Upscaling Remote Estimation on Relative Abundance of Chengal Trees in Tropical Rainforest using Modified Canopy Fractional Cover (mCFC) Approach

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Abstract. Forest degradation and deforestation is crucial to be monitored. Thus, aggressive sustainable forest management is needed. Tree species composition estimations at large spatial scale is crucial to achieve sustainable forest management and monitor forest degradation and deforestation occurrences. Thus, monitoring by using remotely sensed data would be helpful to cover large spatial extend of tropical rainforest. However, due to coarse spatial resolution the estimation of tree species composition nearly impossible due to mixing pixel problem. Nonetheless, utilizing modified Canopy Fractional Cover (mCFC) would help to overcome mixing pixels in coarse spatial resolution satellite data. Accuracy of the results suggest that mCFC is suitable to be utilized for estimating relative abundance of Chengal at large extend area.

1. Introduction

Tropical rainforest degradation and deforestation is at alarming rate. These anthropogenic activities have caused the valuable tree species like Neobalanocarpus heimii or know as Chengal from Dipterocarpacea family deficit in number every year. Due to deforestation, many forested areas have been converted into agricultural area due to market demands. As reported by [1], Chengal species is hardly to be seen in the forest. Thus, Dipterocarpacea family including Chengal trees were monitored by a conventional method called sustainable forest management (SFM). SFM has cost a lot of time and money which is insufficeint to monitor timber harvesting activities.

Remote sensing technology has an advantage to monitor timber harvesting activities due to the capability to provide near real time data. Besides, remote sensing has special characteristics like high spectral and temporal resolution that give advantage to monitor high density forest [2, 3, 5, 6]. Hyperspectral sensing is one of remote sensing technology that have been widely used to estimate the abundance of tree species in high density tropical rainforest [6]. However, most of hyperspectral imagery of remote sensing satellite have coarse spatial resolution for example Hyperion EO-1. Thus, tree species relative abundance estimation is impossible due to the existence of mixing pixels (mixels) [7].

Numerous of studies have been conducted to cope with mixels problem in coarse spatial resolution imagery. The most frequently used method is spectral unmixing approaches. However, non-linearity of the spectral information of tree species in tropical rainforest has made the spectral unmixing approach not well describe the specific tree species in tropical rainforest. Thus, Wang [8] has developed Canopy

Fractional Cover (CFC) to identify vegetation covers based on vegetation index. However, CFC model only can be used generally to identify the tree canopy and the open areas.

Therefore, Hassan [7] has modified CFC into mCFC specifically to estimate the relative abundance of Chengal trees in tropical rainforest. The study has suggested that mCFC well defined the relative abundance of Chengal trees at small spatial scale. Nevertheless, the researcher haven't tested the model capability to identify the relative abundance of tree species at large spatial scale.This study hypothesized that, mCFC is capable to estimate the relative abundance at large spatial scale. Therefore, the mCFC has been employed to Hyperion EO-1 to assess the capability of mCFC model in estimating relative abundance of Chengal trees at large spatial area.

2. Material and Methods

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 two compartments of Pasoh Forest Reserve which is compartment 32 and 33. A long-term ecological plot with 1 km long and 0.5 km wide was located in these two compartments. 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 [9,10,11]. 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 [9,10,12]. 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 Data

There are two type of data were used in this study; (1) remotely sensed data as primary data and (2) in-situ data as ancillary data which will be used as reference data to validate the result of mCFC.

2.2.1 Satellite remotely sensed data

Hyperion EO-1 was used in this study and acquired through United State Geological Survey (USGS) via GLOVIS. The imagery on year 2003 with 20% cloud cover was chosen. Next, Hyperion EO-1 was undergo the Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) to reduce the atmospheric effects and transform the radiance image into reflectance image. The Hyperion EO-1 has been geometrically corrected into Universal Tranverse Mercator projection with WGS 84 datum.

2.2.2 In-situ census data

Tree census data were used to perform accuracy assessment of the results obtained from modified Canopy Fractional Cover (mCFC). Detailed census data usually have information of diameter at breast height (DBH), species, genus and family name of the tree and x,y location. The distributions of tree are plotted to give clear view on distribution of tree in the study area. DBH information was used to estimate the tree height and tree crown for plotting the tree in three dimensional views. Plotted tree distribution was used as reference data in accuracy assessment. In this study, the main focus was on tree that have diameter at breast height (DBH) more than 40cm because the canopy reach the top layer of the tree and sensed by the remote sensor.

2.3 Estimation of Relative Abundance of Tree Species using modified Canopy Fractional Cover(mCFC)

Canopy Fractional Cover (CFC) usually used for identifying the occurrence of forest degradation. However, in this study, CFC had been modified into mCFC to estimate tree species relative abundance where the algorithm derived as below [7]:

$$mCFC = 1 - \left(\frac{VI - VI_{chengal}}{VI_{canopy} - VI_{chengal}} \right) \qquad (1)$$

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 [8,13] Hassan [7] has performed this algorithm at small spatial scale area which is at 50-ha plot of Pasoh Forest Reserve. Thus, this study will upscale the estimation of Chengal trees' relative abundance in two compartment of Pasoh Forest Reserve.

2.4 Accuracy Assessment

As the relative abundance per pixel basis has been estimated by using modified Canopy Fractional Cover by Hassan [7]. This study covered the effectiveness of mCFC when upscaling the estimation of relative abundance at compartmet level. The effectiveness of mCFC was validated using census data that being plotted in three dimensional plot of census data on Hyperion EO-1 30m × 30m grid (refer [7]). 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.This validation was done by statistical analysis.

3. Results

Upscaling the estimation of Chengal trees' relative abundance by using mCFC based on the encouraged results obtained by Hassan [7]. According to the results, mCFC obtained for the estimation of Chengal trees' relative abundance at 50 ha plot was $r^2 = 0.666$ with $p < 0.005$ (see Table 1). Table 1 indicate the percentage of chengal tree per hectare in 50-ha plot using mCFC approach and percentage of chengal tree in 50-ha plot. The percentage of chengal tree estimated was 0.064%. Meanwhile, the ground relative abundance is 0.073%. Due to that, mCFC was employed to upscale the estimation. Results obtained then were density sliced into three classes as stated in Table 2 in order to present unclassified, chengal and other tree species endmember (Figure 1).

Table 1. Estimated percentage of chengal tree in 50-ha plot.

Estimated percentage of chengal tree per hectare in 50-ha plot using mCFC approach	0.064%
Percentage of chengal per hectare in 50-ha plot (ground data)	0.073%

In this study, chengal tree species was estimated only in compartment 32 and 33 that have information on tree census. Table 2 shows an estimated percentage of chengal tree per ha for two compartments 32 and 33. Only 0.029% of chengal tree in compartment 32 which has an area of 2,689,140 hectare. Meanwhile, relative abundance for compartment 33 which has an area of 2,554,470 is about 0.07%.

Table 2. Calculated fractional cover of trees in compartments 32 and 33.

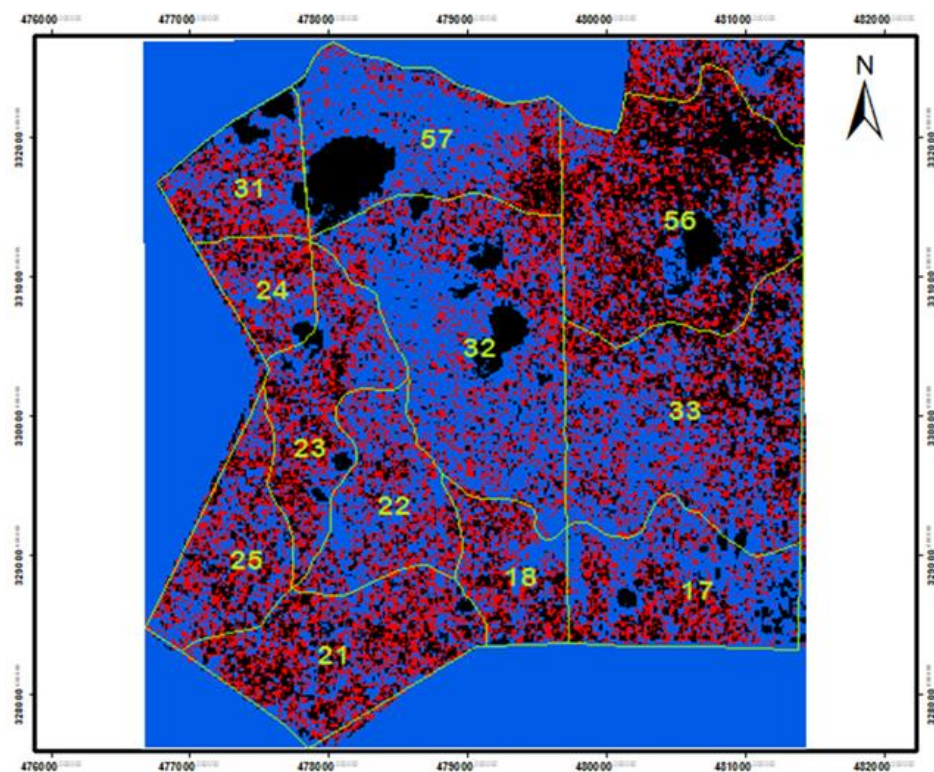| Tree species	Fractional cover
Chengal tree	0.001 – 0.999
Other tree species	1.000 – 78.000
Unclassified	-0.900 – 0.000

4. Discussion

Result shows that the mCFC well explained the estimated relative abundance of chengal tree in compartment 32 and 33. Compartment 32 and 33 mostly has 0.0029% and 0.007% of chengal tree, respectively (Table 3). The statistical test shows that the results obtained was relatively low (as suggested by Hassan [7]). This is may be due to the existence of other effects (for example haze in the image). Besides, the 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 and very few random samples were collected in compartment area.

However, this estimation is also consistent with the previous study by [14] where the total number of chengal trees in 42-ha, 36-ha and 6-ha of Pasoh was 30 trees with diameter at breast height (DBH) exceeding 50cm.

Table 3. Estimated relative abundance of chengal tree in compartment 32 and 33.

Compartment	Size of compartment (Hectare)	Estimated percentage of chengal per hectare mCFC approach
32	2,689,140	0.0029%
33	2,554,470	0.007%

Figure 1. Canopy fractional cover map of chengal tree in each compartment of Pasoh Forest Reserve

5. Conclusion

This study has conducted mCFC to upscale the estimation of Chengal trees' relative abundance. Accuracy shows that the estimation at small spatial scale using mCFC approach is almost consistent as suggested by Hassan [7].Therefore the results obtained was good, thus, estimation of relative abundance of chengal tree using the mCFC model was approximately consistent with density of Chengal tree in each compartment. It is recommended to use other ancillary data as supportive data especially forest inventory of each compartment in Pasoh Forest Reserve. In this study, the accuracy of relative abundance estimated for the whole Pasoh Forest Reserve cannot be assess because ancillary data obtained only for 50-ha plot.

Acknowledgement

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