetation Index
VI	Vegetation Index
WDVI	Weighted Difference Vegetation Index

CHAPTER ONE

INTRODUCTION

1.1 General Review

The Leaf Area Index (LAI) provides information on the structure of plant canopy, showing how much surface area is covered by green foliage relative to total land surface area. It determines a stand capacity to intercept light and precipitation, exchange the carbon dioxide with the atmosphere, and store carbohydrates and nutrients. It is considered as a major variable in ecosystem understanding and a relevant input to productivity models. Due to the importance of LAI for several ecological processes, considerable research has focused on developing tools to measure LAI.

Many methods are available to measure LAI directly and are in variations of either leaf sampling or litterfall collection technique. These methods tend to be difficult to be carried out in the field, extremely labour extensive, require expensive with many replicates to account for spatial variability in the canopy and are thus costly in terms of time and money. Consequently, many indirect methods of measuring LAI have been developed such as destructive harvesting and direct determination (Nel and Wessman, 1993).

Remotely sensed imagery can also be used to estimate LAI and spatial information to indicate plant biophysical attributes. LAI can be determined remotely, relatively, cheaply and easily using imagery from various satellites, as different vegetation indices can be applied to transform the imagery into LAI estimation (Kaufman *et al.*, 1997).

The Normalised Difference Vegetation Index (NDVI) is probably the most commonly used index for analysing vegetation on a continental scale (Gamon *et al.*, 1995; Rouse *et al.*, 1973). Such an approach should provide satisfactory estimates of LAI as this techniques are based on reflectance in the red (R) and near infrared (NIR) spectral bands which are widely used in airborne and spaceborne remote sensing studies. This spectral index makes use of radiances or reflectances in R and NIR spectral regions because they enhance the contrast between soil and vegetation. Hence, the LAI estimation could be made concurrently in this study by applying the NDVI.

1.2 Justification of the Study

The AHFR has been intensively logged its forest since the late 1930's to 1960's. Since then, it was designated as a forest reserve to safeguard the last remaining lowland forest in Selangor. Nevertheless, at present; the compartments in the AHFR are either at earlier stage of succession or recovered well from its past disturbance, and therefore, require consistent data from forest assessment to understand its condition.

The assessment of forest characteristics on a regular and systematic was not institutionalised. Most assessment carried out on ad hoc basis for specific purposes and with the support of external assistance. Thus, there is no organized system to collect, analyse and distribute forest resource data.

A proper forest assessment requires ecological information such as primary productivity which forms the basis for landuse planning and forest activities such as silvicultural treatment. Nevertheless, the actual productivity and its dynamic of AHFR are not clearly known. Hence, the role in sequestering the LAI and stand variables from AHFR is believed to be important in understanding its forest growth.

Leaf Area Index is a major variable in ecosystem understanding and a relevant input to productivity models. Whatever method used, LAI estimation is time consuming and fairly inaccurate. For long term study sites, LAI has to be determined routinely and nondestructively. A number of methods can be applied, each with advantages and disadvantages. Consequently, estimating LAI over large area like AHFR, is problematic.

Remote sensing techniques, particularly the use of satellite imagery, may offer a practical indirect means to measure LAI at the landscape scale or even global scale (Running *et al.*, 1989). With remote sensing techniques, studies have made progress in developing methods that correlate remotely sensed data with regional estimates of a number of forest ecosystem variables, which in this study, including LAI, where, the empirical regression model to predict pixel-based LAI value for LAI mapping is applied by using vegetation index as quantitative indicators of vegetation amount.

Vegetation index reduces the multidimensional spectral space of vegetation scene to one dimension in order to sense variability in such properties as LAI. In this study, Normalised Difference Vegetation Index, NDVI (ratio between the difference in the infrared and red bands and the sum of bands) is used as it commonly preferred because it reduces the effects of atmospheric conditions and topographical variations.

This approach is required for the collection and maintenance of geographic data and information in remote sensing for AHFR. The approach provides the ability to access and readily available and up-to-date sources of forest status assessment for the collection of LAI data as well its variables which include diameter at breast height and crown area, closure and height in this forest.

1.3 Objectives of this Study

Therefore, the main objective of this study is to estimate LAI in Ayer Hitam Forest Reserve, Puchong while else the specific aims are as follows:

1. To develop statistical relationship between stand characteristics and LAI

2. To estimate LAI in Ayer Hitam Forest Reserve using Normalised Difference Vegetation Index (NDVI).

3. To develop statistical relationships between LAI of derived NDVI and ground measured LAI.

4. To develop LAI map for Ayer Hitam Forest Reserve.

CHAPTER TWO

LITERATURE REVIEW

2.1 Forest Coverage in Malaysia

The total forested area in Malaysia as at the end of 2001 was estimated to be 18.91 million hectares or 57.5% of the total land area. Of this total, it is estimated that some 16.41 million hectares are the inland dipterocarp forests, with the remaining 1.69, 0.62 and 0.19 million hectares being fresh water swamp, mangrove swamp and plantation forests, respectively. The distribution and extent of forest areas by major forest types and regions is as shown in Figure 2.1 and Table 2.1. This amount does not include agriculture tree crops, which covers 4.8 million hectares. Thus, if inclusive of the agriculture tree crops, the total tree cover in Malaysia in 2001 amounted to 23.71 million hectares or 72 per cent of the total land area (Anon, 2001[a]).

Forest assessment is a procedure for obtaining information on the quantity and quality of forest resources and in the characteristics of the land areas (Husch *et al.*, 1982). It deals with the methods of obtaining information on forest resources estimation of growing stock, growth and health of the forest. That information is a basis for decisions of the forest industry, the forestry officers and the forest owners (Torma and Hyyppa, 1999).

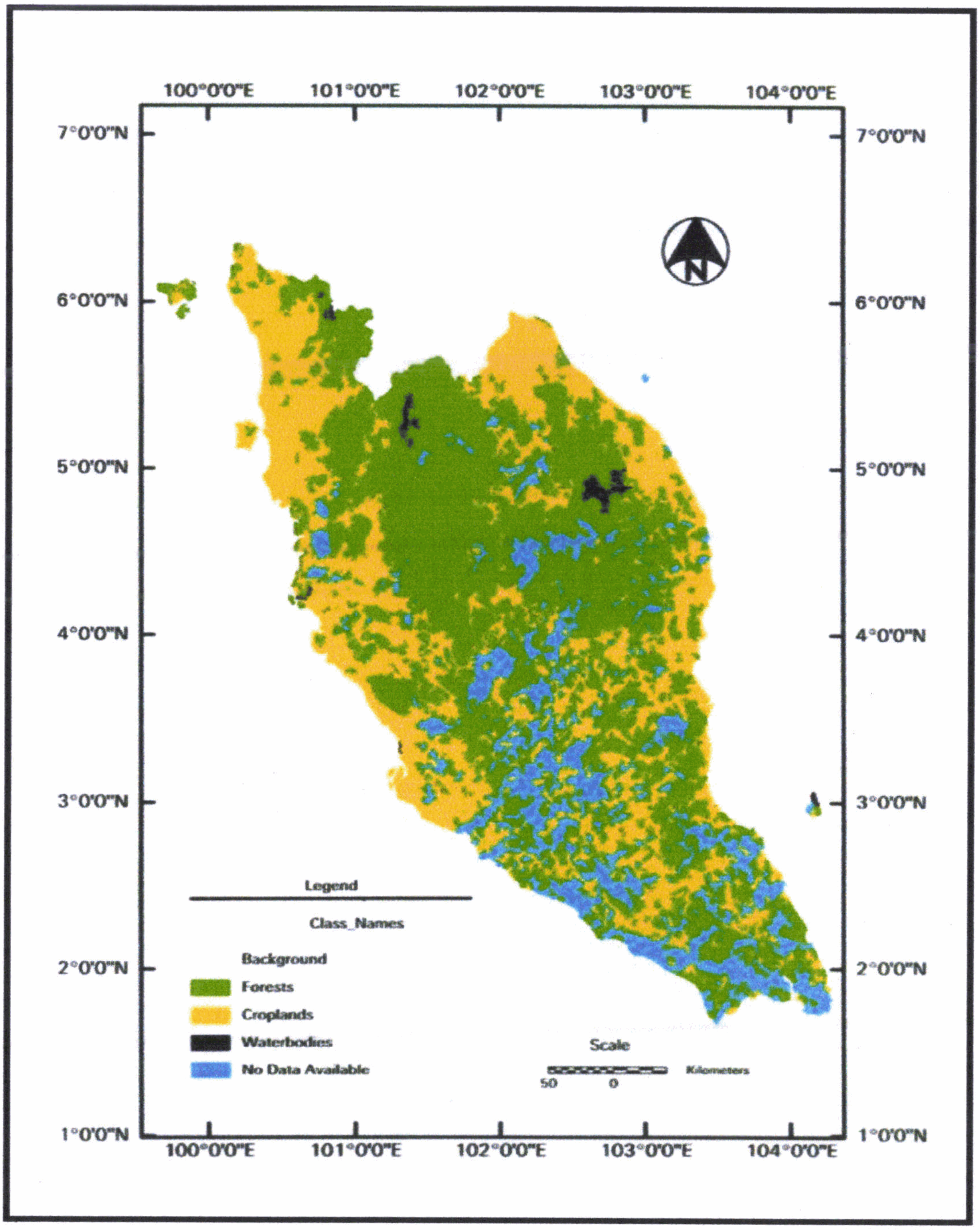

Figure 2.1: Forest cover map in Peninsular Malaysia (Anon[b])

Table 2.1: Distribution and extent of natural forests by major forest types in Malaysia, 2001 (million ha)

Region	*Land Area*	*Dipterocarp Forest*	*Swamp Forest*	*Mangrove Forest*	*Plantation Forest*	*Total Forested Land*	*Percentage Total of Forested Land*
Peninsular Malaysia	13.16	5.38	0.30	0.10	0.07	5.85	44.5
Sabah	7.37	3.83	0.19	0.32	0.11	4.45	60.4
Sarawak	12.33	7.20	1.20	0.20	0.01	8.61	69.8
Malaysia	32.86	16.41	1.69	0.62	0.19	18.91	57.5

Source: Anon, 2001[a]

2.2 Applications of Remote Sensing

For the last few years, satellite remote sensing has been used intensively to monitor fundamental changes in Earth surface properties as a major contribution to studies of environmental change. Much attention has been directed at detecting major land cover changes such as deforestation and desertification (Cochrane *et al.,* 1999; Foody and Boyd, 1999; Lambin, 1999; Nepstad *et al.,* 1999).

Apart from that, remotely sensed data also has been used for a number of agricultural applications as well, it includes the determination of yield and dry matter in durum wheat (Aparicio *et al.,* 2000) measuring the rate of durum wheat senescence (Adamsen *et al.,* 1999) and estimation of grain yield for corn (Shanahan *et al.,* 2001).

Another important issue in today's operational remote sensing is to assess the potentialities of the joint use of multi-sensor satellite imagery to improve the discrimination between forest and non-forest, between forest types, between crops and clear cuts and between crop types. In addition, several complementary issues, relative to terrain topography or include studies on detection and monitoring of man-made infrastructures and natural structures has been also addressed.

Study from Nezry *et al.* (2000) reported that the operational implementation of new techniques for the exploitation of RS data (SAR and optical) in the framework of forestry applications. In particular, it presented a new technique for standing timber volume estimation. This technique is based on remote sensing knowledge (SAR and optical synergy) and forestry knowledge (forest structure models) proves fairly accurate. To illustrate the application of these techniques, an operational commercial case study regarding forest concessions in Sarawak was done. Validation of this technique by comparison of the remote sensing results and the database of the customer has shown that this technique is fairly accurate.

In addition, remote sensing has considerable potential as a source of information on biodiversity as well. Remote sensing may be able to provide useful information on biodiversity such as number of species or species richness. In the study by Foody and Culter (2002), the potential of remote sensing to provide information on species richness and composition in a tropical forest environment was evaluated in Sabah. New method with applications of two types of neural network was used to derive measures of biodiversity from Landsat TM data of tropical rainforest. A feed forward neural network was used to provide information on species composition. The result indicated the potential of remote sensing as a source of maps of biodiversity.

Disturbance to forest ecosystem due to drought and fire may affect biodiversity. A monitoring system to highlight areas of severe drought stress would be advantageous for the management of threatened ecosystem. Hence, one approach to achieving this