Tropical forest degradation monitoring using ETM+ and MODIS remote sensing data in the Peninsular Malaysia

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Abstract. This study was undertaken in order to test the use of remote sensing technology to assess forest degradation in the Peninsular Malaysia. In order to analyse the effect of spatial resolution on forest degradation assessment, coarse and moderate spatial resolution remote sensing data were examined in this study. Moderate Resolution Imaging Spectroradiometer (MODIS) imagery was used as coarse spatial resolution data, while Landsat Enhanced Thematic Mapper+ (ETM+) imagery was used as moderate spatial resolution to compare the accuracy. Geometric and radiometric correction and re-sampling were performed in preprocessing section to enhance the analysis and results. Canopy fractional cover was used as an approach to assess the forest degradation in this study. Then, an optimum vegetation index was selected to apply on canopy fractional cover to enhance the detection of forest canopy damage. At the same time, accuracy assessment for the approach was referred to the location of Neobalanocarpus Heimii and correlate with global evapotranspiration rate. The forest degradation analysis was also applied and compared for all of the states in the Peninsular Malaysia. In conclusion, Landsat ETM+ imagery obtained higher accuracy compare to MODIS using canopy fractional cover approach for forest degradation assessment, and can be more broadly applicable to use for forest degradation investigation.

1. Introduction
The drastic dynamics of ecosystem and landscape could lead to the entire ecology changes regionally or globally with the possible consequences like water contamination, species extinction, flood, land slide and global warming [1,2,3].

The principal advantages of remote sensing technique are the data can be acquired quickly from large area of the earth’s surface. Other than that, the inaccessible areas may be also sensed and the process will not disturb the areas or objects in the ground. Besides that, remote sensing technique is cheaper and fast as compared to data collection on the ground. On top of that, remote sensing enable to manipulate with computer and it can be linked to GIS for further analysis. Many empirical algorithms and modelling can be directly applied to the remotely sensed data, and computation time to extract information is fast [4,5,6,7,8].

The study area chosen is the whole of peninsular Malaysia (Fig.1). The aim of the study is to examine the effectiveness of forest degradation assessment technique by different spatial resolutions satellite sensors.

2. Study area
The Peninsular Malaysia is situated in the Southeast Asia. It is located between 6° 45’ and 1° 20’ N latitudes and 99° 40’ and 104° 20’ E longitudes, and its area is 131,600 km². This study was conducted...
at tropical forest in the Peninsular Malaysia as shown in Figure 1. The Peninsular Malaysia consists of 11 states and two federal territories, including Perlis, Kedah, Penang, Perak, Kelantan, Terengganu, Pahang, Selangor, Negeri Sembilan, Malacca, Johor, federal territories of Kuala Lumpur and Putrajaya. The total forest covers about 21 million hectare, which is about 63.30% of total land area in the Peninsular Malaysia.

Figure 1. Tropical forest in Peninsular Malaysia.

3. **Materials**

Moderate Resolution Imaging Spectroradiometer (MODIS) was used as coarse resolution imagery, while Landsat Enhanced Thematic Mapper+ (ETM+) imagery was used as moderate resolution to compare the forest degradation accuracy. All the satellite images were acquired on 1990, 2000 and 2010, which were downloaded from the U.S. Geological Survey Earth Resources Observation System (EROS) Data Center (EDC).

4. **Methods**

Figure 2 illustrates the operational framework of this study as flowchart. It includes the phase of pre-processing, forest masking, processing, results and analysis, and accuracy assessment.
5. Results and discussion

The forest degradation assessments in this study are based on Landsat TM data since the MODIS data show low coefficient of determination $R^2$ in the validation part. Figure 3 shows the overall forest degradation assessment for the Peninsular Malaysia in years 1990, 2000, and 2010.
Figure 3. Forest degradation assessment for Peninsular Malaysia in year 1990, 2000 and 2010.

As shown in Figure 3, the degraded forest is increasing from year 1990 to 2000 and decreasing to 12.33% in 2010. There are 27.77% of forests in 2000 that classified as degraded forest. This high forest degradation might be caused by lot of forest fire occurred between year 1990 and 2000. Table 3 shows the forest fire statistic from year 1992 to 1998 which obtained from Forest Department Peninsular Malaysia and Forest Research Institute Malaysia. At the same time, the clear cut area is increasing from year 1990 to 2010. The forest lost are having same trend as recorder in Global Forest Resources Assessment (FRA) 2010 for Malaysia by Food and Agricultural Organization (FAO) of the United Nations. The forest lost may be created due to both direct and indirect causes. Some of them are results of anthropogenic activities, and some are caused by natural phenomena. According to the United Nations Framework Convention on Climate Change (UNFCCC) secretariat, the overwhelming direct cause of deforestation is agriculture. Where by 48% of deforestation is due to subsistence farming, 32% of deforestation due to commercial agriculture, and 14% of deforestation due to logging, and 5% of deforestation caused by fuel wood.

Finally, the map of forest canopy fractional cover for the Peninsular Malaysia had been made. The map of canopy fractional cover for year 2010 was shown in Figure 4. The forest canopy fractional cover was density slice into ten classes with the interval of 0.1. However, the area where cover by cloud or no data are represented as black colour in the map.
6. Conclusions
Quantifying forest degradation is more challenging than quantifying deforestation. However, canopy fractional cover can be one of the alternatives to assess the forest degradation. At the same time, vegetation index which best sensitive to the forest in study area need to choose as the optimum vegetation index to apply for canopy fractional cover in order to increase the accuracy. Although remotely sensed imagery can be used for the forest degradation assessment by various techniques, but the appropriate spatial resolution of data should be chosen in order to achieve a certain accuracy level. This is because the spatial resolution of data will affect on the forest degradation assessment results. From this study, Landsat TM imagery showed higher accuracy and more appropriate to be used for forest degradation assessment as compared to MODIS imagery.

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