ESTIMATING RELATIVE ABUNDANCE OF TREE SPECIES IN TROPICAL RAINFOREST USING REMOTELY SENSED DATA

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ABSTRACT

Mixed pixel occurrence in remote sensing imagery is a main source of problems in classifying ground features, especially when dealing with complex ecosystems such as tropical rainforest areas due to its high diversity of tree species. Pure pixel composed of a single species is very rare in most remote sensing imagery even in some advent ultrafine spatial resolution. In order to achieve an optimum output in classification of tree species in the forest, mixed pixel must be spectrally unmixed using sub-pixel approaches. This study was carried out in order to estimates the composition of tree species in Pasoh Forest Reserve by estimating the relative abundance of the tree species. The estimation of relative abundance was carried out using two types of spectral unmixing approaches which are Mixture Tuned Matched Filtering (MTMF) and modified Canopy Fractional Cover (mCFC). MTMF and mCFC were employed to Hyperion EO-1 satellite image with 30 meters spatial resolution. The relative abundance of Chengal trees was firstly estimated at a plot of 50 hectare. The correlation coefficients between the relative abundance obtained from MTMF and mCFC with the relative abundance of ground data in 50 hectare plot was 0.46 and 0.67, respectively. Therefore, mCFC was selected as it gives more encourage result in order to estimate relative abundance of Chengal trees at wider area such as compartment level. The model obtained from this study would be useful in forest monitoring and management.

ABSTRAK

Percampuran pembalikan spektral di dalam piksel imej satelit merupakan salah satu punca permasalahan bagi mengklasifikasikan permukaan bumi, terutamanya apabila berurusan dengan ekosistem yang kompleks seperti kawasan hutan hujan tropika kerana terdapat pelbagai spesies pokok. Piksel tulen yang terdiri daripada sejenis spesies sangat jarang berlaku dalam data satelit walaupun didalam sesetengah imej satelit yang beresolusi tinggi. Dalam usaha untuk mencapai output yang optimum dalam pengkelasan spesies pokok di hutan hujan tropika, spektral pembalikan yang bercampur didalam satu piksel mestilah dileraikan menggunakan pendekatan peleraian pembalikan spektral pada peringkat sub-piksel. Kajian ini telah dijalankan untuk menganggarkan komposisi spesies pokok di Hutan Simpan Pasoh dengan menganggarkan kelimpahan relatif spesies pokok. Penganggaran kelimpahan relatif telah dijalankan menggunakan dua jenis pendekatan peleraian pembalikan spektral pada peringkat sub-piksel iaitu *Mixture Tuned Matched Filtering* (MTMF) dan *modified Canopy Fractional Cover* (mCFC). MTMF dan mCFC telah digunakan untuk imej Hyperion EO-1 satelit beresolusi 30 meter. Kelimpahan relatif spesies pokok didalam plot 50 hektar dianggarkan pada peringkat awal kajian. Pekali korelasi antara kelimpahan relatif diperolehi dari MTMF dan mCFC dengan kelimpahan relatif data rujukan yang diperoleh dari data *census* di plot 50 hektar masing-masing adalah, 0.46 dan 0.67. mCFC telah dipilih kerana ia memberikan prestasi yang tinggi bagi menganggar kelimpahan relatif spesies pokok di peringkat kompartmen di Hutan Simpan Pasoh. Model yang diperolehi daripada kajian ini amat berguna kerana ia boleh digunakan uantuk pemantauan dan pengurusan hutan.

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LIST OF SYMBOLS

%	-	percentage
r	-	mixed pixel signal
M	-	matrix in which number correspond
f	-	column vector
ε	-	proportion of the spectrum
R^2	-	coefficient of determination
H	-	tree height
D	-	diameter at breast height
H_{max}	-	maximum tree height
nm	-	nanometer
ρ	-	pixel surface reflectance
ρ_e	-	average surface reflectance
S	-	spherical albedo of the atmosphere
L_a	-	radiance back scattered by the atmospehere
μm	-	micrometer
$R(\lambda_i)$	-	reflectance in band i
$R(\lambda_j)$	-	reflectance in band j
$\vec{v}$	-	Match Filter vector
$\vec{e}_i$	-	interpolated vector of eigenvalue
$\vec{e}_{MNF}$	-	vector of MNF eigenvalue
$\vec{e}_n$	-	vector of MNF noise

LIST OF ABBREVIATIONS

IFOV	-	Instantaneous Field of View
LMM	-	Linear Mixture Model
MTMF	-	Mixture Tuned Matched Filtering
CFC	-	Canopy Fractional Cover
SMA	-	Spectral Mixture Analysis
REDD	-	Reducing Emission from Deforestation and Forest Degradation
MESMA	-	Multiple Endmember Spectral Mixture Analysis
SFM	-	sustainable forest management
LSU	-	Linear Spectral Unmixing
CoB	-	Count based selection
IES	-	Iterative Endmember Selection
SAM	-	Spectral Angle Mapper
LDA	-	Linear Discriminant Analysis
AVIRIS	-	Airborne Visible Infrared Imaging Spectrometry
USGS	-	United State Geological Survey
FRIM	-	Forest Research Institute Malaysia
DBH	-	Diameter At Breast Height
VNIR	-	Visible near infrared
SWIR	-	Shortwave near infrared
FLAASH	-	Fast line of Sight Atmospheric Analysis of Hypercubes
MNF	-	Minimum Noise Fraction
PPI	-	Pixel Purity Index
MSAVI	-	Modified version of Soil Adjusted Vegetation Index
RMSE	-	Root Mean Square Error

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Satellite remote sensing scenes recording involve the multi-spectral responses from numerous types of features from a single pixel (Keshava and Mustard, 2002). Multiple spectral responses from features that existed in a single pixel causes non-uniqueness of a single pixel's spectral pattern to represent a single class, instead the pixel contained a collections of all spectral responses and usually referred to as a mixed pixel. Therefore, the understanding of spectral unmixing is essential in decomposing mixed pixels to identify the individual constituents materials present in the mixture. However, mixels are in fact inevitable when the target of interest is equal or smaller than the sensor instantaneous field of view (IFOV). High contribution of various spectral reflectance from the land surface may result in the occurrence of mixels (Keshava and Mustard, 2002; Kanniah *et. al.,* 2007; Boardman and Kruse, 2011; Quintano *et. al.*, 2012). In surfaces of natural ecosystems, pixels of IFOV seldom represent as single uniform pure class (Figure 1.1(a)), and mixels frequently observed in an IFOV (Figure 1.1 (b)).

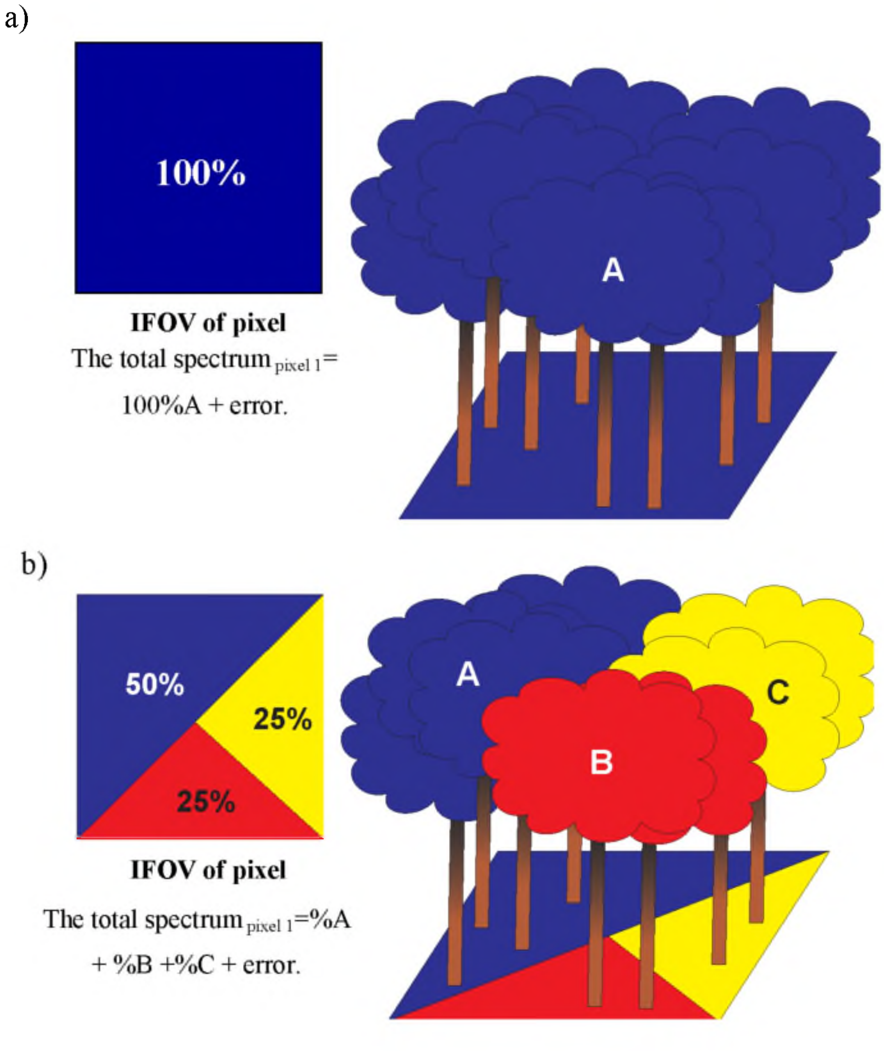

Figure 1.1: (a) Pure pixel represents one feature per pixel (b) Spectral mixing from three different features per pixel.

Furthermore, single dominant pure pixel occupying the entire IFOV is very rare, especially in studying vegetated landscape such in tropical rainforest areas, where the diversity is commonly very high. For example, Figure 1.1 (b) illustrates that the total spectrum is made of the three classes. In such case, the existences of mixels problem are mainly due to three factors: (1) spatial resolution, (2) feature heterogeneity, and (3) spectral resolution. As the spatial resolution increases, the variations of spectral responses increase causing difficulties in uniqueness of signature vector for spectral classes of interest leading to difficulty in achieving precise accuracy. Variations of spectral responses may also lead to feature heterogeneity. Therefore, there are challenges for estimating the forest species composition in a complex forest ecosystem characterized by its heterogeneous and high density multilayer canopies. On the other hand, the spectral resolution of remotely sensed data also plays an important role in order to achieve high classification accuracy. High spectral resolution with high spatial resolution results in well-define signature vectors for target of interest, hence, able to distinguish similar features.

To solve these problems, the spectral unmixing approach has been widely used in many applications for heterogeneous land cover like tropical rainforest because these approaches are useful to estimate relative abundance of tree species by using satellite remotely sensed image. Spectral unmixing decomposes mixed pixels into a collection of distinct endmembers and sets of fractional abundances that indicate the proportions of each endmember in a pixel (Keshava and Mustard, 2002; Ball *et. al.*, 2004). Spectral unmixing approaches including Linear Mixture Model (LMM), Mixture Tuned Matched Filtering (MTMF), Canopy Fractional Cover (CFC) and Spectral Mixture Analysis (SMA) have been widely used to decompose mixed pixels existed in the remotely sensed image (Keshava and Mustard, 2002; William and Hunt, 2002; Ball *et. al.*, 2004; Kanniah *et. al.*, 2007; Somers *et. al.*, 2011; Boardman and Kruse, 2011).

1.2 Problem statement

Forest management is important for assessing the sustainability of a forest. Therefore, comprehensive operational and spatial basis of forest monitoring are needed to achieve the sustainability forest management (Food and Agriculture Organization (FAO), 2005). To achieve the sustainable forest management, estimation of tree species composition per unit compartment of forest reserve is crucial to be identified. The ground measurement has a limited capability to identify the composition of each species that exist in one unit area and time consuming. Thus, estimating relative abundance of tree species in large scale is urgent task for sustainable forest management.

Satellite based remote sensing techniques are capable to overcome this problem due to acceptable accuracy and covering continuous region of earth surface. However, there would be mixels problems when estimating relative abundance of tree species due to high heterogeneity features of a lowland dipterocarp rainforest due to high density and multilayer canopies. Hence, the utilization of spectral unmixing to decompose mixed pixels is good option for estimating relative abundance of tree species as it may decompose mixed pixels into endmember fraction and abundances map.

Numerous of study carried out the study on species richness and evenness. According to Foody and Cutler (2006) tree species richness and composition are important for conserving forest diversity and to sustain forest management. Therefore, to achieve sustainable forest management, forest diversity need to be monitored in large scale. Therefore, this study employs spectral unmixing for decomposing mixed pixels for estimating tree species composition at compartment level of a lowland dipterocarp rainforest.

1.3 Objectives of the study

The aim of this study is to estimate tree species abundance using satellite remotely sensed image by decomposing mixed pixels using spectral unmixing approaches.

1) To determine the best spectral unmixing models for identifying tree species within the given IFOV of the selected satellite remote sensing image;

2) To apply the selected model to entire forest reserve in operational scale of forest management.

1.4 Scopes of the Study

Scopes of the study are as follows:

1) Two types of data were used to develop spectral unmixing models. Primary data was hyperspectral Hyperion EO-1 with 30m spatial resolution. This data was chosen due to high spectral resolution which has narrow bands and more information for estimating tree species in high density dipterocarp forest. To assess accuracy of the models, tree census data of the 50-ha plot were used.

2) Two types of spectral unmixing approach were used in this study: (1) Canopy Fractional Cover (CFC) and (2) Mixture Tuned Matched Filtering (MTMF). Hyperion EO-1 was used as primary input in each approach. Firstly, CFC is derived from Linear Mixture Model (LMM). According to Keshava and Mustard (2002), LMM is the most frequently used algorithm that can determine high accuracy result. However, CFC was chosen due to its ability to identify the relative abundance of degraded area much better than LMM because CFC has a capability to eliminate soil background that may contribute to multi-spectral responses. Secondly, MTMF was chosen in this study because of the ability to eliminate the false positive to classify the features based on endmember that been fixed by user (William and Hunt, 2002).

3) Relative abundance of chengal (*Neobalanocarpus heimii*) was estimated in this study. In addition, meranti langgong (*Shorea lepidota*) and damar laut daun kecil (*Shorea maxwelliana*) also included in this study because this tree species tended to occur around chengal trees. In addition, these three species were selected due to their high commercial value and importance in biodiversity conservation. Only trees with diameter at breast height > 40cm was selected because tree with high DBH may have a big canopy. In this study, only big canopy and highest height (> 30m) were chosen.

4) Mapping relative abundance of the tree species in the operational scale of forest management (i.e. forest compartment) to monitor forest biodiversity.

1.5 Significance of Study

This study has several significances in tropical forest management in Malaysia. There are various tropical rainforest with rich flora and fauna in Malaysia. Therefore, to sustain integrity of the forest ecosystems, enhanced forest monitoring is one of the urgent issues. Remote sensing approach has advantage on this issue in terms of cost-effectiveness, ability to provide data in large areal extent and also continuous temporal observation. In particular, utilization of hyperspectral satellite could be useful to support monitoring methods because it provides more information in spectral bands that could distinguish spectra of different tree species in the same genera. Using spectral unmixing models, relative abundance of individual species can be estimated in operational scale of forest management. The development of novel spectral unmixing method may allow relative abundance of tree species being estimated in operational scale.

1.6 Study Area

This study focused on Pasoh Forest Reserve. The study area is located in Jelebu district of Negeri Sembilan (2° 58' N latitude and 102° 18' E longitude). Pasoh Forest Reserve is located approximately 70 km from southeast Kuala Lumpur. The study area is further confined to 50-ha plot which is 1 km long and 0.5 km wide of Pasoh Forest Reserve (Figure 1.2). Pasoh Forest Reserve is covered with primary lowland mixed dipterocarp forest, which contains of several timber species called *Shorea* and *Dipterocarpus* species. The 50-ha plot contains 338,360 trees with ≥1cm in DBH, comprising 81 families, 295 genera and 818 species (Kochummen *et al*,. 1990;

Manokaran *et al.*, 1992; Okuda *et al*,. 1997, Hoshizaki *et. al.,* 2004). 50-ha plot was dominated by 30 species of Dipterocarpaceae accounting for 27.3% of basal area. The Euphorbiceae is the richest family in the 50-ha plot with 85 species. *Shorea* is the fifth most abundant species in 50-ha plot. The emergent layer averages 46 m and the height of the main canopy is 20-30 m (Kochummen *et al*,. 1990; Manokaran *et al.*, 1992; Okuda *et al*,. 1997, Hoshizaki *et. al.,* 2004). The chosen study area is selected based on remotely sensed data availability over the study area. Moreover, various timber species exist in 50-ha plot of Pasoh Forest Reserve which represent heterogeneous of tropical rainforest in Malaysia.

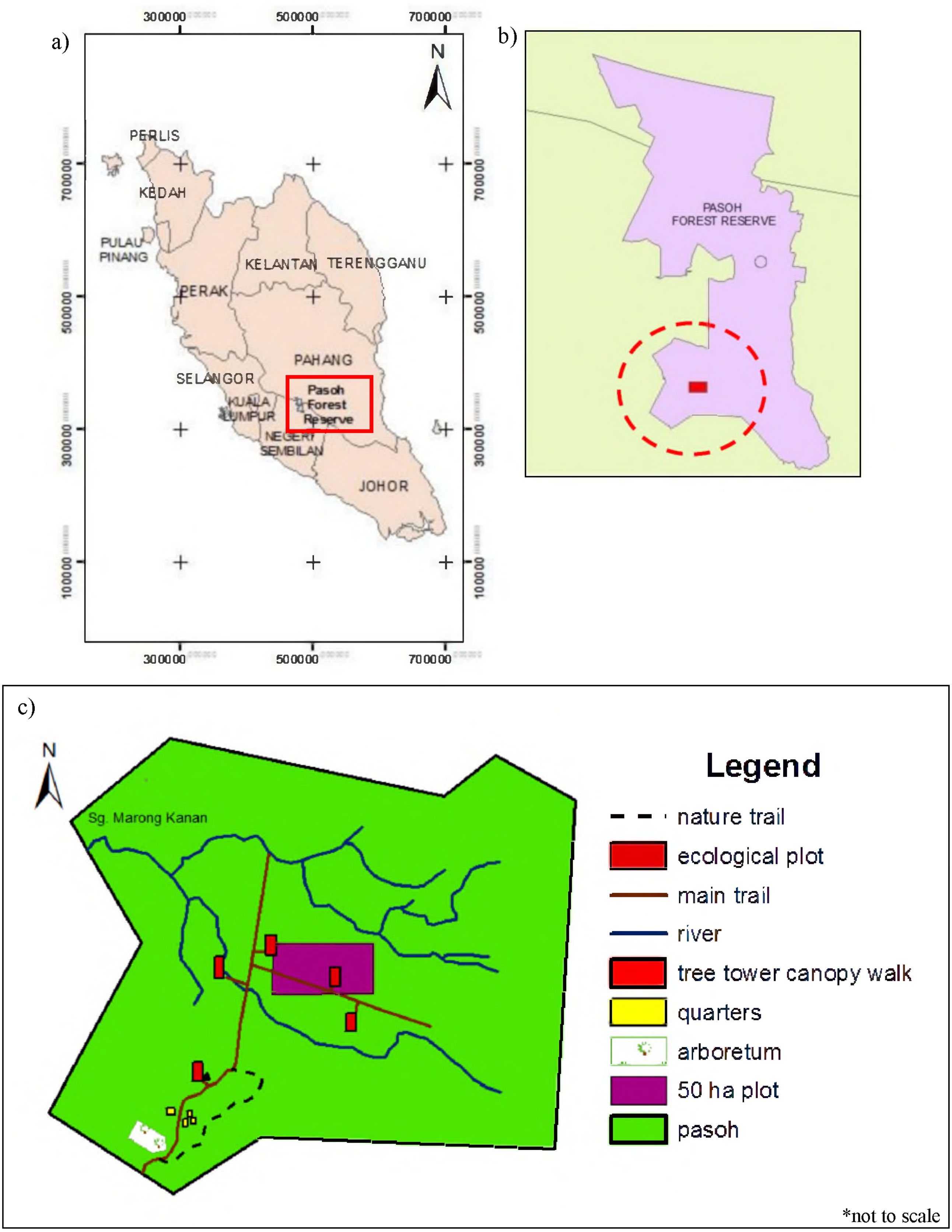

Figure 1.2: Study area. a) Peninsular Malaysia, b) Pasoh and c) Pasoh forest reserve and 50 ha plot of Pasoh forest reserve.

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