Assessing success of forest selective management system using geospatial technology

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Abstract. Since 1960s, forestry activities in Malaysia have been pushed towards steeper and erosive hilly areas which comprised of less big trees and less seedlings requiring a more precautionous management practice in achieving forest sustainability. Hence in 1978, the Selective Management System (SMS) concept was adopted, planned for 25 years harvest cycle ensuring the next harvest with per hectare minimal 32 trees of above 30-45 cm diameter, producing minimal output of 40-50m³/ha, enriched with more Dipterocarp species. SMS conducted activities of pre and post felling inventories, flexible tree cutting limits and post felling treatment. However, after more than 30 years the success of SMS has not been fully determined though many visual observations inferred reduced merchantable stand and higher damaged of the residual forest. Consequently, this project intent to assess the success of SMS using geospatial technology. In this project, five forest parameters as SMS success indicators were measured: (a) forest density – estimated from Sentinel satellite image (10 x 10m) and GLAMA-GAP apps (b) tree number – enumerated at site plots (c) tree volume – determined by site plots measurement (d) tree composition – determined at site plots and (e) harvesting cycle duration – determined by historical data observation. Based on site measurement, it was found that all the plots have more than 32 trees/ha of above 30-45 cm diameter, comprising tree volume more than 40m³/ha and Dipterocarp species were 75% more than non-Dipterocarp. Meanwhile, NDVI from Sentinel 2 satellite image revealed that the density of the logged forest were more than 80% and subsequently confirmed 100% accurate by GLAMA-GAP apps. Results acquired concluded that in these project areas, SMS proved to be successful by complying all the requirement of SMS residual forest characteristic.

1. Introduction
Malaysia has gone through two decades of massive clearing of virgin forests for conversion to rubber plantations in 1960s and 1970s. These were mainly land development programs under FELDA schemes to cater for the low-income rural communities. Under present circumstances, there is unlikely to be a need to develop more such schemes [1]. Yet today, forests continue to diminish. Vast areas of forest land continue to be opened for development. Forests are cleared not any more for the under-privileged, but to cater for high capital, corporate ventures to serve investors’ self-interest. A new dimension to the term deforestation has emerged and this plagues all environmentalists and foresters.
Malaysia has on several occasions, since its declaration at the Rio Earth Summit of 1992, and more recently, at the Copenhagen Climate Change World Convention, that the country will keep more than half of its land area under forest. Malaysia has since, observed the principles of sustainable development [6]. These are commitments to future generations and attaining to it, a new forest system called Selective Management System (SMS) was adopted since 1980’s. After 35 years the proficiency of SMS, it is yet to be proven successful. This paper intent to assess the effectiveness of SMS in retaining the forest sustainability by using geospatial technology.

1.1. Background
In 1960s, large stretches of lowland forest in Peninsular Malaysia (PM) were cleared for agriculture as a result of Federal Government land policy on poverty eradication. Forestry activities have been pushed towards steeper and hilly areas. The remaining virgin forests are left on steeper slopes in the remote part mainly in the central and eastern regions. A new forest management system called the Selective Management System (SMS) was introduced in 1978 and adopted in 1980s due to the shifting of harvesting areas from lowland forest to the hill forest [10, 4, 7]. The hill forest of PM has a different silviculture characteristic such as lack of seedlings in the original stand, slow growing and shade demanding in nature. Other problems include the danger of soil erosion on steep slopes and the heavy presence of the wood species of *Eugeissona triste* Griff (bertam), which discourage a drastic opening of the canopy. SMS implementation is considered as the new dimension of forest management to sustain timber supply and efficient harvesting of hill dipterocarp forest of PM to replace the MUS.

1.2. SMS concept and objectives
The important concept favoring the adoption of SMS are ; (i) it is the most economically and surest means of restocking the dipterocarp forest (infrequency of good seed year), (ii) the stand structure, reproduction, growing habits, response to light after harvesting and selective logging within variations, (iii) the intermediate sized trees and poles (30-45 cm dbh) grow faster to harvestable size compared from the seedling to grow to timber size, (iv) the sufficient number of young trees of many size classes can be saved under careful directional felling and vigorously survive, (v) SMS can be adapted to different silvicultural conditions because of the floating (variable) diameter limits for specific area and species groups. The objective of the SMS is to save young potential tree species from damage especially during harvesting of the merchantable timber from the virgin forest, through tree marking and directional felling. This is to retain an adequate stand and volume of healthy trees of desired species after harvesting to assure a future timber crop, after harvesting to assure a future timber crop, forest cover for the protection of soil and water. SMS also has the flexibility to manage the highly variable forest conditions (socio-economic environment), allows for the optimization of forest management goals for an economic cut, the sustainability of the forest and the minimum cost of forest management [11, 3, 7].

1.3. SMS technical requirement
Based on the current application of SMS, it has been envisaged that bicyclic cutting of 25-30 years cycle is practiced. The SMS selectively logged forest has an intention to return at the end of the cutting cycle (25-30 years) until the next harvest. SMS harvesting regimes are based on inventory data instead of arbitrary prescription, which consider equitable to both stakeholders (loggers and forest owners).

PreFelling inventory is carried out to provide reliable estimates of the population. After the pre-felling inventory data such as market value and socio-economic considerations, a felling regime will be formulated to optimize the stated goals. All commercial timber based on SMS specified diameter is identified for felling [7]. Following the first cut, number of residual was left behind and the interval required for them to reach merchantable sizes for a second cut.

When the next harvesting is expected in 25-30 years after the first logging with an expected net economic outturn of 40-50 m3 per hectare enriched with dipterocarp species, the prescriptions for
implementation applied are; (i) the cutting limit prescribed for dipterocarp species should not be less than 50 cm dbh except for Neobalanocarpus heimii (chengal) not less than 60 cm dbh; (ii) the cutting limit prescribed for non-dipterocarp species should not less than 45 cm dbh; (iii) the difference in the cutting limits prescribed between the dipterocarp and that of non-dipterocarp species should be at least 5 cm; (iv) the residual stocking should have at least 32 sound commercial trees per hectare in the dbh class from 30 to 45 cm dbh (substitutions using trees with dbh larger than 45 cm were given equivalent value of 2 stems/ha, while trees in the dbh class from 15 to 30 cm were given equivalent value of 1/3 stems/ha; and (v) the percentage of dipterocarp species in the residual stand for trees having dbh greater than 30 cm and above should not be less that in the stand prior to harvest.

SMS employs a split cut approach, which favors the retention and growth of the dipterocarp species to avoid the eventual elimination from future crops as they have a tendency to dominate higher diameter classes and grow faster than other economic species.

1.4. Justification
Trying to achieve “sustainability,” in forest management is a noble but misplaced and ultimately unrealistic goal. Even practicing modified SMS approach, forest composition and structure inevitably change with time, both in response to endogenous processes (e.g., forest succession) and external pressures (e.g., changes in rainfall and temperature regimes, human disturbances). Species respond to environmental change individually rather than synchronously as communities or ecosystems. Some species are lost or become rare (affecting usage) whereas new ecosystems emerge with new combinations of species, interactions, and properties. Relieving modern stressors, such as logging or hunting, will not necessarily result in these altered ecosystems reverting to their original state [8].

Furthermore, faced with today’s scenario of a declining forest cover aggravated possibly in various degrees by exploitative excesses, it is crucial that the right steps be taken so that forests are managed successfully with minimal risk. The quality of the remaining forests available for effective management under SMS is questionable. The impacts of the SMS process will inevitably be reduced, and the potentialities of the forests’ benefits to future generations will be affected. The current forest management system, SMS must provide with enough confidence that it will achieve the sustainability results just as it was expected when SMS was designed thirty-five years ago.

The logical step is to find the clues on whether SMS remains a sound system for forests under today’s condition. This is by carrying out a rapid assessment of the state of the worked over forests that have been managed under SMS in various strategic locations.

Hence, the study envisaged to provide data and information on the composition as well as volume, of the growing stock in the forests under survey. These are the kind of inputs much needed for forest policies and planning. The primary aim is to seek the clues that tell the strengths and weaknesses of SMS that has been applied to the forests. The study will help identify which aspects of the system will need to be improved or perfected. It will subsequently give ideas on how best SMS could be made suitable as an instrument of Sustainable Forest Management under today’s circumstances.

1.5. Objectives
This study is to conduct a forest inventory and mapping using Geospatial technology to provide a most recent and accurate assessment of forest resources in Peninsular Malaysia managed under SMS which is essential for formulating sound strategy for forestry sector. Precise data and latest information on forest cover and volume of growing stock of forests therein are basic ingredients for policy and planning purposes.

In this project, the specific objectives is estimate the overall forest density and the logging cycle, whereas at inventory plots tree measurements were taken including site canopy density to assess its compliance with the minimal SMS residual stand criteria.
2. Methodology
The platform technology conducted in this project is geospatial which incorporated GIS and remote sensing functionalities. A medium resolution of 10m x 10m satellite, known as SENTINEL was acquired to provide precise and real-time information of the forest density. Data extracted later analyzed and displayed using GIS. Ground measurement were also conducted to estimate number of trees and tree volume. Following para will further details the activities conducted in this project.

2.1. Project Area
This study was carried out on partially seven forest reserves at two states of Terengganu (4,2017 ha) and Pahang (15,033 ha) comprising of 64 compartments, both known for being the premier states in practicing SMS in Malaysia. Seven inventory plots of 20m x 50m were established within the study area to conduct ground measurements as shown at Table 1.

| Plot No | State     | Forest Reserve | Compt | Ha  |
|--------|-----------|----------------|-------|-----|
| 1      | Terengganu| Besul          | 1     | 418 |
| 2      |           | Cerul          | 30    | 311 |
| 3      | Pahang    | Klau           | 21    | 216 |
| 4      |           |                | 20    | 236 |
| 5      |           | Tersang        | 55    | 219 |
| 6      |           |                | 94    | 163 |
| 7      |           |                | 90    | 156 |

2.2. Method
Upon completing processing and mosaicking of satellite image SENTINEL, a Normalized Differential Vegetation Index (NDVI) process was conducted to estimate and map the forest density. Subsequently measurements of trees above 30 cm diameter were taken at site plots including species, number, height, and diameter and density percentage (using GLAMA-GAP apps). All these parameters were then analyzed to obtain per hectare value. Results generated were then compared with the residual stand minimal criteria to determine how well it comply.

Assessment were based on three indicators namely logging cycle interval, residual stand canopy density and forest quality which stipulate residual stand minimal criteria as shown in Table 2.

| Indicator       | Parameter (Unit) | Unit | Measurement Technique | Residual Stand Minimum Criteria |
|-----------------|------------------|------|-----------------------|--------------------------------|
| 1 Logging cycle | Logging cycle duration | year | Canopy historical data | Essentially more than 25 years |
| 2 Forest Density| Canopy Density Category | (%) | Canopy density was estimated from Sentinel NDVI divided into 4 categories and compared between before and after logging year | Essentially be more or at least equivalent to original canopy (as for this project >80% canopy density considered as acceptable) |
| 3 Forest Quality| Tree Number | Number | Tree height and tree diameter measurements were taken at site 20 x 50m plots (tree >30 cm dbh) | More than 40m3/ha |
|                 | Tree Volume     | m3   | Tree species were identified at site plots and categorized under Dipterocarp or Non-Dipterocarp group | Essentially Dipterocarp group % should be more or at least equivalent to Non-Dipterocarp group |
2.2.1. Normalized Differential Vegetation Index (NDVI). NDVI has found a wide application in vegetative studies as it has been used to estimate crop yields, pasture performance, and rangeland carrying capacities among others. It is often directly related to other ground parameters such as percent of ground cover, photosynthetic activity of the plant, surface water, leaf area index and the amount of biomass. In this project, NDVI is related to the percent of ground cover and will be overlaid with forest type to generate new forest sub type [2].

The NDVI values vary according to the radiation absorption by the chlorophyll in the red (RED) spectral area and its reflectance in the near infra-red (NIR) spectrum. These values are between -1 and +1, corresponding to the consistency of the green vegetation. The ones close to +1 (light color) represent a higher consistency of the vegetation and are specific to the dense broadleaf forest. The ones close to -1 (dark color) represent the land with lack of vegetation, having visible soil or rock surface. The 0 value (intermediate color) is associated with grass lands. The formula for calculating this index is:

\[
\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}
\]

In this project, using SENTINEL imagery, NDVI calculations used bands as follows:

\[
\text{NDVI} = \frac{\text{Band 8} - \text{Band 4}}{\text{Band 8} + \text{Band 4}}
\]

2.2.2. Ground measurement at plots. In this project, seven inventory plots of size 20m x 50m were established. Only big trees above 30cm diameter were measured to predict potential timber volume production for the next logging cycle. Tree parameters measured include number, species, height and diameter. Forest canopy density was also measured using the GLAMA technique.

Forest canopy ground measurement. Forest canopy density measurement at inventory plots used ‘Gap Light Analysis Mobile App’ (GLAMA) technique which is a program for calculation of the Canopy Cover Index estimating canopy cover from hemispherical photographs. The program, which is freely accessible from the Google Play website, can be used for hemispherical, wide angle and standard photographs (with known lens angle of view). The program was primarily designed for use in the field, but can also analyses hemispherical photographs saved on external storage. The canopy cover will be measured by looking at the percent of canopy openness using a mobile phone app (GLAMA canopy cover). Each plot have 15 points of observation located at four ordinal directions (N, E, and S, W) at three main points within the plot. Figure 1 shows the schematic overview of the sampling design.

Figure 1. The design for the 3 main points with 4 points surrounding at each plot
The Canopy Cover Index is a quick and robust method for precise canopy cover estimation comparable to visual canopy cover estimation but unaffected by observer bias. Not only can it be used on already-captured photographs, but the index can also be employed on smartphones by using the GLAMA Android application to rapidly capture hemispherical photographs and immediately calculate their index values directly in the field [9].

3. Results and Discussion

3.1. Logging cycle
Logging historical data were gathered to know the logging cycle year duration. Observation shows that from 35 compartment studied, only 5 compartments were found logged within less than 25 years cycle. This indicates that 85.7% of the study area were following the SMS logging cycle.

3.2. Ground measurement results
All trees above 30 cm diameter in the inventory plots were measured and recorded (Table 3). Tree volume was calculated based on tree diameter and height factor. In these measurement, it was found that there were about 4-13 trees per plot with 13-38 m3 tree volume. After conversion to per hectare, it calculated that in each plot there were about 40-130 trees/ha with 124-377 m3/ha tree volume. Meanwhile, forest density ground measurement estimated high percentage of 86.97-97.12%.

| Plot | 20 x 50m | Per hectare | Forest Density (%) |
|------|----------|-------------|--------------------|
| Tree Number | Tree Volume (m³) | Tree Number | Tree Volume (m³) | % m³ | % tree number | NDVI | GLAMA |
| Dip | NonDip | Dip | Non Dip | Dip | Non Dip | Dip | Non Dip | Dip | NonDip | Dip | Non Dip | Dip | NonDip |
| 1 | 2 | 12 | 6 | 20 | 20 | 120 | 64 | 65 | 35 | 50 | 14 | >80 | 86.97 |
| 2 | 6 | 7 | 24 | 14 | 60 | 70 | 237 | 140 | 63 | 37 | 46 | 23 | >80 | 93.20 |
| 3 | 1 | 3 | 9 | 4 | 10 | 30 | 91 | 43 | 68 | 32 | 25 | 25 | >80 | 97.12 |
| 4 | 3 | 2 | 15 | 5 | 30 | 20 | 154 | 53 | 74 | 60 | 11 | >80 | 94.82 |
| 5 | 2 | 4 | 28 | 6 | 20 | 40 | 279 | 55 | 84 | 16 | 33 | 13 | >80 | 91.36 |
| 6 | 5 | 3 | 10 | 18 | 50 | 30 | 103 | 181 | 36 | 64 | 63 | 23 | >80 | 93.00 |
| 7 | 2 | 2 | 5 | 8 | 20 | 20 | 45 | 79 | 36 | 64 | 50 | 31 | >80 | 91.68 |

3.3. Analysis on complying SMS minimal criteria
SMS system requires residual stand to achieve minimal criteria to sustain for the next logging cycle. In this project, seven inventory plots were used as basis to indicate project area residual stand characteristics. In overall all the plots comply to all the criteria. All trees above 30 cm diameter in the inventory plots were measured and recorded. Tree volume was calculated based on tree diameter and height factor. As shown at Table 4, it was found that there were about 4-13 trees per plot with 13-38 m³ tree volume. After conversion to per hectare, it calculated that in each plot there were about 40-130 trees/ha with 124-377 m³/ha tree volume. Meanwhile, forest density ground measurement estimated high percentage of 86.97-97.12% and on average NDVI data were >80% for all plots. Figure 2 shows forest density by NDVI and GLAMA.
Figure 2. Forest density by NDVI (left) and GLAMA (right)

Table 4. List of indicators complying minimal criteria

| Indicator          | Minimal Criteria                        | Terengganu | Pahang |
|--------------------|-----------------------------------------|------------|--------|
| Forest Reserve     |                                        |            |        |
| Compartment        |                                        |            |        |
| No Plot            |                                        |            |        |
| 1 Forest Density   | Canopy Density >80% (using NDVI)        | YES        | YES    |
|                    | Canopy Density >80% (using GLAMA)       | YES        | YES    |
| 2 Forest Quality   | More than 32 tree (>30 cm dbh) per ha  | YES        | YES    |
|                    | More than 40m³ (>30 cm dbh) per ha     | YES        | YES    |
|                    | % m³ Dipt > % m³ Non Dipt              | YES        | YES    |
|                    | % tree Dipt > % tree Non Dipt          | YES        | YES    |

4. Conclusion
Assessment conducted in this study including on logging history shows that 85.7% of the compartments were logged more than 25 years cycle as well as 100% of the residual stands have more than 32 trees/ha, tree volume more than 40 m³/ha and forest density of above 85%. Meanwhile, 65% of plots have Dipterocarp group more than non-Dipterocarp group by tree number and tree volume. Deriving results concluded that the residual stand of logged forest at these project areas has complied the minimum criteria as required by SMS denoting that SMS has been successfully accomplished in these areas. However, it is highly recommended that this similar study to be conducted more extensively throughout Malaysia to ascertain the success story of SMS.
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References
[1] Anon (a) 2018, Rainforest, Timber and Deforestation in Malaysia http://factsanddetails.com/southeast-Asia/Malaysia/sub5_4e/entry-3705.html
[2] Anon (b) 2018, Measuring NDVI, https://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php
[3] Appanah, S. & Weinland, G. 1993. Will the management system for hill dipterocarp forests, stand up?, Journal of Tropical Forest Science 3:140-158
[4] Appanah, S., Ismail Harun, P.F. Chong and M. Kleine. 1999. Internal Assessment Procedures for Sustainable Forest Management in Malaysia – A consultancy report to the Forest certification Project (GTZ), Kuala Lumpur, Malaysia
[5] Chin, T.Y. 1999. Protected Forest Area Management in Malaysia. Paper presented at the International Experts Meeting on Protected Forest 2000. 7-12 Aug. 2000, Kuala Lumpur. Vol 1:7
[6] FAO 2010 Global Forest Resource Assessment 2010, FAO Rome Italy http://www.fao.org/docrep/013/i1757e/i1757e02.pdf
[7] Hassan-Zaki P., Shinohara, T., Nakama, Y. and Yukutake, K. 2004 : A Selective Management System (SMS): A case study in the implementation of SMS in managing the dipterocarp forests of Peninsular Malaysia Kyushu J. For. Res. 57 : 39—44
[8] Kanta Kumar 1995 Sustainable Forest Management: Myth or Reality? Exploring the Prospects for Malaysia Cserge Working Paper Gec 95-15
[9] Lubomír Tichý 2015 GLAMA – Gap Light Analysis Mobile App Manual User ver 3.0, Dept. of Botany and Zoology Masaryk University Brno, Czech Republic
[10] Thang, H.C. 1987. Forest management systems of tropical high forests, with special reference to Peninsular Malaysia. Forest Ecology and Management 21:3-20
[11] Thang, H. C. 1988, Selective Management System concept and practice in Peninsular Malaysia. (Second Edition), 19 pp, Forestry. Department. Headquarters., Malaysia