Estimation of forest degradation distribution using landsat satellite imagery in Besitang forest landscape

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Abstract. Sumatra rain forest is a hot spot for flora and fauna biodiversity in the world and also habitat for many endangered species. Of the mammal species, four key species were found here those were Sumatran Tiger (Panthera tigris sumatrae), Sumatran Elephant (Elephas maximus sumatrensis), Orangutan (Pongo abelii) and Sumatran Rhino (Dicerorhinus sumatrensis). Forest degradation has been a global phenomenon and while being an important indicator to further forest loss, decreasing habitat quality of wild animal and species extinction. Besitang Forest is the habitats for three key mammal species in North Sumatra. Forest conversion, forest disturbance, and human activities in this site threaten the existence of these species. The objective of this research was to determine the spatial model of forest canopy cover and spatial distribution of forest degradation in Besitang Forest in period 2008 - 2016. Forest canopy cover value was estimated through Normalized Difference Vegetation Index (NDVI) value from satellite Landsat imagery using the regression model. Forest degradation was measured by comparing the spatial distribution of forest canopy cover in 2008 and forest canopy cover in 2016. The result showed that NDVI approaches could estimate the forest canopy cover with R² value 79.0. Forest degradation in Besitang landscape was classified into high (527.85 ha), medium (9,763.83 ha) and low (28,898.73 ha).

1. Introduction

Forest degradation is a quality decrease in the forest which is characterized by a decrease of canopy density in the field; this phenomenon is common in forests in the world, including Indonesia. The process of forest degradation is difficult to distinguish because it involves a process of reducing the quality of forest canopies and the vertical structure of forest canopies over a long period [1].

The method of detecting forest degradation using remote sensing has been widely used to assess forest canopy density as an indicator of forest degradation [2–4]. Monitoring of forest degradation is essential for monitoring activities, reporting, and verification (MRV) in reducing emissions from deforestation and forest degradation (REDD) scheme [5]. According to Penman et al. [6], to get operational procedures MRV about forest degradation is still a crucial problem. The main problem is the lack of standards on forest degradation classification methods, both using remote sensing imagery and forest degradation measured in the field.
On the other hand, in the context of conservation, the existence of Besitang Forest landscapes is very important considering the forests in Besitang are the habitat of three key species of Sumatran endemic wildlife, namely the Sumatran elephant (*Elephas maximus sumatrensis*), Sumatran tiger (*Panthera tigris sumatrae*), and Sumatran orangutan (*Pongo abelii*). Forest degradation can affect the habitat quality of wildlife that lives in it [7]. For this reason, information about the distribution of the level of forest degradation that occurs is important to be studied. This study aimed to build a spatial model of the percentage of canopy cover to estimate the level of forest degradation in the forest landscape of Besitang.

2. Materials and method

2.1. Research location

This research was conducted in National Park Management Section (NPMS) 6 Besitang. NPMS 6 Besitang is part of the Gunung Leuser National Park located in Langkat Regency, North Sumatra Province, covering an area of 115,208.55 ha (figure 1).

![Figure 1. Map of the study area in Besitang, North Sumatra](image)

2.2. Spatial model of forest cover

The measurement of canopy cover in the field was carried out at the center point of a 30x30m plot. The canopy cover was measured using a fisheye lens, then to determine the percentage of canopy cover used a canopy cover android application. Determination of plots in the field was carried out by purposive sampling.

Pre-processing of satellite image carried out was an geometric and radiometric correction. The radiometric correction was carried out by equating a 2008 satellite image histogram and satellite imagery in 2016 using the histogram matching method. In this study, NDVI values were obtained from images of Landsat satellites 5 Path/Row 129/57 and 129/58 recording on February 18, 2008, and images of Landsat 8 Path/Row 129/57 and 129/58 recording on July 1, 2016. NDVI formulas were calculated with the equation [8–10]:

\[
NDVI = \frac{NIR - R}{NIR + R}
\]  

NIR : digital number in the Near Infrared band  
R : digital number in the Red band
Estimation of canopy cover distribution was done by regressing 39 data of canopy cover measurement values in the field with NDVI values. Normality tests used Kolmogorov-Smirnov test and heteroskedasticity tests were carried out to test the assumption of Ordinary least square (OLS) regression. The OLS regression equation model used is:

1. Linear
   \[ Y = a + bX \]  
2. Ln 1
   \[ Y = a + b(LnX) \]  
3. Ln 2
   \[ LnY = a + bX \]  
4. Double Ln
   \[ LnY = a + b(LnX) \]

\( Y \) : percentage of canopy cover (%)
\( X \) : NDVI value

Validation test was carried out to determine the deviation of the canopy cover from the model with canopy cover from the field. The amount of data used to conduct validation tests was 19 data. Validation test for canopy cover model used aggregate deviation test (AD) and relative deviation (RD). A good equation has AD between -1 to +1. RD value shows that a model can be said to be good if its value is less than 10%.

2.3 Estimation of forest degradation

The level of forest degradation was obtained by comparing the canopy cover in 2008 with canopy cover in 2016. Criteria for changes in canopy cover can be seen in table 1.

| No | Criteria          | Criteria         |
|----|-------------------|------------------|
| 1  | Low degradation   | Down 1-2 level   |
| 2  | Medium degradation| Down 3-5 level   |
| 3  | High degradation  | Down 6-9 level   |
| 4  | Enrichment        | Level up         |
| 5  | No change         | Fixed level      |

3. Results and discussion

3.1. Spatial model of forest cover

The result of the normality test using the Kolmogorov-Smirnov test showed that the canopy cover data normally spread (sig> 0.05). The heteroskedasticity test results showed that the spread of residual variance was not patterned, which means there was no heteroskedasticity problem. These results provide information that the assumption of the regression model is fulfilled.

The results of analysis variance (ANOVA) of the four regression models used showed that NDVI variables on Landsat satellite images could be used to estimate the percentage of canopy cover (sig 0.000). Validation test results also showed that there were no differences in the four regression models with the measurement of data in the field (-1<AD<1 and RD < 10%). The full results can be seen in table 2.

The best regression model of canopy cover is the Ln 1 regression model with R² value of 0.790. This regression model is chosen because it has the highest R² value. The results of this study confirm the results of the study by [11–12] who state that the use of canopy density percentages with Landsat satellite imagery to detect degradation results in high accuracy and is very promising.
Table 2. The result of statistic model and validation.

| Model     | Equation                        | Sig of ANOVA | R²  | R     | AD     | RD (%) |
|-----------|---------------------------------|--------------|-----|-------|--------|--------|
| Linear    | y = -137.341 + 322.150 NDVI    | 0.000        | 0.786 | 0.887 | -0.019 | 4.838  |
| Ln 1      | y = 158.083 + 459.446 Ln NDVI | 0.000        | 0.790 | 0.889 | -0.019 | 4.814  |
| Ln 2      | Ln y = 0.695 + 5.513 NDVI     | 0.000        | 0.752 | 0.867 | -0.007 | 3.667  |
| Double Ln | Ln y = 5.748 + 3.419 Ln NDVI | 0.000        | 0.759 | 0.871 | -0.005 | 3.586  |

The results of the canopy cover classification in this study were divided into ten classes. The canopy closure map can be seen in figure 2, while the area of each class can be seen in table 3.

![2008, 2016 canopy images](image)

Figure 2. Map of forest canopy closing classes.

Table 3. Class of canopy cover in forest landscape of Besitang.

| Level | Class of canopy cover | 2008 | 2016 |
|-------|-----------------------|------|------|
|       | Area (ha)             | Percentage (%) | Area (ha) | Percentage (%) |
| Cloud | Cloud                 | 7,837.02 | 6.80 | 6,372.27 | 5.54 |
| 1     | 0-10%                 | 2,177.64 | 1.89 | 2,400.93 | 2.09 |
| 2     | 10-20%                | 4,154.49 | 3.61 | 3,178.89 | 2.76 |
| 3     | 20-30%                | 5,308.02 | 4.61 | 5,088.33 | 4.42 |
| 4     | 30-40%                | 11,072.07 | 9.61 | 9,684.00 | 8.41 |
| 5     | 40-50%                | 15,293.34 | 13.28 | 17,566.11 | 15.26 |
| 6     | 50-60%                | 23,213.52 | 20.15 | 24,791.40 | 21.54 |
| 7     | 60-70%                | 23,297.22 | 20.23 | 26,905.77 | 23.37 |
| 8     | 70-80%                | 16,675.11 | 14.48 | 14,859.36 | 12.91 |
| 9     | 80-90%                | 5,889.87 | 5.11 | 4,009.23 | 3.48 |
| 10    | > 90%                 | 269.01 | 0.23 | 253.89 | 0.22 |
|       | Total                 | 115,208.55 | 100.00 | 115,208.55 | 100.00 |

3.2. Forest degradation

Analysis of forest degradation carried out only in the areas in 2008 was detected as forest and in 2016 was detected as forest too. Forest areas that occurred in forest degradation are forest areas that experienced a decline in the class percentage of canopy cover in the period 2008 - 2016. The results of the classification of forest degradation levels that occurred in the forest landscape of Besitang can be seen in table 4.
Table 4. The rate of forest degradation in the Besitang Forest landscape in 2008 – 2016.

| Rate of degradation | Area (ha) | Percentage (%) |
|---------------------|-----------|----------------|
| High degradation    | 527.85    | 0.48           |
| Medium degradation  | 9,763.83  | 8.93           |
| Low degradation     | 28,898.73 | 26.44          |
| Enrichment          | 35,804.61 | 32.75          |
| No change           | 23,306.04 | 21.32          |
| cloud               | 11,012.76 | 10.07          |
| Total               | 109,313.82|                |

Low of forest degradation occurs if the reduction in canopy cover is less than 30%; medium forest degradation occurs if the reduction in canopy cover is 30-70%, while high forest degradation occurs if forest canopy closure is more than 70%. Based on table 3, it can be seen that 35.85% of forest landscapes in Besitang have been degraded, with details of low degradation covering 28,898.73 ha (26.44%), medium degradation covering 9,763.83 (8.93%) and high degradation of 527, 85 ha (0.48%). The spatial distribution of forest degradation can be seen in figure 3.

Figure 3. Forest degradation in the period 2008 – 2016.

4. Conclusion
The result showed that NDVI approaches could estimate the forest canopy cover with R² value of 79.0 %. Forest degradation in forest landscape of Besitang was classified into high (527.85 ha), medium (9,763.83 ha) and low (28,898.73 ha).

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