Abstract: Currently, the management of forests in Malaysia is facing new challenges as harvesting of production forests experiences a shift from the generally rich and productive undisturbed forests to logged-over forests. In the very near future, all forest harvesting is expected to take place only in logged-over forests. One of the main challenges involves the classification of the forests by stocking classes. This problem does not exist in the management of undisturbed forest as the forests are generally homogenous in terms of size class distribution, and as such the implementation of pre-felling inventory throughout the whole compartment to assess the growing stock is adequate. However, second growth forests logged more than 20 years ago are more heterogeneous in nature with high variations in size class distribution due to the previous harvesting operations. This characteristic is expected to be more profound in forest types with high clumping features or where harvesting was unevenly implemented, thus creating a patchy nature. To understand this, a study was conducted to assess and classify the second growth forests located in Tekam Forest Reserve in Pahang and Cherul Forest Reserve in Terengganu. A look at the stocking of second growth forests of various ages on both sites indicated that there was no particular trends of forest recovery. Classifying such forests based on years after logging was found to be unveiling. Since the study areas are large and heterogeneous, classification was made based on forest canopy densities. The approach was based on Forest Canopy Density (FCD) Model developed by the International Tropical Timber Organisation (ITTO) and was successfully tested in several tropical forest areas. Landsat 7 ETM+ imageries of the year 2003 were used for the classification. The classification yielded 4 FCD classes, namely Low (1-30%), Medium (31-50%), High (51-70%) and Very High (>70%). It was found that this approach gave a better reflection of the forest stocking classes and was more pragmatic to be implemented in large forest areas. The FCD classes could be used for forest classification although further refinement may be required to enhance forest management at the operational scale.

Key words: logged-over forest, forest classification, forest canopy density

INTRODUCTION

Forests remain an important asset to Malaysia as they continue to play a significant role in the country’s socio-economic development process. It is in Malaysia’s own interest that timber and other forest products from the 10.8 million hectares of production forests are managed on a sustainable basis. In Peninsular Malaysia, the production forests comprise about 2.8 million hectares of which more than 80% had already been logged. Peninsular Malaysia is currently still harvesting mainly the primary production forests to meet its timber demand. Such forests which have evolved over many years are stable ecosystem and are rich in large sized valuable commercial timber species. However, it is predicted that in the next 5-19 years, all
of the primary production forests in Peninsular Malaysia are expected to be completely harvested. In fact, some states have already turned to their second growth (logged-over) or second rotation forests for re-logging and other states may follow soon. When this happens, there will be new challenges in forest management as the structure, composition and productivity of the second growth forests could be quite different from the rich primary forests.

Second growth forests may not be as productive as the primary forest and may not have the desired species composition. Under normal circumstances, these forest stands are expected to be logged for the second time after 30 years under Selective Management System (SMS). Therefore, some forms of classification of second growth forest are necessary.

Forest Classification

To address the issue of productivity of the second growth forests, a study was undertaken by FRIM, through collaboration with the Forestry Department Peninsular Malaysia in logged-over production forests in Pahang and Terengganu. The objectives of the study were to assess the stocking of the forests, ascertain its recovery status, and develop appropriate silvicultural prescriptions that will enhance its productivity and contribute to its management on sustainable basis. However, current operational level inventories undertaken by the Forestry Department that uses systematic line plots at 10% sampling intensity cannot be adopted, as the study areas at about 11,034 ha and 3555 ha respectfully in Pahang and Terengganu were too large and thus would incur high cost and would be too time consuming. The study had to use a more pragmatic approach that can be adopted by the Forestry Department as a rapid assessment method. In this regard, recognizing that second growth forests are patchy and have very high variations in terms of the spatial distribution of trees (Samsudin et al, 2003), the study adopted a two stage sampling design where the first stage involved the classification of the forests into stocking classes. The classification approach utilized remote sensing data as current techniques were capable of providing reliable stratification of tropical forests. The second stage involved variable plot sampling of trees and other non-timber vegetation. This study utilized a methodology developed by Rikimaru (1996) entitled Forest Canopy Density Model (FCD). The method was tested in tropical forests of Malaysia and Indonesia and was reported to be reliable in classifying forests into tree density classes that can reflect their stocking status.

MATERIAL AND METHODS

Study Area

Two forest reserves logged from 13 to 28 years ago were chosen. The first study area is located in Tekam Forest Reserve (Tekam F.R) in the district of Jerantut, Pahang. It covers about 11,034 and consists of forests logged 17 to 28 years ago. The forest type is classified as hill dipterocarp, which is common at elevations between 300 to 750 m above sea level. The topography of the area is undulating with steep and rugged slopes exceeding 45 degree on the north-east of the reserve. The elevation ranges from 60 to 800 m above sea level. Second study site with an area of about 3555 ha is in Cherul Forest Reserve in the district of Dungun, Terengganu. It is situated in the proximity of the main Range of Peninsular Malaysia. The area generally has a very hilly topography, ranging from 50 to 650 m above sea level and it has short and steep slopes of greater than 15 degree (Figure 1).
Figure 1. Location of the two study areas: Tekam Forest Reserve in Pahang and Cherul Forest Reserve in Terengganu.

The classification of the second growth forests was by using Landsat ETM+ Thematic images of March 2003 acquired from Malaysian Center for Remote Sensing (MACRES). The ERDAS remote sensing software was used to process the Landsat TM images of the study areas. The images underwent all related processing operations such as geometric correction, topographic correction, and filtering to minimize noise. Other standard pre-processing operations were also undertaken such as subset to study area, merge, layer stacking and visual enhancement, as they are important procedures that could contribute substantially to the accuracy of the final products. On top of these automatic procedures, the images also utilised unsupervised classification based on qualitative data analysis derived from “training areas”. Features like open area, roads, agriculture, logged area and non-forest could be determined easily by raw data. Supervised and unsupervised classification is done by an image interpreter who has experiences with first hand knowledge of ground data and other references such as aerial photo, topographic map or other classified satellite images.

Forest Canopy Density Model (FCD Model)

FCD-Mapper model was developed by ITTO to assess forests based on canopy density. The methodology is presently identified as the Forest Canopy Density Mapping Model, or in short the FCD Model. Unlike the conventional method, the FCD Model classifies the forests using Landsat TM satellite. The degree of forest density is expressed in percentage, i.e., 10%; 20%; 30%; 40% FCD and so on. The FCD Model also makes it possible to monitor transformation of forest conditions over time, including degradation. Additionally, the model can detect reforestation activities and differentiate between vegetation in the canopy and on the ground (e.g.
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Image produced by the FCD Model conveys a clear picture of forest conditions for further interpretation by forest management team.

Four broad FCD classes were adopted in this study namely:

- Low FCD - less than 30% canopy density
- Medium FCD - 30% to 50% canopy density
- High FCD - 50% to 70% canopy density
- Very High FCD - more than 70% canopy density

The FCD model contains indices that influence the result of a classification. The indices are vegetation index (VI), bare soil index (BI), shadow index (SI) and thermal index (TI). By combining these indices it creates a model that can assess the status of forestlands on a continuum that ranges from vegetation to exposed soil conditions. The flow chart of the FCD procedure is shown in Figure 2.

\[\text{Flow step to derived FCD}\]

Vegetation sampling

An inventory was undertaken with 240 sampling plots in Tekam F.R. and 291 sampling plots in Cherul F.R., distributed randomly in each of the FCD classes. The total numbers of plots was determined based on a standard statistical formula (Samsudin et. al, 2003) that was determined by the variation of each forest class and a 10% standard error. The study employed the variable plot method or also known as point sampling. All trees with dbh equal and greater than 15 cm were enumerated. The size of the variable plot is proportional to the dbh of trees in the plot.
The inventory also included bamboo, rattan, palms and other non-timber forest products (NTFPs). The information collected was used to indicate the degree of disturbance.

**RESULTS**

**Forest Classification using FCD Model**

Forest classification for second growth forest was categorized into 4 classes as in Figure 3 in each of the study areas. The program allows division into more classes but it this would make management more difficult. The ground samples were analysed for stocking in each of the forest canopy density classes. Results clearly showed that about 5.5% or 606 hectare from the 11,034 hectare of the Tekam FR area had less than 30% canopy density (Low FCD). The classification for Cherul FR showed that the segregation into different classes was less pronounced compared with Tekam FR. Cherul FR had less than 1% of the Low FCD category or about 32 hectare of the total 3,555 hectare. Inventory results for all trees > 15 cm dbh with four FCD classes are shown in Table 1 and Table 2 for Tekam FR and Cherul FR respectively. It could be seen that the stocking for the FCD 4 (High FCD) is high and the stand could be considered to have recovered and ready for the second cut. On the other hand, FCD 1 reflects a poor stand that may not be able to recover within the cutting cycle.

**Figure 3.** Forest Canopy Density Map Model for both study areas
Table 1. Tree density and Volume by Forest Canopy Density Classes for all trees >15 cm dbh in Tekam F.R.

<table>
<thead>
<tr>
<th>Forest Stocking</th>
<th>F CD Class</th>
<th>Area (ha)</th>
<th>Percentag e Cover (%)</th>
<th>Tree Volume/ha</th>
<th>Tree Stem/ha</th>
<th>Basal Area/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low 0-30</td>
<td>32.24</td>
<td>0.91</td>
<td>32.43</td>
<td>245</td>
<td>135</td>
<td>20.01</td>
</tr>
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<td>1.75</td>
<td>53.46</td>
<td>367</td>
<td>213</td>
<td>23.78</td>
</tr>
<tr>
<td>High 51-70</td>
<td>1053.6</td>
<td>29.64</td>
<td>513.96</td>
<td>137</td>
<td>78</td>
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<td>Very &gt;70</td>
<td>2406.7</td>
<td>67.70</td>
<td>137.46</td>
<td>160</td>
<td>94</td>
<td>23.67</td>
</tr>
<tr>
<td>Total or Average</td>
<td>3554.9 7</td>
<td>100.00</td>
<td>126.33</td>
<td>402.19</td>
<td>23.67</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Tree density and Volume by Forest Canopy Density Classes for all trees >15 cm dbh in Cherul F.R.

<table>
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<tr>
<th>Forest Stocking</th>
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<th>Area (ha)</th>
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</table>

Forest Stocking

Figure 4 shows classification of forest by volume, for FCD classes categorized into 10 classes and 4 classes. The volume/ha shows an increasing trend from Low FCD to Very High FCD categories. Tree density/ha and basal area/ha also show a similar increasing trend.

Average of Volume/Ha for 10 FCD Classes (unfiltered)  Average Volume/Ha for 4 FCD Classes (filtered)
Figure 4. Total Volume (per hectare) for Forest Canopy Density Classes for Tekam Forest Reserved
Figure 5 shows the tree density per hectare and volume per hectare for forest stands at different years after logging for the study areas. It showed that there were no specific trend between tree density and tree volume for stands of different ages after logging. It is expected that the tree density and volume should show an increasing trend from the more recently logged forests to the older stands. This indicates that the classification using year after logging is not a good indicator for forest classification.

**DISCUSSION**

Forest classification was the first stage in the two-stage sampling design adopted to assess the stocking of second rotation forest in study sites. It is important that the classification approach to be adopted was able to produce homogenous strata that will enhance the sampling and reduce the sampling intensity required to provide reliable results. The current approach that uses years after logging could not be adopted, as a clear trend in the stocking was not established between various compartments logged between 13 to 28 years ago. This reflects that the recovery of the forests was dependent on the intensity and the way logging was carried out in the past. The logging practices were not consistent and thus the age of the forests since logging did not reflect the recovery of the forests. It must be noted that the logging practices in the past were not as strictly supervised as today. Thus, there could be a tendency for over removal of trees in some parts of the forest that often had led to a residual forest having very patchy and highly variable basal area distribution. However, currently harvesting practices have improved with advent of timber certification and reduced impact logging practices.

A different approach using forest canopy density classes was adopted in this study for the classification and was found to be able to provide a better reflection of the stocking of the forests. In this classification method, it was found that within an individual compartment (logged in the same year), there were different density classes ranging form low density to high density classes. In other words some parts of the forest within an individual compartment have recovered while other parts are still recovering and there are also areas that would not be
expected to recover within the 30 year cutting cycle. This implies that implementing the current management approach which allows logging to be carried out by compartments after an overall inventory is undertaken for the whole compartment is not optimal. This could result in situations where the pre-felling inventory may show that overall the compartment may have enough stocking due to the contribution of only the well stocked sites within the compartment. Consequently, when a cutting limit is applied and harvesting implemented, there will be a tendency for high removal within well stocked portions of the compartment resulting in further exacerbating the patchy nature of the residual stand and making future cuts within the cutting cycle almost impossible as the stand would have been impoverished.

The study has shown that forest classification based on FCD model has produced reliable results and thus is recommended for classification of second rotation forests. FCD model is useful for monitoring and managing forest, and does not require intensive ground truthing. However, FCD model is only suitable for Landsat TM & ETM images. Since Landsat TM images are no longer available, further improvements would have to made to this classification approach if it is to be fully adopted for management of the production forests in Malaysia. Remote sensing technologies are ever improving and becoming more cost-effective and should be fully explored as a pragmatic approach to classifying second growth forests and to enhancing their management on a sustainable basis.

**REFERENCES**


