Faculty of Resource Science and Technology

Mapping of *Shorea kunstleri* King (Critically Endangered Species) Within Lambir Hills National Park

Dayang Rafiedah Awang Rapiee

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Dayang Rafiedah Awang Rapiee

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Signature

Name: Dayang Rafiedah binti Awang Rapiee

Matric No.: 18020090

Faculty of Resource Science and Technology

Universiti Malaysia Sarawak

Date :

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ABSTRACT

Shorea kunstleri King is one of the tree species that has been categorized by the International Union for Conservation of Nature (IUCN) as facing an extremely high risk of extinction in the wild. The importance to monitor the population of endangered tree species is to make sure that species receive continuous protection and assistance. This study was conducted at Lambir Hills National Park located in Miri, Sarawak. It is a mixed dipterocarp forest that has high species composition diversity in the area. Despite all that, there is a species that is critically endangered which is *Shorea kunstleri* King. The information on the distribution of *Shorea kunstleri* King can be used to assist conservation management. Therefore, remote sensing technology is incorporated into this study to facilitate the process of species identification. An airborne hyperspectral image mosaic was utilised in the research to evaluate the ability of this high spectral fidelity dataset with two types of classifiers Support Vector Machine (SVM) and Maximum likelihood (ML) to detect and map a tree species of interest (*Shorea kunstleri* King) within the mixed dipterocarp forest stand of the Lambir Hills National Park. In this study, two types of feature extraction Principal Component Analysis (PCA) and Spectral Derivative (SD) were applied to the classifiers. To demonstrate the effect, hyperspectral images with no feature extraction were classified using SVM and ML classifiers. The accuracies achieved from different feature extraction and classifiers were compared statistically. Based on the results, the image classified using SVM classifier achieved the most accurate characterisation with and without feature extraction compared to ML classifier. SVM classifier is known for its ability to generalise well even with limited training samples and is commonly used in image classification. The Kernel parameter in SVM classifier alongside feature extraction significantly affects the classification accuracy. The accuracy results from ML classification without feature extraction acquired poor

classification. Therefore, feature extraction does affect the classification accuracy, but it depends on the morphology of the study area. It can be concluded that the SVM method with SD feature extraction could detect tree crowns of *Shorea kunstleri* with a Kappa coefficient of 0.8126 which showed a great agreement with the observed samples and overall accuracy of 89.89% that shows the accuracy of the final map.

Keywords: Classification, feature extraction, remote sensing, species identification, SVM

Pemetaan Shorea kunstleri King (Spesis Terancam Kritikal) di Taman Negara Lambir

ABSTRAK

Shorea kunstleri King adalah salah satu spesis pokok yang telah dikategorikan oleh International Union For Conservation of Nature (IUCN) sebagai menghadapi risiko kepupusan yang sangat tinggi dalam kalangan hidupan liar. Kepentingan untuk memantau populasi spesies pokok terancam adalah untuk memastikan spesies mendapat perlindungan dan bantuan berterusan. Kajian ini dijalankan di Taman Negara Bukit Lambir yang terletak di Miri, Sarawak. Ia merupakan hutan campuran dipterokarpa yang mempunyai kepelbagaian komposisi spesis yang tinggi di kawasan tersebut. Di sebalik semua itu, terdapat spesies yang sangat terancam iaitu Shorea kunstleri King. Maklumat mengenai Shorea kunstleri King boleh digunakan untuk membantu pengurusan pemuliharaan. Oleh itu, teknologi penderiaan jauh dimasukkan ke dalam kajian ini untuk memudahkan proses pengecaman spesies. Mozek imej hiperspektral bawaan udara telah digunakan dalam penyelidikan untuk menilai keupayaan set data kesetiaan spektrum tinggi ini dengan dua jenis pengelas Mesin Vektor Sokongan (SVM) dan Kemungkinan Maksimum (ML) untuk mengesan dan memetakan spesies pokok yang diminati (Shorea kunstleri King) dalam dirian hutan dipterokarpa campuran Taman Negara Bukit Lambir. Dalam kajian ini, dua jenis pengekstrakan ciri Analisis Komponen Utama (PCA) dan Spectral Derivative (SD) telah digunakan pada pengelas. Untuk menunjukkan kesannya, imej hiperspektral tanpa pengekstrakan ciri dikelaskan menggunakan pengelas SVM dan ML. Ketepatan yang dicapai daripada pengekstrakan ciri dan pengelas yang berbeza dibandingkan secara statistik. Berdasarkan keputusan, imej yang dikelaskan menggunakan pengelas SVM mencapai pencirian paling tepat dengan dan tanpa pengekstrakan ciri berbanding pengelas ML. Pengelas SVM terkenal dengan keupayaannya untuk membuat generalisasi dengan baik

walaupun dengan sampel latihan yang terhad dan biasanya digunakan dalam pengelasan imej. Parameter Kernel dalam pengelas SVM bersama pengekstrakan ciri memberi kesan ketara kepada ketepatan pengelasan. Hasil ketepatan daripada pengelasan ML tanpa pengekstrakan ciri memperoleh pengelasan yang lemah. Oleh itu, pengekstrakan ciri memang mempengaruhi ketepatan pengelasan, tetapi ia bergantung kepada morfologi kawasan kajian. Dapat disimpulkan bahawa kaedah SVM dengan pengekstrakan ciri SD dapat mengesan mahkota pokok Shorea kunstleri dengan pekali Kappa 0.8126 yang menunjukkan persetujuan yang besar dengan sampel yang diperhatikan dan ketepatan keseluruhan 89.89% yang menunjukkan ketepatan peta akhir.

Kata kunci: *Klasifikasi, pengekstrakan , penderiaan jarak jauh, pengecaman spesis, SVM*

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
CBFE	Clustering-Based Feature Extraction
ENVI	Environment for Visualising Image
FT-NIR	Fourier Transform Near- Infrared
FRIM	Forest Research Institute of Malaysia
GPS	Global Positioning System
HSI	Hyperspectral Image
IUCN	International Union Conservation of Nature
LiDAR	Light Detection and Ranging
LTER	Long- Term Ecological Research
MDF	Mixed Dipterocarp Forest
ML	Maximum Likelihood
MLC	Maximum Likelihood Classifier
MSI	Multispectral Imaging
OA	Overall Accuracy
PA	Producer's Accuracy
PCA	Principal Component Analysis
QUAC	Quick Atmospheric Correction
RBF	Radial Basis Function
RDID	Research Development & Innovation Division
RF	Random Forest
SADU	System Application and Development Unit
SAR	Sarawak Herbarium

SD	Spectral Derivative
SPSS	Statistical Package for the Social Sciences
SVM	Support Vector Machine
TPA	Totally Protected Forest
UA	User’s Accuracy
WLCL	Wavelength Class

CHAPTER 1

INTRODUCTION

1.1 Study Background

Sarawak is a state of Malaysia and the largest among 13 states. Forest land in Sarawak is classified as Permanent Forest Estate which are under Forest reserves, Protected forests and Communal forests. In Sarawak, protected areas are referred as Totally Protected Area (TPA) which consist of national park, wildlife sanctuaries and nature reserves. Based on information gathered on Sarawak Forest Department website there are 42 total of national parks, 5 wildlife sanctuaries and 14 nature reserves. The protected areas were constituted to conserve the wildlife flora and fauna and most importantly for research education. According to Ashton (1995), MNS (1998) and Pearce (2006) stated that the highland forest ecosystems of Sarawak are unique as there are no definite forest type with changes of altitude due to gradual and continuous in floristic composition of forests. This contributes to high plant endemism. In general, the climatic factors, temperature, humidity, rainfall index and potential evapotranspiration are all the strong influence which may explain high species diversity in mixed dipterocarp forests. Therefore, high tree species diversity in Sarawak must be protected and monitored for a sustainable forest management. Lambir Hills National Park in Miri is one of the mixed dipterocarp forests that has high species composition. Despite all that, Lambir Hills National Park has a species that is categorised as critically endangered by IUCN red list which is *Shorea kunstleri* King up until 2022. The study about *S.kunstleri* is still scarce. Plus, due to a lack of data estimates of tree diversity at large geographic areas continue to rely heavily on published lists of species representations that are geographically uneven in coverage.

This limitation is possible to be overcome by remote sensing technology. It offers a great opportunity to ecologists. This technology can help to facilitate the process of species identification over large areas. This approach has been used for many years especially in vegetation classification and change monitoring; this claimed is proven by studies done by Gress (1993), Roshier and Rumbachs (2004), Rebelo et al. (2009) and Zeshan (2021). Due to its ability, the application of remote sensing is applied in this study since it is impressive and potentially cost-effective way to do inventory (Ballanti et al., 2016). Perhaps the easiest way to evaluate the cost-effectiveness of a remote sensing survey is to compare it to other ways of accomplishing the same set objectives. For instance, remote sensing analysis is time saving and can cover large areas compared to conventional method of species identification. Hyperspectral image acquired contains hundreds or even thousands of bands depending on the type of sensor used. The quality of hyperspectral image increases as the spectral bands increases (Reuda et al., 2014). This is due to each pixel in the image contains a highly detailed reflectance of ground materials that found on earth surfaces. Spectral reflectance data for each object has different spectral response that allows researchers to distinguish them. However, the complexity of data analysis has become a challenge because of too much information that can be acquired from hyperspectral image. Therefore, to get on the level of detailed required data according to the extension of study area, the right algorithm is needed to ingest all the information.

Examining the data and refining the algorithm is the crucial part. Therefore, Support Vector Machine (SVM) was chosen in this study. Research shown that SVM has been recently used in numerous applications in image processing (Ustuner et al., 2015). SVM is a machine learning that can overcome multiclass problem of hyperspectral imagery. The advantage of this approach is that it defines the optimal hyperplane between the class of

interest and the rest of the classes. In addition, SVM only requires small training classes compared to Maximum likelihood (ML). As described by Moughal (2013), ML is a parametric classifier that is often used in pattern classification and image classification. ML requires enough ground truth data to allow the estimation of the mean vector and the variance-covariance matrix of population. The variance-covariance matrix becomes unstable if there is high correlation between two bands or the similarity of ground truth data is high.

Given this situation, the number of bands can be reduced by using feature extraction such as Principal Component Analysis (PCA) and spectral derivative. In this study, different feature extraction used to acquire high classification including raw hyperspectral data as a constant. All features of hyperspectral image were classified using SVM and ML. Area of this study contains high species diversity which gave more complexity in tuning the suitable algorithm.

Therefore, this study could contribute an extent learning of critically endangered species *S.kunstleri* in Lambir Hills National Park. Scientists and researchers from all over the world consider Lambir Hills, which include 52 hectares of greenery, to be one of the most ecologically diverse locations to date (SFC, 2022). The mapping of *S.kunstleri* is one of a way to monitor the population of the species and to make sure that the species receive continuous protection and assistance.

1.2 Problem Statement

Lambir Hills National Park is known for its high species composition. However, *Shorea kunstleri* King, a species of tree, is included on the IUCN Red List as being critically endangered. Losing another tree species can have a domino effect of extinctions, threatening habitats of animals and plants and the overall resilience of ecosystem. Therefore, an accurate

identification of critically endangered tree species is necessary to quantify the current species management and to prioritise conservation efforts. According to Silva et al. (2022), the reassessments of already red-listed species are often less appealing and hence down-prioritized as keeping extinction risk assessments up to date is a major challenge for the IUCN red list. Thus, the advances of remote sensing technology should be fully utilised especially in mapping *Shorea kunstleri* King in Lambir Hills National Park.

1.3 Objectives

The study attempts to facilitate in species identification process with the application of hyperspectral image. This can be achieved through the following set of objectives:

i. To analyse the differences in spectral response of *S.kunstleri* within genus and between other taxa in Lambir Hills National Park study plot.

ii. To map the distribution of *S. kunstleri* in Lambir Hills National Park study plot.

1.4 Study Scope

This study is focus on the mapping of critically endangered *S.kunstleri* in Lambir Hills National Park with the aid of remote sensing technology. Mapping of critically endangered species is one of a way to help in contributing sustainable forest management and monitoring of tree species. *S. kunstleri* is one of the important species that is use in light construction and it is also found that the stembark extract of *S.kunstleri* possessed antioxidant and antimicrobial properties. However, the availability of new studies on this species is still limited, and yet it is classified as a critically endangered species. In this study, the focus study area is at Lambir Hills National Park in Miri, Sarawak. Remote sensing

technology by using hyperspectral image is a tool to map the *S.kunstleri* distribution. Hyperspectral imaging sensors measure the radiance of materials on the surface within a pixel area. A collected hyperspectral image pixel will form a high- dimensional vector in which represents the radiance at different wavelength. The wavelength bands can provide a sufficient discriminative information to identify the tree species and it is termed as spectral signature. The precise depiction of spatial variability by ground truth data is a need for predictive modelling with remotely sensed data. The information collected were the indices for testing data and training data. Two types of classifiers parametric and non – parametric classifiers were used in this study. The classification accuracy and information content of species maps produced using hyperspectral image vary with different types of classifiers and feature extractions.

CHAPTER 2

LITERATURE REVIEW

2.1 Mixed Dipterocarp Forest in Sarawak

The forest in Malaysia is mostly dominated by family Dipterocarpaceae. Therefore, it is called dipterocarp forest. Most of timbers in Malaysia comes from Dipterocarpaceae family. Forests in Malaysia are mostly heterogeneous which means more than one tree species type can be found at one place. In Sarawak, both lowland and hill dipterocarp forests are known as mixed dipterocarp forest (MDF). Mixed dipterocarp forests are categorised as forest that has high diversity of tree species as this forest has high species richness. However, it is low in species abundance which indicates the number of individuals of each species in that area is low. It is totally different from homogenous forest type where only one type of tree species can be found at one place. Tree species composition in natural forests are hard to identify as each of the tree species looks almost similar. A research study done at Anap Muput Forest Management in Bintulu by Demies at al. (2019), stated that MDF is a tall forest with a thick, deep canopy, the top of which is frequently highly uneven. The height of the canopy ranges from 35 to 55 metres, with emergent trees occasionally reaching 60 metres. Besides, Lambir Hills National Park was found to have the highest diversity of trees anywhere on Earth. The 52 hectares permanent forest plot was found to have 125 species of Euphorbiaceae and 87 species of Dipterocarpaceae and these two families were the most species-rich families. As stated by Lee et al. (2002) the Dipterocarpaceae dominated the forest with 42% of the basal area and 16% of the trees. Therefore, the requirements of detailed information on tree species description found in the forest is vital for sustainable forest management.

Forest inventory is a tool that provides quantitative and qualitative information of trees within the forest ecosystem. This can be achieved by collecting ground data and sample collection. This method requires expertise that major in plant systematics and skilled workers to do ground works. The sample collection will be brought to the herbarium and compared with the standard reference collection. To practice this method over a large area is time – consuming and subjective. Different experts might have different opinion on certain species and the results may vary. Therefore, to facilitate the current practice it is preferable to utilise remote sensing technology.

2.2 Critically Endangered Species of *Shorea kunstleri* King (Ashton, 2004)

Shorea kunstleri is from the family of Dipterocarpaceae. Known as Red Meranti, Selangan merah in Sarawak and Seraya sirap in Sabah. *Shorea kunstleri* can be found in North Sumatra, Peninsular Malaysia and Borneo in mixed dipterocarp forest on yellow sandy and sandy clay type of soil. Usually on high ridges at 800 m altitude. In Sarawak, *S.kunstleri* can be found at Kubah National Park and at Lambir Hills National Park. It is listed in IUCN red list as critically endangered species under criteria A1cd. There are five quantitative criteria that is used to determine which category of threats it belongs which are population reduction size, geographic range size, small and declining population size, very small and declining population size and lastly quantitative analysis of extinction risk (IUCN red list, 2022). *S.kunstleri* has met the first A1cd criteria in which the species has declined in the area of occupancy and potential level of exploitation as shown in Table 2.1. However, *S.kunstleri* was last assessed by IUCN red list in 1998. As recorded in Tropical Plants Database (2022), *S.kunstleri* is also important as it is used in light flooring, construction, exterior joinery, box, crates including musical instruments.

Table 2.1: Summary Criteria A used to Evaluate Taxon in a Threatened Category (Source : IUCN Standards and Petitions Committee) https://www.iucnredlist.org/documents/RedListGuidelines.pdf

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered	Endangered	Vulnerable
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.

A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) *[(a) cannot be used for A3]*.

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

(a) direct observation *[except A3]*

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality

(d) actual or potential levels of exploitation

(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

Since *S.kunstleri* also a part of commercial timber tree species, research has been made to *S.kunstleri* for example on its antioxidant properties. Research done by Daud et al. (2014) reported that *S.kunstleri* stembark contains steroid, terpenoids, saponins, flavonoids and phenolic compound which possessed antimicrobial and antioxidant properties.

2.2.1 Description of *Shorea kunstleri* King

S. kunstleri King was first collected by George King in 1893 (Royal Botanics Garden, Kew, 2022). *S. kunstleri* King locally can be found in North Sumatra, Peninsular Malaysia and Borneo (Soepadmo et al., 2004). The trees are large and emergent with height up to 60 m tall, 2 m diameter with very large crown, cauliflower-shaped, somewhat diffuse, with a few large ascending branches; trunk tall, cylindrical; buttress low but sometime to 1.5 m tall, spreading, stout. Bark becoming pale mauve- to grey-brown, deeply narrowly v-section fissured and flaky, with yellow dammar smears, inner bark orange brown. Sapwood hard; heartwood dark reddish brown. Young parts shortly pale buff puberulent; more or less caducous on twig, petiole and leaf blade; denser and more persistent on inflorescence, leaf bud, ovary, nut, stipules and bracteole outside (sparse within). Twigs c. 2 mm diam. apically, terete, much branched. Leaf buds falcate, 5–7 x 2–2.5 mm. Stipules narrowly lanceolate, to