MAPPING OF SELECTIVE LOGGING IMPACT ON FOREST CANOPY COVER USING SPOT-6 SATELLITE IMAGERY IN PENINSULAR MALAYSIA

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ABSTRACT

Satellite imagery has proven extremely useful for monitoring forest harvesting activity. However, impact of selective logging is much more difficult to detect than clear cutting. The main objective of this study is to investigate the feasibility of high-resolution remote sensing data in order to detect and monitor the impact of selective logging activities in the tropical forest. The study area located at a 417 ha of dipterocarp forests in Jengai Forest Reserve, Dungun, Terengganu. Two SPOT 6 multi-spectral satellite images consisting of an image before logging activity and an image after logging activity was used in this study to assess the impact of selective logging activities based on forest canopy openings. Impact of logging activities were identified based on the local concentration of large gaps resulting from the construction of roads, trails and logging decks area. Based on the analysis, the logging trails are clearly detected in the study area with different degrees of success depending on the image geometry and canopy closure. From the post classification results there was a reduction in forest cover area by 9.9 hectares within a period of 19 month between 16 June 2016 (before logging) and 11 February 2018 (after logging). This figure is equivalent to 2.38% decrease in forested area. Thus, the present study illustrates that the geospatial technology are important technologies to assess the impact of selective logging on forest canopy cover which is otherwise not possible to attempt through conventional mapping techniques.

Key words: Tropical forest, Selective Management System, Remote Sensing, Geographic Information System

INTRODUCTION

Malaysian forest has been acknowledged to be amongst the most complex ecosystem in the world. The natural forests of Peninsular Malaysia can be classified into seven major forest types namely the Lowland Dipterocarp Forest, Hill Dipterocarp Forest, Upper Dipterocarp Forest, Lower Montane Forest, Upper Montane Forest, Peat Swamp Forest and Mangrove Forest. As at the end of 2017, the total forested area in Peninsular Malaysia was estimated to be 5.77 mil. ha or 43.7 % of the total land area. Of this total, it is estimated that some 4.1 mil. ha are the inland dipterocarp forests, with the remaining 0.25, 0.09 and 0.4 million ha being peats warp forest, mangrove swamp and plantation forests respectively (FDPM, 2017). The important of forest is unarguable because they stabilize climate, regulate the water cycle, and provides habitat to thousands of life forms. For this reason, forest must be managed, protected and utilized in a sustainable manner for not only current but also future generations. Much of the current forest management practices can be improved through the use of current technologies including remote sensing and geographic information system (GIS) which may enhance and support any decision-making process (Khali, 2001).

Malaysia has been practicing sustainable forestry management (SFM) for more than a century (Kamaruzaman Jusoff, 2008). All states in Malaysia also subscribe to common National Forestry Policy (NFP) 1978 and the National Forestry Act 1984, although Sabah and Sarawak have their independent forest management policies which contain similar provisions to the NFP. The SFM practiced in Malaysia has evolved to optimize an economic cut, the sustainability of the forests and minimum cost for forest development. Satellite imagery has proven extremely useful for monitoring forest harvesting activity (Ekena Rangel Pinage, et al. 2019; Yan Gao, et al. 2020; Azadeh Abdollahnejad, et al. 2019, Jules R. Ngueguim, et al. 2009). It is evident that logging has multiple effects on forest composition and structure (Azadeh Abdollahnejad et al., 2019). However, selective logging practices significantly limit damage compared to conventional logging practices, particularly at intermediate harvest intensities. Logging not only decreases the tree density, but also regulates forest canopy gaps dynamic. The main objective of this study is to investigate the feasibility of high-resolution remote sensing data technique in order to detect and monitor the impact of selective logging activities in the tropical forest based on canopy openness due to felled logs, clearings, roads and log decks. Digital change detection essentially comprises the quantification of temporal phenomena from multi-date satellite imagery. Various angles of analysis can be conducted to see the impact of logging activities. In this study, the evaluation was only conducted on canopy openings through the remote sensing data analysis. Although the opening area due to construction of roads, trails and logging decks area can be clearly seen in the field, but the impact of this activity on the opening of the forest canopy is lower based on the assessment made through satellite images because most of that area is sheltered under a tree canopy.

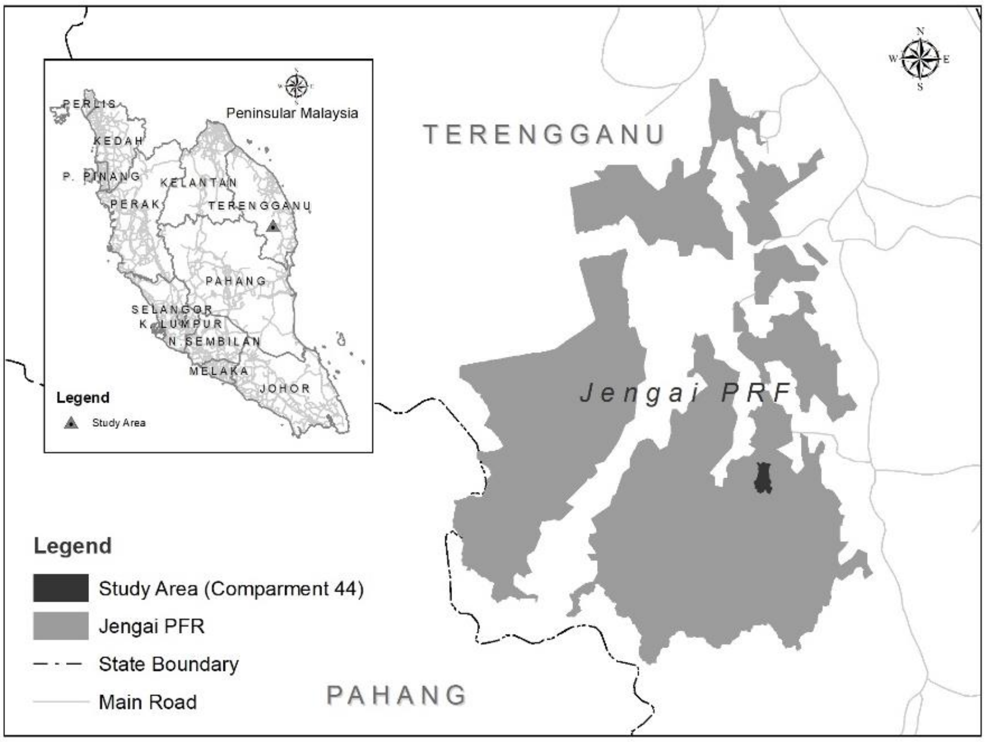
Using high resolution satellite imagery for landuse change detection has the advantage compared to conventional survey technique. Since the emergence of high spatial resolution satellite imagery, object-based classification has been applied extensively to this type of data for producing landuse map (Dingle Robertson, et al. 2011; Wenjie Wang, et al. 2018; Jinquan Ai, et al. 2020; Adistina Lailia, et al. 2019; Mohd Azahari, F. et al., 2018). In an object-based approach, the most important step is to perform a good segmentation of the image such that the objects are delineated clearly to characterize the specific objective of interest. SPOT-6 satellite image with 1.5 m spatial resolution obtained in 16 June 2016 and 11 February 2018 were used in this study to precisely determine forest canopy openness changes after the logging period.

METHODOLOGY

Study Area

The study area located at a 417 ha of dipterocarp forests in Compartment 44, Jengai Forest Reserve, Dungun, Terengganu under the management of Kumpulan Pengurusan Kayu Kayan Terengganu Sdn. Bhd (KPKKT). KPKKT is the timber management company that responsible to manage a long-term forest concession area of approximately 126,940 hectares in the State of Terengganu on the East Coast of Peninsular Malaysia which covering 106,697 hectares of Dungun Timber Complex and 20,243 hectares of Cherul Forest Concession. The 106,697 ha Dungun Timber Complex is located about 120km to the southwest of the State capital Kuala Terengganu. The area consists of 6 Permanent Reserved Forests (PRFs) which are located north, west and east of the Sungai Dungun Valley. They are Jengai PRF (51,840 ha), Besul PRF (6,270 ha), Jerangau PRF (9,810 ha), Pasir Raja Barat PRF (6,547 ha), Pasir Raja Selatan PRF (31,712 ha), and Besul Tambahan PRF (518 ha). The area has a typical tropical monsoon climate with uniformly high temperatures from 24.2°C to 29.9°C, high humidity from 70% to 98% and a relatively high rainfall of up to in excess of 4,000mm per year (KPKKT, 2019).

Figure 1: Jengai PRF, Dungun, Terengganu



Method

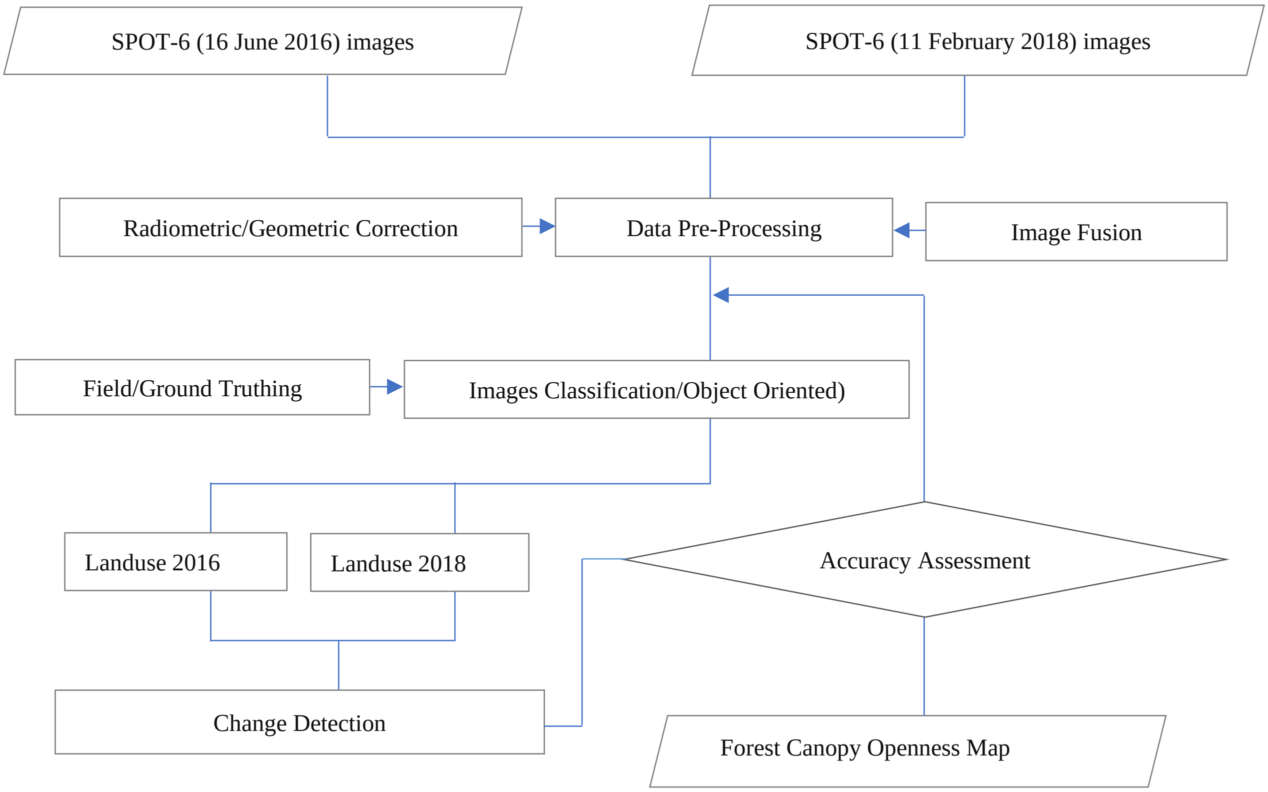
The use of remote sensing technology for mapping at national scale has been widely used because of cost-effective and able to provide a series data. Level 1A SPOT-6 satellite image was used as primary data source to produce landuse map. The data was obtained from Malaysian Space Agency (MYSA). SPOT-6 is an optical imaging satellite with a resolution of 1.5 meter panchromatic and 6 meters multispectral (blue, green, red, near-IR) (Table 1). Currently, three types of GST are in use around the world. Each differs primarily in its method of handling the tax on investment (capital) expenditures. The most common method, the consumption type, permits businesses to deduct immediately the full value of the tax paid on capital purchases. A second approach, the national income type, allows only a gradual deduction of the GST paid on capital purchases over a number of years, much like depreciation.

Table 1: Satellite parameters of SPOT-6

Bands	Spectral range (µm)	Resolution	Imaging Swath (km)	Angle of incidence (°)
1 (blue)	0.45 ~ 0.52	6	60	± 30
2 (green)	0.53 ~ 0.59	6		
3 (red)	0.62 ~ 0.69	6		
4 (near-IR)	0.76 ~ 0.89	6		
5 (panchromatic)	0.45 ~ 0.75	1.5		

The SPOT-6 images were obtained on 16th of June 2016 and 11th of February 2018. Since the study area is dominated by dipterocarp forest area, the landuse classes is divided to two landuse type namely forest and open area. In this study, object-based classification approaches have been used to assess the impact of selective logging activity to the forest canopy openness. Object-based classification has two steps namely segmentation and classification. Segmentation process is employed to identify objects from images using shape, color, texture characteristics and adjacency of pixels. The workflow of satellite image processing applied in this study is shown in Figure 2. All the SPOT-6 imagery, as well as additional datasets, are referenced in a projected coordinate system. The geographic coordinate system used is the Rectified Skew Orthomorphic (RSO) and the selected datum is Kertau 1948. A Top of Atmosphere and Bidirectional Reflectance Distribution Function (TOA BRDF) were applied to the images following the pan-sharpening process. Pan-sharpening is used to produce a higher spatial resolution image using the panchromatic image (band 5) information while attempting to maintain the spectral information of the multispectral data.

Figure 2: Workflow



In this study, object-oriented classification methods were employed on SPOT-6 data. At the first stage of data classification, training and test data covering the study area was prepared. The object-based classification method separating images into homogeneous regions, which may have particular common attributes, such as grey levels, mean values, shapes, and textures. This object-based approach provides a new avenue to the classification of remotely sensed imagery and has demonstrated its advantages over the object-based approach. Nearest Neighbours classification was applying to the segmented images by selecting representative samples for each landuse class based on field data observations.

RESULTS AND DISCUSSION

As a result of the classification methods, two land-use categories were distinguished in the study area namely forest and open area. In this study, open area is referring to the loss of area due to logging activity. Open area can be seen clearly as a brightly features in the satellite image. This open area mapping is being use to identify the impact of logging activities through the forest canopy openings. Ideally the accuracy assessment of landuse maps produced using satellite imagery should be based on field data or higher resolution imagery. However, these reference datasets can be very difficult to obtain, especially when historical information is needed. Moreover, in the case of selective logging, the reference dataset should be of a close date for comparison due to the rapid changes of logging activities. Thus, for assessing the accuracy of our results, we do the field data verification to identify some of the logging decks, forest canopy gaps and logging roads within the study area. It has to be noticed that we did not assess regrowth from deforested areas in our study, as our focus was to assess changes within the forest areas. SPOT-6 satellite imagery that has been obtained on 16th of June 2016 shows that almost all the study area is covered by a forested area (Figure 3a). In order to retrieve information at a pixel level and enhance the disturbances based on canopy cover within the harvesting area, the object-based Nearest Neighbours approach has been apply to the images obtained on 11 February 2018 (Figure 3b) where the logging activity has been completed.

Figure 3: Maps of a) Satellite image before logging activity on June 2016, b) Satellite images after logging activity on February 2018, and c) Forest canopy openness map of study area 2018.

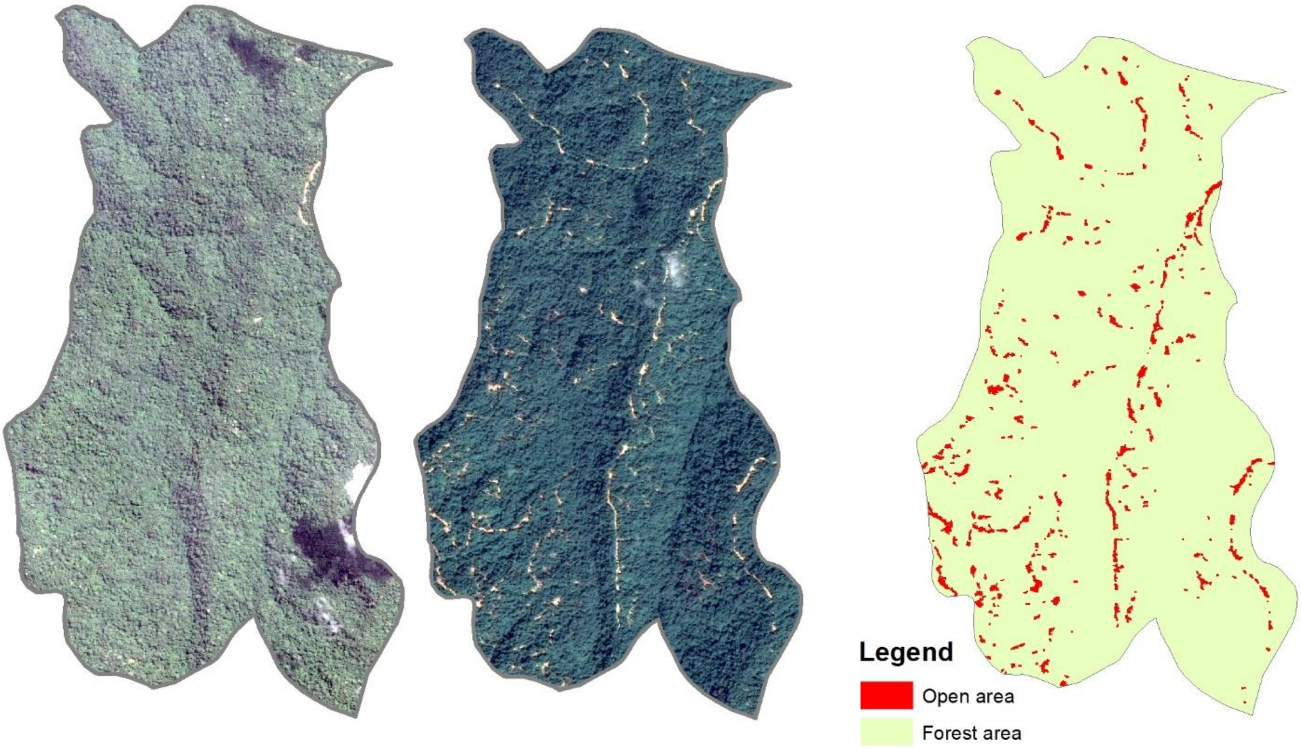
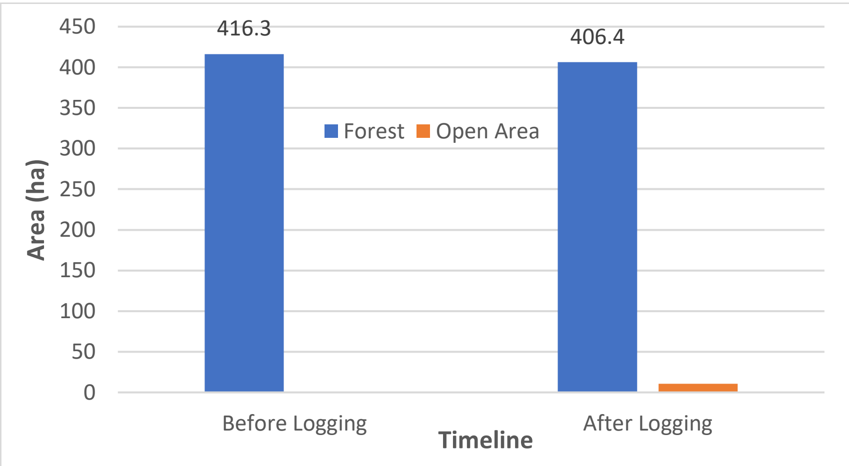


Figure 4: Landuse map statistic of the study area



Accuracy of image classification is most often reported as a percentage correct (Amit Sarkar, 2018). In this study, the performance of classification result has been identified using the accuracy assessment contingency table (Table 4) or error matrix. Error matrix is an array of numbers set out in rows and columns corresponding to a particular classification unit relative to the actual landuse type as verified on the ground. The column headings represent the land use classification as determined in the field and the row headings represent the land use classification taken from the classification result. Based on the error matric result, the overall accuracies of landuse map 2018 that represent the open area as a forest canopy openness was 97%. The land use mapping accuracy using this remote sensing method in this study can be further enhanced by adding more ground samples during the image classification process.

Table 3: Accuracy assessment of landuse 2018 classification result

	References			
Landuse Class	**Forest**	**Open area**	**Total**	**User Accuracy**
Forest	47	2	49	0.93
Open area	0	32	32	1.0
Total	47	34	81	
Producer Accuracy	1.00	0.94		
			Overall Accuracy:	0.97

The cross-tabulation matrices (Table 4) show the change of different landuse classes (Figure 4) or in other words the shift in the landuse classes before and after the logging activity. Out of the 416.3 ha forest area in 16 June 2016, 406.4 ha was still forest area in 11 February 2018 where 9.9 ha was converted to open area. After the logging activity, open area was increased from 0.7 ha to 10.6 ha in 11 February 2018.

Table 4 Cross-tabulation of landuse classes before and after logging (area in ha).

		After logging (11 February2018)	
	Landuse Class	**Forest**	**Open area**
Before logging (16 June 2016)	**Forest**	406.4	9.9
	Open area	0	0.7
	Total	406.4	10.6

Optical satellite data capabilities are relatively limited to see the effects of erosion and soil clearing under forest canopies. There are more advanced remote sensing imaging technologies such as the use of LiDAR (Light Detection and Ranging) scanners that can provide detailed information on terrain features under the dense forest environment. By using multi-temporal LiDAR data, the rate of forest canopy recovery and understory forest layers changes can be identified and are therefore capable of characterizing forest structure caused by logging and monitoring tropical forest biomass dynamics (Ekena Rangel Pinage, et al. 2019, Peter Ellis, et al. 2016). To make sure the evaluation of the impact of selected logging systems is being carried out more comprehensively, the combination of remote sensing methods should be integrated with the geographic information systems (GIS), where the ground information on forest area opening due to construction of roads, trails and logging decks is also should be taken into account.

CONCLUSION

This study was seeking to assess the impacts of logging activities on tropical forest in Peninsular Malaysia using Remote Sensing and GIS techniques. Detection of changes due to harvesting activity was examinate on two Spot-6 satellite images of different years (2016 and 2018). In this study, we use object-based classifications technique to map the forest canopy gap resulting from selective logging activity due to development of logging decks and logging roads. From the accuracy assessment analysis, the overall accuracies of the classification result were 97%. From the post classification results there was a reduction in forest canopy cover by 9.9 hectares within a period of 19 month between 16 June 2016 (before logging) and 11 February 2018 (after logging). This figure is equivalent to 2.38% decrease in forest canopy cover in the study area. Thus, the present study illustrates that the geospatial technology are important technologies to assess the impact of selective logging on forest canopy openness which is otherwise not possible to attempt through conventional mapping techniques. The results found through this study can help the relevant parties as a guide to manage forest resources better using the latest technology that was easier and more cost-effective.

ACKNOWLEDGMENTS

This study was supported by Forest Research Institute Malaysia (FRIM) and Forestry Department of Peninsular Malaysia. Special thanks to Eco-hydrology Programme, Forestry and Environment Division, FRIM.

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