

Relative abundance estimations of chengal tree in a tropical rainforest by using modified Canopy Fractional Cover (mCFC)

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Abstract. Tree species composition estimations are important to sustain forest management. This study challenged estimates of relative abundance of useful timber tree species (chengal) using Hyperion EO-1 satellite data. For the estimation, modified Canopy Fractional Cover (mCFC) was developed using Canopy Fractional Cover (CFC). mCFC was more sensitive to estimate relative abundance of chengal trees rather than Mixture Tuned Matched Filtering (MTMF). Meanwhile, MTMF was more sensitive to estimate the relative abundance of undisturbed forest. Accuracy suggests that the mCFC model is better to explain relative abundance of chengal trees than MTMF. Therefore, it can be concluded that relative abundance of trees species extracted from Hyperion EO-1 satellite data using modified Canopy Fractional Cover is an obtrusive approach used for identifying trees species composition.

1. Introduction

Rapid forest degradation and deforestation of tropical rainforest is a serious problem in the world [1]. Forest degradation and deforestation may negatively affect livelihood, ecosystem function, climate and biodiversity of the forest where it become key issues which in line with the Reducing Emissions from Deforestation and Forest Degradation (REDD) especially on tree species which also the animals habitats [2]. Forest degradation and deforestation are caused by anthropogenic pressure such as unsustainable timber harvesting [1]. Hence, to cope with this problem, Sustainable Forest Management (SFM) has been introduced by Food and Agriculture Organization (FAO). To achieve SFM, selective logging scheme was used [3]. In this scheme, a conventional ground measurement was conducted to estimates the abundance, distribution and the volume of trees. However, it was time and cost consuming [1].

Remote sensing technique was used as a tool to estimate tree composition of tropical rainforest due to its ability to provide spatial and temporal resolution data. Numerous of studies using remote sensing techniques have been widely conducted [2,4,5,6]. On tropical rainforest, selective and illegal logging that caused forest degradation can be monitored frequently due to the existence of temporally remote sensing data. There are some studies to estimate relative abundance of tree species that have high commercial values which is one of the solutions to cope with forest degradation and deforestation problems at large scale area extent and cost effective [1,2]. Thus, the useful information obtained can be used for planning and sustainable management of forest [1].

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Previous study suggested that relative abundance of tree species may be estimated by using spectral unmixing approach such as Canopy Fractional Cover (CFC) developed based on Linear Mixture Model (LMM) and Mixture Tuned Matched Filtering (MTMF) [7-10]. Spectral unmixing used to model each pixel problem as linear combination of a finite number of spectrally distinct signatures or “endmembers”, subpixel estimates of endmember abundance can be obtained [8]. In this study, spectral unmixing approach used was Mixture Tuned Matched Filtering (MTMF) and modified Canopy Fractional Cover (mCFC) which has been modified by author from Canopy Fractional Cover (CFC) developed by [11] to estimate relative abundance of chengal trees exist in Pasoh Forest Reserve. The main goal of this study was to assess the modified spectral unmixing model for estimating relative abundance of chengal trees. The best model to estimate relative abundance of chengal trees was identified based on accuracy evaluation. The accuracy of mCFC and MTMF were evaluated using census data provided by Forest Research Institute of Malaysia (FRIM). As such, we can hypothesize that mCFC may give encourage results than MTMF as it apply vegetation index in the model which can eliminate soil background effects.

2. Materials and methodology

2.1. Description of study site

This study was conducted in Pasoh Forest Reserve, Jelebu district, Negeri Sembilan (2° 58' N latitude and 102° 18' E longitude). The study area was confined to a long-term ecological plot with 1 km long and 0.5 km wide. Pasoh Forest Reserve was covered with primary lowland mixed dipterocarp forest. Primary lowland mixed dipterocarp forest contains several timber species called *Shorea* and *Dipterocarpus* species. In the reserve, the 50-ha plot was established by Forest Research Institute of Malaysia (FRIM) which contains 338, 360 trees with ≥ 1 cm in DBH which comprising 81 families, 295 genera and 818 species [12-14]. The plot was dominated by 30 species of Dipterocarpaceae accounting for 27.3% of basal area. The height of emergent trees averages 46 m and the height of the main canopy was 20-30 m [12,13,15]. Various useful timber species exist in the 50-ha plot of Pasoh Forest Reserve which represent heterogeneous of tropical rainforest in Malaysia. The study area was selected based on remotely sensed data availability over the study area.

2.2. Materials

Two types of data were used in this study: (1) satellite remote sensing data and (2) in-situ data (i.e. in-situ spectral reflectance data and census data) as reference for validating the results obtained from MTMF and modified Canopy Fractional Cover (mCFC).

2.2.1. Hyperion EO-1

To estimate the relative abundance of Chengal trees, spectral unmixing approach was employed to Hyperion EO-1 which was acquired from official United State Geological Survey website (USGS) via GLOVIS. Data downloaded was captured by Earth Observation satellite on year 2003 with 20% cloud cover. In order to remove atmospheric effects that existed in the Hyperion EO-1 scene, Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) was employed. Moreover, FLAASH is the most commonly used method to transform radiance image into reflectance image especially for hyperspectral imagery. There are two function of FLAASH that was useful which are (1) can be used as atmospheric correction tool that corrects wavelengths in the visible through near-infrared and shortwave infrared regions, up to 3 μm and (2) can be used for converting radiance image into reflectance image. Geometric correction was carried out through EO-1 Hyperion L1R image which already been projected in Universal Transverse Mercator with WGS 84 datum. This geometric correction was employed to the image in order to convert the UTM projection into RSO projection.

2.2.2. In-situ data

In-situ spectro-radiometer data were collected on February, 2000. The data was collected at spectral resolution ranged from 0.4 – 1.07 μm with 1 nm interval. Spectral reflectance was measured under laboratory conditions. In this study, leaves samples were collected for (i) Meranti langgong (*Shorea lepidota*), (ii) Damar laut daun kecil (*Shorea maxwelliana*) and (iii) Chengal (*Neobalanocarpus heimii*). Apart from the spectro-radiometer data measurements, tree census data obtained on year 2000 was used in this study. Structural information of trees – diameter at breast height (DBH) and the location coordinate of each tree within 50-ha plot of Pasoh Forest Reserve were main input in the data processing. Census data were also used as reference data to assess the mapping accuracy of chengal trees that been derived from Hyperion EO-1. As the diameter breast height (DBH) was collected, the height and crown of tree were calculated based on diameter breast height that we can obtain from census data. From the tree height and crown size calculations, census data was plotted into three dimensional views to identify the highest chengal trees 50-ha plot.

2.3. Model Development

2.3.1. modified Canopy Fractional Cover (mCFC)

In CFC, vegetation index for canopy and open area was an input to identify fractional cover of degraded area where canopy fractional cover was modified from Linear Mixture Model (LMM) equation. The CFC equation can be written as

$$fc = \frac{VI - VI_{open}}{VI_{canopy} - VI_{open}} \quad (1)$$

Each pixel of satellite remote sensing data used in logged area is assumed to consist of two components which are tree canopies and open areas especially in forest degradation studies [11]. In this study, mCFC has been used to estimate chengal tree species relative abundance based on CFC algorithm where the algorithm has been modified as below:

$$fc = 1 - \left(\frac{VI - VI_{chengal}}{VI_{canopy} - VI_{chengal}} \right) \quad (2)$$

where $VI_{chengal}$ and VI_{canopy} was the average value extracted from Hyperion image. VI used was MSAVI2 which have high potential to eliminate soil reflectance effects on vegetation reflectance [16]. In this study, the most sensitive band to chengal was selected based on first and second order derivatives analysis.

2.3.2. Vegetation Index used in Canopy Fractional Cover

Modified Soil Adjusted Vegetation Index (MSAVI2) [16] has been used as an input for modified Canopy Fractional Cover (mCFC). This vegetation index was chosen due to its ability to eliminate soil effects. The MSAVI2 model can be expressed as:

$$MSAVI_2 = \frac{2\rho_{NIR} + 1 \sqrt{(2\rho_{NIR} + 1)^2 - 8(\rho_{NIR} - \rho_R)}}{2} \quad (3)$$

where ρ_{NIR} is the reflectance at near infrared band;
 ρ_R is the reflectance at red band.

2.4. Mixture Tuned Matched Filtering (MTMF)

Mixture analysis was carried out using MTMF with input features selected from the MNF transformation of the Hyperion EO-1 data set. MTMF is the fraction of an image which allows false

positives to be identified and eliminated from the abundance results [8,10,17]. Therefore, MTMF can be used to identify chengal trees in the Hyperion EO-1 dataset as it can calculate the quantity of target that is much smaller than pixel size. There are two phases in MTMF algorithm which are a Matched Filter calculation for abundance estimation and Mixture Tuning calculation for false positive identification or rejection. In remote sensing context, Matched Filtering (MF) is a filtering process of input data for matching the target spectrum and eliminates the remaining background spectra. The Mixture Tuning has segregating power in MTMF algorithm. The Mixture Tuning calculates a value of infeasibility for each MF classified pixel. The MTMF algorithm as described here implicitly requires zero mean, unit noise variance input data (such as MNF transformed data) for proper Mixture Tuning calculation. The output of MTMF would be in fraction image with tree species fraction values and feasibility image.

2.5. Assessment of Relative Abundance Estimation of Chengal Trees.

As the relative abundance per pixel basis has been estimated by using modified Canopy Fractional Cover, next step is to estimate relative abundance of tree species per hectare in each compartments that been built by Forest Research Institute Malaysia (FRIM). Percentage of relative abundance of tree species obtained using modified Canopy Fractional Cover (mCFC), then was evaluated using census data that being plotted in three dimensional plot of census data on Hyperion EO-1 30m × 30m grid. The relative abundance of chengal tree species from three dimensional plot of census data being measured based on tree crown that cover the Hyperion 30m × 30m grid.

3. Results

3.1. Chengal Trees Relative Abundance Estimation using Mixture Tuned Matched Filtering

MTMF was employed to Hyperion EO-1 which allows false positive to be identified and eliminated from abundance results [9]. The results obtained from MTMF were in fraction with the sub-pixel abundance values of chengal trees and feasibility image that ranging from 2 to 20. Eight points which represent chengal trees were figured out based on MTMF fraction and infeasibility scale (Appendix A). Highest percentage number of chengal trees had low infeasibility value which is (≤ 6.00). This is because low infeasibility value shows the significant of MTMF fraction. Meanwhile, higher MTMF fraction value with higher infeasibility value (≥ 6.00) shows that the pixel was dominated by meranti langgong and damar laut. Figure 1(a) represents the relative abundance of chengal and other tree species where chengal was classified as red and other tree species classified as blue. Those species was classified based on MTMF fractional value as shown in Table 1. From the results of regression analysis, the P-value of regression analysis indicates that MTMF fraction is not significant with census fraction value (Appendix B (a)). Despite insignificant with the census fractional value, correlation of determination obtained relatively low.

3.2. Relative Abundance of Chengal Trees Estimation by modified Canopy Fractional Cover (mCFC)

mCFC was applied to Hyperion EO-1 and the relative abundance of chengal trees was estimated. A result obtained was represented in fractional image with fractional value of chengal tree and other tree species that exist in Hyperion EO-1 image. Figure 1(b) shows chengal and other tree species fractional cover in 50-ha plot. Red, blue and black area represent the existence of chengal, other tree species and unclassified respectively. Those species was classified based on fractional value in Table 1. From Table 1, chengal was found in range 0.000 to 0.999 of fraction values. Meanwhile, other tree species were detected within 1.000 to 10.000 of fraction value and unclassified endmember was found in range -0.9000 to 0.000. The existences of unclassified endmember may be due to haze that exist in the image and due to coarse spatial resolution of Hyperion data. The overall performance of mCFC was good with $r^2 = 0.667$ (Appendix B (b)). There are no significant different between mCFC fractional values and census data fractional values ($P < 0.05$). The standard error of y-estimates was ± 0.16 , hence accept our hypothesis that mCFC give better result of relative abundance as it applied vegetation index in the model which can eliminate soil background effects.

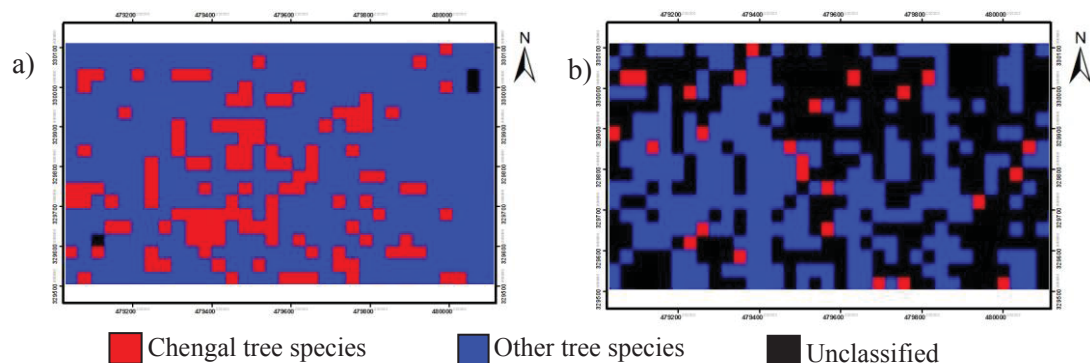


Figure 1: Chengal trees relative abundance estimation using a) MTMF model and b) mCFC in 50-ha plot.

Table 1: Calculated fractional cover of trees in 50-ha plot.

Tree species	Fractional cover	
	MTMF	mCFC
Chengal tree	0.2 – 0.93	0.001 – 0.999
Other tree species	0.94 – 1.66	1.000 – 10.000
Unclassified	-	-0.900 – 0.000

4. Discussion

From the findings, mCFC model well explained the relative abundance of chengal tree than MTMF model. MTMF model may not well explain the estimated relative abundance of chengal trees in 50-ha plot due to high contribution of background effects (i.e. haze existed in the image, soil background, target species and another species). Background effects exist may be due to the gap between tree canopies or degradation. Moreover, limited number of ground sample data also may be affecting the result obtained. The number of ground sample data chosen was small due to low number of chengal tree with highest height existed in 50-ha plot. However, this result showed better performance than previous study [9] that applied MTMF on Landsat TM 5 with 30-m spatial resolution and low spectral resolution where the accuracy obtained only 35%. In this study, MTMF result obtained more encourage with coefficient of determination obtained was 0.462 because Hyperion has more spectral information rather than Landsat TM which can be used to differentiate the tree species (Appendix B (a)). Meanwhile, mCFC model shows better performance than MTMF as it applying vegetation index which can eliminate soil background effects that exist in Hyperion EO-1 image. However, the results obtained from mCFC relatively low due to low spatial resolution of data as well as due to existence of haze in data inevitable obscure the clarity of the data set, despite the removal of atmospheric effects [18].

5. Conclusion

In this study, mCFC and MTMF were compared for estimation of relative abundance of useful timber species. From the accuracy evaluation, mCFC is better than MTMF to estimate relative abundance of chengal trees in a 50ha plot, a Malaysia lowland rainforest. Results of the accuracy test also suggest that mCFC model would be better for estimating relative abundance of tree species especially for lowland dipterocarp forests where focal forests are relatively degraded or number of ground sample data are limited (i.e census data). Therefore, in order to estimate relative abundance of tree species for the whole area of Pasoh Forest Reserve (2450 ha), scale up technique is required. Further study is needed to focus

on relative abundance of tree species for the whole Pasoh Forest Reserve by applying mCFC model in scale up technique.

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7. Appendices

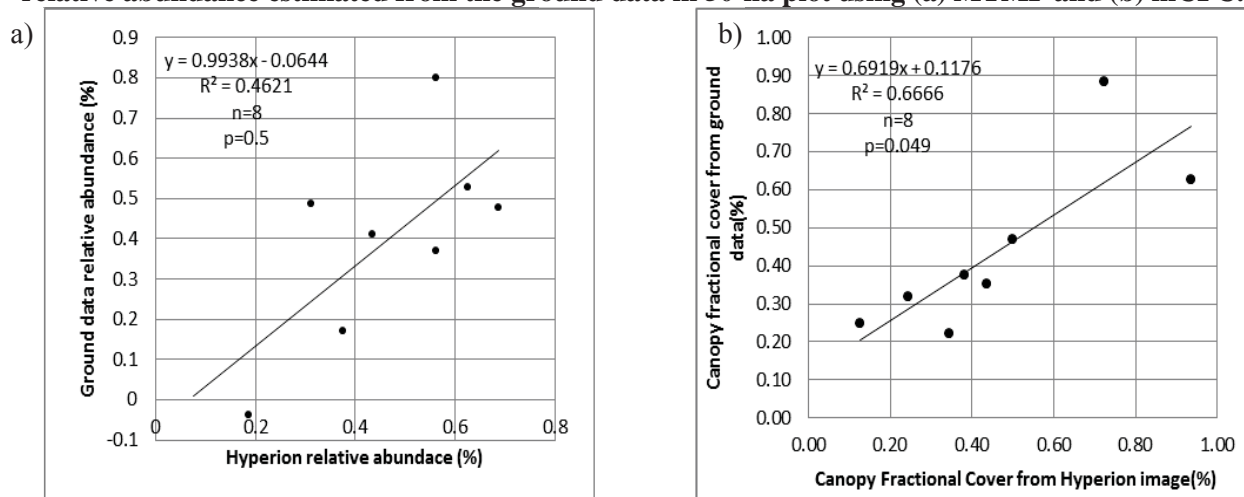
Appendix A

Match Filter fraction and feasibility scale extracted from Hyperion-EO1 for chengal, and other species (meranti langgong and damar laut).

Pixel	MF fraction			Pixel	Feasibility scale		
	Chengal (<i>Neobalanocarpus heimii</i>)	Meranti langgong (<i>Shorea Lepidota</i>)	Damar laut (<i>Shorea Maxwelliana</i>)		Chengal (<i>Neobalanocarpus heimii</i>)	Meranti langgong (<i>Shorea Lepidota</i>)	Damar laut (<i>Shorea Maxwelliana</i>)
1	0.410	0.320	0.270	1'	4.11	6.26	6.73
2	0.800	0.090	0.110	2'	5.32	7.25	7.89
3	-0.037	-0.021	-0.042	3'	8.00	12.85	11.73
4	0.488	0.312	0.200	4'	3.50	6.35	6.52
5	0.528	0.250	0.222	5'	5.26	6.34	6.45
6	0.478	0.283	0.239	6'	4.60	7.01	6.55
7	0.172	0.025	0.803	7'	7.20	6.81	4.07
8	0.370	0.333	0.297	8'	4.21	4.51	6.50

Appendix B

Evaluation of chengal relative abundance estimated from Hyperion EO-1 satellite data against relative abundance estimated from the ground data in 50-ha plot using (a) MTMF and (b) mCFC.



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