CONSERVATION ANALYSIS OF DIPTEROCARPS IN SARAWAK USING GEOGAPHICAL INFORMATION SYSTEMS AND REMOTE SENSING

STEPHEN TEO PING

SCHOOL OF INTERNATIONAL TROPICAL FORESTRY
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DECLARATION

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CERTIFICATION

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ABSTRACT

This study attempts to evaluate the status and extent of dipterocarp conservation in Sarawak as well as provides an updated quantitative information for conservation planning and identification of dipterocarp conservation hotspots.

Multitemporal Landsat data of early 1990's and late 2010's were used for assessing spatial and temporal patterns of forest cover change in Sarawak. A total of 9 Landsat scenes covers the whole of Sarawak. As a consequence of defective scan line corrector on-board the Landsat satellite the data acquires from Landsat 7 ETM+ is suffering from missing line error since May of 2003. To overcome this problem, a series of same scene with nearest time and minimal cloud cover is chosen. The missing line error is corrected by overlaying 2 to 3 Landsat images in order to fill in the gap between the best images. Moreover, Image pre-processing is applied before overlaying. For the classification process, false colour composite of Landsat images band 5, 4, 3 to RGB is use enhance the visual interpretation where the vegetation appear as green and soil appear as red A supervised classification approach to classify the Landsat data to obtain the land cover class according to its difference in spectral signature. A post classification filtering using minority 3x3 followed by median 5x5 and were used to remove the "salt and pepper" effect. As for the land cover map on 1990, the accuracy assessment was carried out with aids of land use map which was acquired around 1990 with 1:50,000 scale which are detail enough to provide clear division of land cover classes. The accuracy of land cover map in 2009 was validated by using ground truth data and the recent hi-resolution satellite preview image in from Google Earth. Ground truth verification was done along the pan-Sarawak highway and the result shows an accuracy of over 80%. It shows that forests at coastal plains were rapidly cleared for the establishment of oil palm plantations. Remaining areas of natural forest are mostly confined to protected areas and mountainous region along the Sarawak-Kalimantan border.

Next, modelling the natural occurence of dipterocarp species in Sarawak is equally important for dipterocarp biodiversity conservation in order to know where they are in the landscape. Two statistical methods (Binary Logistic Regression and Multivariate Adaptive Regression Spline) and two geostatistial methods (Universal Kriging and Inverse Distance Weighting) were explored to build the best models for three selected genera (twelve species) of dipterocarps. The three genera were selected based on the whole ecological range the species in the genera cover and also include endemic and non endemic species. Herbarium distribution data were databased, georeferenced, digitized and divided into two halves for model building and validation. For statistical models, climatic, topographical and edaphic parameters were used. Proxy were used to represent the parameters which were highly correlated($p>0.75$) to avoid overfitting. Inverse Distance Weighting gives the best prediction with an average accuracy at over 80 %. Species Occurrence Models (SOMs) were then generated for all species of dipterocarps recorded in Sarawak.

The species occurrence density map for each genus and category (endemic and non endemic) was generated by overlaying the SOMs of all species in each genus or category. The species occurrence density maps were analyzed with land cover map from Landsat 7-EMT+ images and protected forest areas for identifying hotspots for conservation in Sarawak. It reveals that areas in Central Sarawak and the southwest region (northwest Borneo around Kuching) are the main hotspots of dipterocarp diversity in Sarawak while the coastal lowland areas in Lower Rejang and Baram River which.are mainly peat swamp forest are poorer in species occurrence density. The difference in the hotspots is only the extent in size. In terms of endemism, as with dipterocarp diversity, the mixed diptercarp forest of central Sarawak is also the most important hotspot. Similarly the different genera also share more or less the same hotspots in the southwest region and central Sarawak. The hotspot in central Sarawak could be attributed to the overlapping of three biogeographical region-Riau pocket, northeast Borneo hotspot and biogeographical region of central Sarawak flora. The northwest Borneo around Kuching can be attributed to the heterogeneous geological makeup and older geological history.

Gap analysis revealed that most protected forest areas are concentrated in southwest Sarawak (e.g. Bako, Kubah, Tanjung Datu and Gunung Gading National Parks) and in the northern part of Sarawak (e.g. Niah, Lambir Hills and Mt Mulu National Parks). This leaves the hotspots in the central part of Sarawak least protected. Existing Protected areas only covers between 1.5% to 4% of the total areas for the different hotspots for all the different genera, endemic species and non endemic species. while majority of the hotspots that are still forested are outside the protected areas.

Keywords: DIPTEROCARPS, PREDICTIVE MAPPING, HABITAT ASSESSMENT, HOTSPOT, GAP ANALYSIS

ABSTRAK

ANALISIS PEMELIHARAAN DIPTEROKAP DI SARAWAK MENGUNAKAN SISTEM MAKLUMAT GEOGRAFI DAN PENDERIAAN KAWALAN JAUH

Kajian ini cuba untuk membuat penilaian keatas status dan setakat mana pemeliharaan dipterokap di Sarawak serta memberikan maklumat kuantitati terkini bagi perancangan pemeliharan dan identifikasi hotspot pemeliharaan dipterokap.

Data Landsat pelbagai masa dari awal 1990's dan akhir 2010's digunakan untuk menilai corak tutupan hutan secara spatial dan temporal di Sarawak. Sejumlah 9 scene Landsat melitupi seluruh Sarawak. Disebabkan oleh scan line corrector yang rosak atas satelit Landsat maka data yang diperolehi dari Landsat 7 ETM+ mempunyai ralat jalur hilang semenjak Mei 2003. Bagi mengatasi masalah ini, satu siri scene yang sama dengan masa yang terdekat serta mempunyai tutupan awam yang minimum dipilih. Ralat jalur hilang diperbetulkan dengan menindih 2 atau 3 imej Landsat untuk mengisi jurang dari imej terbaik. Lebih-lebih lagi pra-pemprosesan imej digunakan sebelum penindihan. Untuk proses klasifikasi, komposit warna palsu untuk imej Landsat band 5, 4, 3 ke RGB diunakan untuk meningkat penterjermahan visual yang mana vegetasi wujud sebagai hijau dan tanah wujud sebagai merah. Pendekatan klasifikasi terkawal untuk mengkelas data Landsat untuk memperolehi kelas tutupan bumi mengikut perbezaan dalam 'spectral signature'. Penapisan pasca klasifikasi mengunakan minority 3x3 diikuti oleh median 5x5 dan digunakan untuk membuang kesan "salt and pepper". Bagi tutupan bumi untuk 1990, penilaian ketepatan dijalankan dengan bantuan peta guna tanah yang diperolehi sekitar 1990 dengan skala 1:50,000 yang cukup terperinci untuk memberi sempadan jelas kelas tutupan bumi. Ketepatan tutupan bumi bagi 2009 divalidasi dengan menggunakan data 'ground truth' dan imej satelit resolusi tinggi terkini dari Google Earth. Verification dijalankan sepanjang lebuh raya pan-Sarawak dan keputusan menunjukkan ketepatan melebihi 80%. Ia menunjukkan bahawa hutan di kawasan pamah tepi pantai dibersihkan dengan pesat untuk penubuhan ladang kelapa sawit. Kawasan hutan semulajadi yang masih tinggal kebanyakan didapati dalam kawasan terlindung dan kawasan pergunungan di sepanjang sempadan Sarawak-Kalimantan border.

Seterusnya, pemodelan kewujudan semulajadi spesies dipterocap di Sarawak adalah sama penting bagi pemeliharan kepelbagaian dipterokap untuk mengetahui di mana mereka wujud dalam landskap. Dua kaedah statistik ('Binary Logistic Regression' dan 'Multivariate Adaptive Regression Spline') dan dua geostatistial methods ('Universal Kriging' dan 'Inverse Distance Weighting') diuji untuk membina model terbaik bagi tiga genera dipterokap terpilih (duabelas species). Ketiga-tiga genus dipilih berasaskan keseluruhan julat ekologi species merangkumi dalam genus tersebut dan juga merangkumi spesies endemik dan bukan endemik. Pengkalan data taburan herbarium diwujudkan, digeoreferensi dan dibahagi kepada dua bahagian untuk pembinaan model dan validation. Bagi model

statistik, parameter iklim, topografi dan tanah digunakan. Proxi digunakan untuk mewakili parameter yang mempunyai korelasi tinggi (p>0.75) bagi mencegah 'overfitting'. 'Inverse Distance Weighting' memberi ramalan yang terbaik dengan ketepatan melebihi 80 %.

Model Kewujudan Spesies (SOM) kemudiannya dijana bagi kesemua spesies dipterokap yang wujud di Sarawak. Peta kepadatan kewujudan spesies bagi setiap genus dan kategori (endemik and bukan endemik) dijana dengan menindih SOMs kesemua spesies dalam setiap genus atau kategori. Peta kewujudan spesies dianalisa dengan peta tutupan bumi dari imej Landsat 7-EMT+ dan kawasan hutan terlindung untuk mengidentifikasi hotspot bagi tujuan pemeliharaan di Sarawak. Didapati kawasan di bahagian Tengah Sarawak dan kawasan southwest (barat laut Borneo sekitar Kuching) merupakan hotspot utama kepeblagaian dipterokap di Sarawak sementara kawasan pamah pantai di hilir Sungai Rejang dan Baram yang kebanyakan terdiri dari hutan paya gambut yang miskin dalam kepadatan kewujudan spesies. Perbezaan hotspot cuma dari segi saiz keluasan. Dari segi endemisme, sama seperti kepelbagaian dipterokap, hutan dipterokap campuran central Sarawak adalah hotspot yang paling penting. Begitu juga dengan genus berbeza yang kongsi hotspot yang lebih kurang sama di kawasan barat laut dan Sarawak tengah. Hotspot di Sarawak tengah mungkin disebabkan oleh penindihan tiga kawasan biogeographi - kawasan 'Riau pocket', hotspot timur daya Borneo dan kawasan biogeografi flora Sarawak tengah. Hotspot barat daya Borneo sekitar Kuching mungkin disebabkan oleh kandungan geologi heterogenus yang dan sejarah geologi yang lebih lama.

Analysis jurang menunjukkan bahawa kebanyakan hutan terlindung adalah tertumpu di barat daya Sarawak (contohnya Taman Negara Bako, Kubah, Tanjung Datu and Gunung Gading) dan di bahagian utara Sarawak (contohnya Taman Negara Niah, Bukit Lambir dan Gunung Mulu). Ini meninggalkan hotspot di bahagian tengah Sarawak paling kurang dilindungi. Kawasan terlindung hanya melingkungi antara 1.5% to 4% keseluruhan kawasan bagi hotspot untuk genus berbeza, spesies endemik dan bukan endemik. sementara majoriti hotspot yang masih kekal hutan adalah di luar kawasan terlindung.

Kata kunci: *DIPTEROKAP, PEMETAAN RAMALAN, PENILAIAN HABITAT, HOTSPOT, ANALYSIS JURANG*

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°	Degree
'E	East
'N	North
'S	South
ha	Hectares
km	Kilometre
m	Meter
%	Percent

LIST OF ABBREVIATIONS

BIOCLIM	Bioclimaic Data
BLR	Binary Logistic regression
GIS	Geographic Information System
GLCF	Global Land Cover Facilities
GLOVIS	Global Visualization Viewer
GPS	Global Positioning System
IDW	Inverse Distance Weighting
MARS	Multivariate Adaptive Regression Spline
MSS	Multi-Spectral Scanner
PFE	Permanent Forest Estate
TM	Thematic Mapper
RMS	Root Mean Square
R-Square	Goodness of Fit
SOM	Species Occurence Model
TPA	Totally Protected Area
UPEM	Jabatan Ukur dan Pemetaan Malaysia

CHAPTER 1

INTRODUCTION

1.1 Background

Borneo's lowland rain forest dominated by dipterocarps has been subjected to exploitations under different policy regimes leading to degradation and deforestation. Deforestation is an inevitable part of development in the tropics including Borneo. It is estimated that the average deforestation rate for Borneo between 2002 and 2005 was 1.7% per annum with a higher rate of 2.2% per annum for peat swamp (Langner *et al.*, 2007) which is about double the rate for the whole region of Southeast Asia as reported by Achard *et al.* (2002) and more than three times the global rate of tropical forest loss at 0.52% (Achard *et al.*, 2002). The tropical aseasonal forests of Sarawak are logged as well as converted into other land uses to provide capital for development.

Several conservation plans, strategies and policies are, however, in place to cope with high deforestation rate such as the establishment of protected area system and reforestation. Sarawak is committed to gazette about 10% or about 1.2 million hectares of its total land area as Totally Protected Areas (national parks, nature reserves and wildlife sanctuaries) by 2020 under its Forest Ordinance and the Wildlife Ordinance. The existing Totally Protected Areas currently cover 534,747.5 hectares (source: Nature Conservation and Constitution Division, Forest Department Sarawak) or 4.46 % of Sarawak's land area which is about slightly less than half of the target.

However, the quality of the protected area such as biodiversity is as important as the quantity (size) conserved. Such keystone and dominant tree family of Sarawak's forest as dipterocarps ought to be conserved whereby there is a need to know where they are located in the landscape.

Dipterocarps have been the subject of taxonomic and systematics studies (Ashton, 1982; 2004). Nevertheless, crucial information on the species distribution density are seriously lacking for sustainable management and conservation efforts. A review of literature, however, indicates that information on the habitat loss and species distribution density are absent and will therefore be undertaken by this study.

GIS-based multicriteria evaluation can be used to derive conservation values of forest (Phua and Minowa, 2000) and be integrated with decision making approach in prioritizing areas for conservation (Phua and Minowa, 2005). Such multicriteria framework also allows the use of probabilistic prediction of landslide occurrence (e.g. Chung and Fabbri, 1999) and deforestation (e.g. Lee *et al.*,2007). Integration of predictive model in multicriteria evaluation coupling with field data were used to derive the species distribution density and influence of land cover changes

This research embarks on an integrated approach in deriving critical information on the losses and conservation gaps on the major commercial timber species of dipterocarps in Sarawak. To address such a vast land area, the most technically sound methodology is based on the use of satellite remote sensing and GIS coupling with ancillary data such as the dipterocarps specimens from herbarium with georeferenced information of the dipterocarps. This is especially useful to the development of predictive model of the species based on GIS modelling of the species data and environmental variables such as altitude, climate, soils and topography.

1.2 Rationale of the study

This study is done on dipterocarps to include the whole of Sarawak and the rationale is provided as follows::

i. Borneo is one of the global megadiverse hotspots where biodiversity and endemism is high (Ashton, 1995; MacKinnon *et al.*, 1996; Roos *et al.*, 2004). Therefore, the study on the biodiversity conservation status is of

importance. The northern part of Borneo (Sarawak included) is thought to be a refugium for the last ice age (Corner, 1960).

ii. Dipterocarpaceae or dipterocarps is the dominant tree family of the tropical rain forests of Southeast Asia (and Borneo) and a commercially important timber family as well. It has its centre of diversity in Borneo where at least 267 species are found (Ashton 1982). They are also keystone species and at the same time economically important timber species of the rain forest.

iii. Borneo is the centre of diversity for dipterocarps. About 50 percent of dipterocarp species worldwide are found in northern Borneo (that includes Sarawak), which also represents a significantly high proportion of endemic dipterocarp species (Ashton, 2004). The northern part of Borneo also harbours a higher wealth of biodiversity than the rest of Borneo (Corner, 1960). For instance, over 90% of dipterocarps species in Borneo occur in Sarawak (Ashton, 2004).

iv. Dipterocarps are keystone species of the tropical rain forests of Southeast Asia and Borneo.

v. There is a need to study the dipterocarp as deforestation is currently at a rapid rate, particularly with the expansion of oil palm plantations which affects its habitat and conservation. As dipterocarps are climax species, deforestation will affect its diversity greatly.

vi. Deforestation needs to be quantified in order to enable the provision of baseline data for monitoring purposes.

1.3 Objectives

This research aims at filling the gap of missing information about the dipterocarp species distribution and conservation gap at a landscape scale through an integrated approach that combines remote sensing, GIS and field data. The results

will support policy adaptation in Sarawak. The objectives of this study are as follows:

i. To determine the rate of deforestation and land use change in Sarawak between 1990 and 2009 using multitemporal Landsat data.
ii. To model the natural occurrence dipterocarp species in Sarawak.
iii. To pinpoint the hotspots of dipterocarp diversity and endemism on dipterocarps in Sarawak using the predictive distribution.
iv. To perform a gap analysis for dipterocarp diversity and endemism in Sarawak .

1.4 Scope of studies

This study covers the entire family of the dipterocarpaceae recorded in Sarawak which consists of nine genera, *viz Cotylelobium*, *Dryobalanops*, *Parashorea*, *Shorea*, *Upuna* and *Vatica*. To address research in such a vast land area, the most technically sound methodology is based on the use of satellite in remote sensing and GIS coupling with ancillary data. The dipterocarps specimens from herbarium with georeferenced information and existing plant census data provide groundtruths on hotspot of diversity and endemism of the dipterocarps. This is especially useful to the development of predictive model of the species based on GIS modelling of the species data and environmental variables such as topography, soil and climate. Analysis of deforestation and degradation was conducted using the free global dataset (Landsat) of 1990 and 2009 and was used as the baseline data for this research. The model output of all the species distribution in Sarawak as well as the resulted species density maps (all the nine genera, endemic, non endemic species and overall) were assessed. Accuracy assessment was done using the reserved half herbarium dataset for the purpose as herbarium specimens are more evenly distributed due to a longer history of collection. The information derived will be used for adapt policy to changes in the habitat of these most important timber species. Sarawak was chosen because the northern part of Borneo harbours a higher wealth and endemism of plants including dipterocarps (Corner, 1960).

1.5 Flowchart and Research Layout

This study attempts to map out the natural occurrence of dipterocarps at the species and generic level in the landscape using statistical modelling. Land use maps were also generated in this study. By means of overlapping the land use map as well as the map for protected areas, a gap analysis on the adequacy of conservation and protection of dipterocaprs in Sarawak can be determined. This study commences with Chapter One which furnishes the rationale, objectives, scope of studies and flowchart and research layout while Chapter Two provides a background on the study area (Figure 1.1). This is followed by Chapter Three which gives a literature review on past work or research done and identifies missing gap in research.

Figure 1.1 below shows the flow and layout of the research for this study:

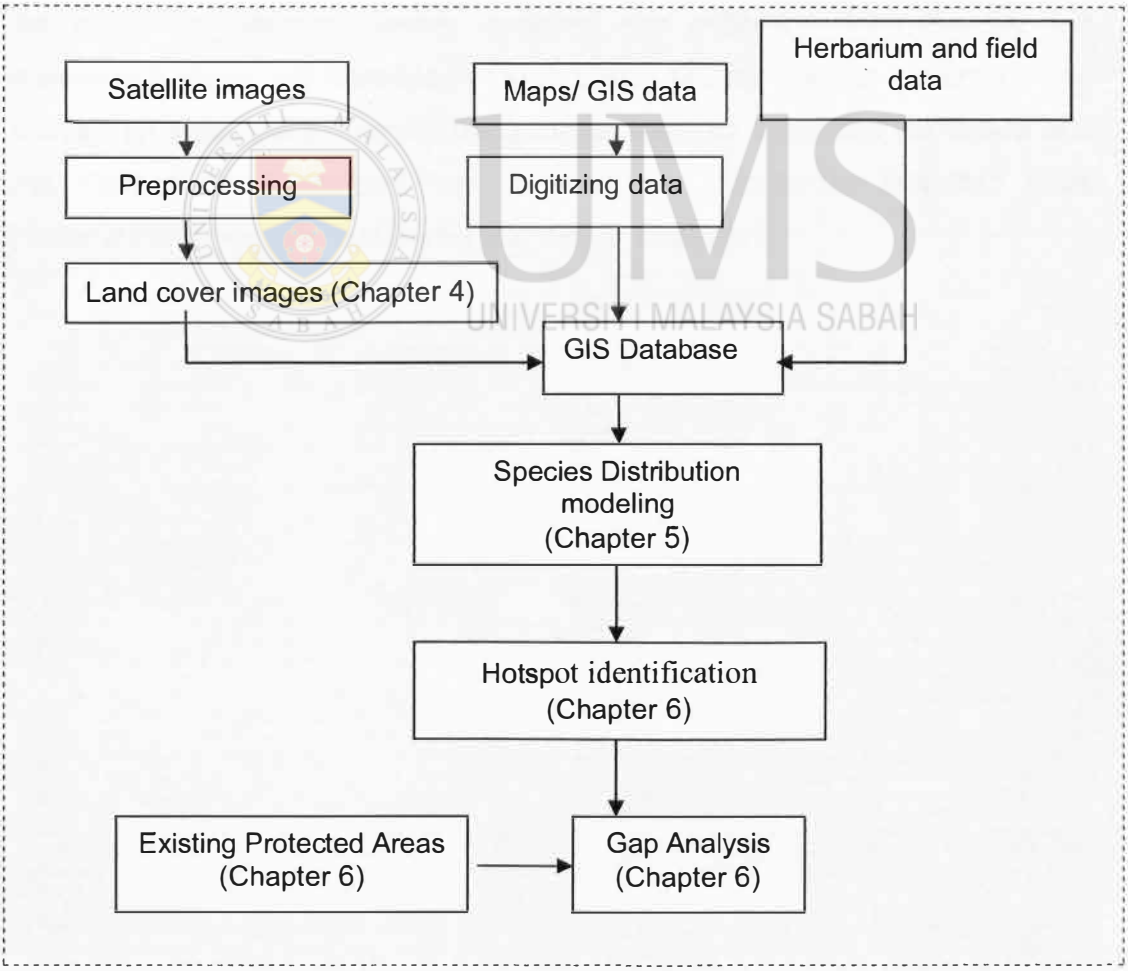

Figure 1.1: Flow chart showing the layout and setting of the research.