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Application of Forest Canopy Density (FCD) Model for the Hotspot Monitoring of Crown Fire in Tebo, Jambi Province

Muhammad Attorik Falensky[1], Anggieani Laras Sulti[1], Ranggas Dhuha Putra[1], Kuswantoro Marko[1]

[1] Department of Geography, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok, Indonesia

E-mail: futama123@gmail.com, kuswantoro@sci.ui.ac.id

Abstract. *Indonesia is one of the owners of the 9th largest forest area in the world. Forest area in Indonesia reaches 884,950 km^2. Tebo Regency is a regency in Jambi Province which has a wide forest area of 628,003 Ha. However, this forest area has been reduced due to the conversion of functions of Industrial Plantation Forests (HTI), oil palm plantations, and forest clearing activities for both settlements and plantations which led to the phenomenon of forest and land fires (karhutla). This study aims to get a better knowledge of crowns of fire potential locations in forest areas using remote sensing technology. Remote sensing data used in this study is from the satellite imagery of Landsat 8 OLI - TIRS in 2019. Remote sensing data is used to produce a Forest Canopy Density (FCD) model that can be overlapped with a hotspot location, so the crown fire potential locations will be explored in the forest area of Tebo Regency, Jambi Province. Identification of hotspot patterns in Forest Areas was analyzed using spatial analysis. The results of this study are useful for the government as the information of the hotspot area as the cause of fires in the Forest Region of Tebo Regency Jambi Province.*

***Keywords**: Spatial Analysis, Forest Cover Density (FCD), Hotspots, Forest Areas, Remote Sensing*

1. Introduction

Forest is land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ* (FAO, 2015). Forests which should be protected and utilized optimally by taking into account aspects of sustainability, have experienced degradation and deforestation. Deforestation rates in Indonesia in the 2010-2014 period were 1.8 million. Forest Fire is one of the biggest causes of forest damage and is very detrimental. In addition to the effects of smoke caused, it can result in huge losses. Both in ecological economic and social term, can cause the spread of smoke across the State (transboundary haze). Fire may be caused by dry atmospheric and weather conditions. This condition is exacerbated by land clearing for plantations and agriculture by burning, so that the surface temperature is relatively higher than the surrounding area and hotspots emerge.

Forest degradation is a process that leads to temporary or permanent damage to the density or structure of vegetation cover or species composition (Grainger 1993). Monitoring forest change in degraded areas by sensing is far more challenging than monitoring deforestation. Deforestation is easily detected, especially if it occurs on a large scale. But forest degradation, such as the loss of several trees per hectare by selective logging, bush fire, or branches and small trees for firewood is far more difficult to observe from a distance. These activities only slightly affect forest canopy cover but can significantly affect forest stock (Defries, 2007). Therefore, an assessment of forest status needs to be conducted with an approach that is able to show the phenomenon of forest growth. According to Azizi (2008), for better forest management, changes in density must be considered. Monitoring the density of the forest canopy makes it possible to see changes in forest conditions over time including forest degradation, this FCD methods has been used by several research before such as Rikimaru (2002) and Rikimaru & Miyatake (1997). The purpose and the novelty of this study is to map the forest canopy density (FCD), and also to analyze the relationship between FCD and hotspots in Tebo Regency, Jambi Province.

2. Research Methodology

2.1. Study Area

Geographically, Tebo Regency is located at 0º 52 '32 "- 01º 54' 50" South Latitude and 101º 48 '57 "- 102º 49' 17" East BT in Jambi Province, Sumatra Island, in the north bordering Riau Province, in the East bordering Tanjung Regency West Jabung and Batang Hari Regency, the south bordering Marangin Regency and Batang Regency and the west bordering Bungo Regency and West Sumatra Province.

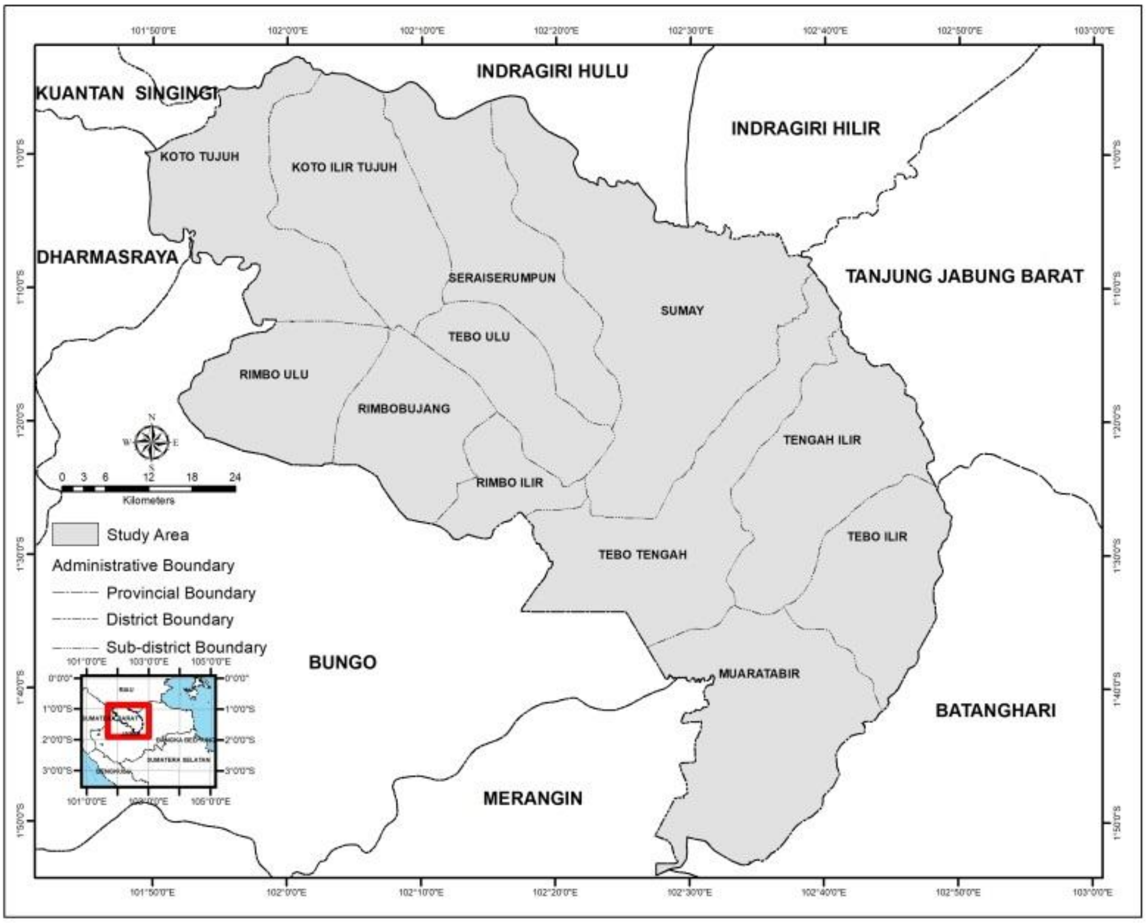


Figure 1. Study Area

2.2. Data

This research used Landsat 8 imagery obtained on May 2, 2019. Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Satellite Imagery consists of spectral bands with spatial resolution of 30 meters for Bands 1 to 7 and 9. Resolutions for Band 8 (panchromatic) is 15 meters and Thermal Bands 10 and 11 are collected at 100 meters. Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Satellite Imagery consists of eleven Bands: Ultra Blue (Coastal or Aerosol) (0.43 -0.45 µm), blue (0.450 -0.51 µm), green (0.53 -0.59 µm), red (0.64 - 0.67 µm), Near Infrared (NIR) (0.85 -0.88 µm), SWIR 1 (1.57 -1.65 µm), SWIR 2 (2.11 -2.29 µm), panchromatic (PAN) (0.50 -0.68 µm), cirrus (1.36-1.38 µm), TIRS 1 (10.6 -11.19 µm) and TIRS 2 (11.5 -12.51 µm) (Ardiansyah, 2015). In addition this research also requires a hotspot shapefile (hotspot) and forest area in Tebo Regency, Jambi.

2.3. Forest Canopy Density Model

Forest Canopy Density (FCD) is a calculation method used to calculate the density of vegetation cover by using and integrating 4 indexes related to forest vegetation cover index (Rikimaru, 2002).

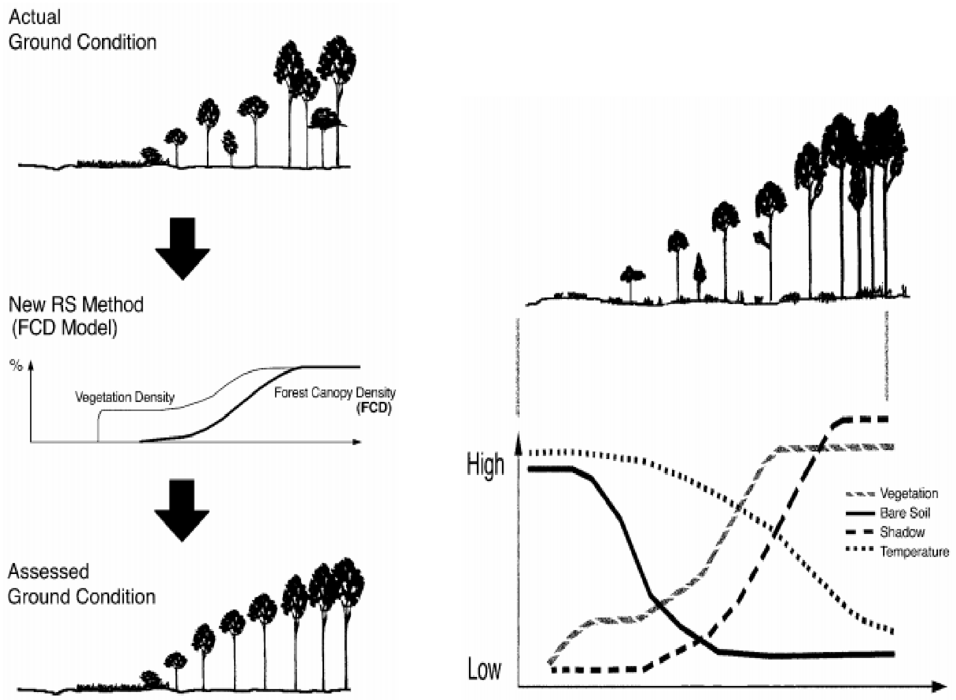


Figure 2. Analysis of the FCD Model Index

Figure 2. illustrates the relationship between forest conditions and the four Forest Canopy Density indices (AVI, BI, SI and TI). The vegetation index response for all vegetation objects such as forests and grasslands. Vegetation Advance Vegetation Index (AVI) which is a synthetic index of NDVI so that it is more sensitive to the amount of vegetation compared to NDVI. Shadow Index (SI) increases directly proportional to forest density. Thermal Index (TI) increases with the increase in the amount of land / no vegetation. This index value is calculated for each pixel. The formula for each calculation as explained below.

1). Advanced Vegetation Index (AVI)

Advanced Vegetation Index (AVI), calculates the AVI value using the following formula (Rikimaru, 2002) :

$$\text{AVI} = \text{AVI} = \sqrt[3]{(\text{B5}+1)\text{x}(65536-\text{B4})\text{x}(\text{B54})} \ldots\ldots (1)$$

Where : B5 = Band NIR, B4 = Band Red

2). Bare Soil Index (BI)

Bare Soil Index (BI) or Open Land Index, calculates the BI value using the following formula (Rikimaru, 2002) :

BI = $\frac{(B6+B4)-(B5+B2)}{(B6+B4)+(B5+B2)}$x 100 + 100………………………...…………..................................(2)

Where : B6 = Band SWIR 1, B5 = Band NIR, B4 = Band Red, B2 = Band Blue (0 < BI < 200)

3). Shadow Index (SI)

Shadow Index (SI) or Shadow Index, calculate the SI value using the following formula (Rikimaru, 2002) :

$SI = \sqrt[3]{(256 - B2)x(256 - B3)x(256 - B4)}$ …………………..…(3)

Where : B4 = Band Red, B3 = Band Green, B2 = Band Blue

4). Thermal/Temperature Index (TI)

Thermal / Temperature Index (TI), the calculation of TI is done through 2 stages, namely changing the thermal channel into radians and performing T calculations with the formula (Ardiansyah, 2015):

$T = \frac{K2}{\ln(\frac{K1}{L\lambda}+1)}$…………………………………………………….................................(4)

Where: T = radian temperature in Kelvin units (K), K1 = spectral radian calibration constant (W / m2.sr.µm), K2 = absolute temperature calibration constant, Lλ = spectral radian value.

In forest areas which have tall and dense trees, will cause high AVI and SI values, otherwise there will be low values for BI and IT. Likewise, forest areas that are already open where the condition of the trees are relatively rare will cause an increase in the value of BI and IT and decrease the value of AVI and SI (Rikimaru & Miyatake, 1997; Roy, et al. 1997).

5). Vegetation Density (VD)

Vegetation Density (VD) is derived through integration by applying Principal Component Analysis (PCA) between AVI and BI. The PCA image is then normalized to produce a Vegetation Density image in the range of 0-100.

The normalization process uses the formula(Rikimaru, 1996):

Normalization VD = $\frac{(B1-\min)x(\max'-\min')}{\max-\min}$……………….……………................................…(5)

Where: B1 = Digital value for AVI and BI cross index images (PCA image), Min = Minimum value in image, Max = Maximum value in image, Min '= Normalized minimum value, Max' = Maximum value of normalization.

6). Scaled Shadow Index (SSI)

The Scaled Shadow Index (SSI) is derived through integration by applying Principal Component Analysis (PCA) between SI and TI. The PCA image is then normalized to produce a Scaled Shadow Index image into the range 0-100.

The normalization process uses the formula(Rikimaru, 1996):

Normalization SSI = $\frac{(B1-\min)x(\max'-\min')}{\max-\min}$..(6)

Where : B1 = Digital value for the SI and TI cross index images (PCA image results), Min = Minimum value in image, Max = Maximum value in image, Min '= Normalized minimum value, Max' = Maximum value of normalization.

7). Forest Canopy Density (FCD)

FCD value calculation using the formula (Rikimaru, 2002) :

$$\mathrm{FCD} = \sqrt[3]{\mathrm{SSI} * \mathrm{VD} + 1} + 1 \qquad (7)$$

Where: SSI = Results of processing SSI, VD = Results of processing VD

2.2. Principal Component Analysis (PCA) Model

Principal Component Analysis (PCA) is a statistical technique that linearly changes the shape of a set of original variables into a collection of variables that can represent information from a collection of original variables. (Dunteman. 1989). The purpose of the PCA is to extract the results of the integrity of the Forest Canopy Density (FCD) variable.

2.3. Analysis of Change in the Jambi Forest Area

Forest area data analysis was obtained from the Ministry of Environment and Forestry (KLHK), the result of mapping the Tebo Regency forest area. The Tebo Regency's forest area includes protected forest, production, limited production, and the Nature Reserve Forest Area (KSA) - Nature Conservation Forest (KPA) and Buru Park (TB). The forest area will be overlaid with the results of the Forest Canopy Density (FCD) to determine the density of the canopy in the forest area.

2.4. Analysis of Relationships between Forest Areas, Hotspots and Forest Canopy Density (FCD)

Analysis of the Tebo regency hotspot in Jambi Province whose data was obtained from the Ministry of Environment and Forestry (KLHK) was done by selecting hotspots that were> 80% confident, including those in the high class with immediate response status (Giglio, 2015) in Tebo Regency in the year 2019. Analysis of Forest Canopy Density (FCD) value by identifying canopy density in forest areas that have hotspots in Tebo Regency, Jambi Province.

3. Results and Discussion

3.1. Results of Advanced Vegetation Index (AVI)

Based on the formula (1) obtained the results of AVI as in Figure 3**.** A large AVI value in the study area proves that the area is an object of vegetation and is marked in bright green. The lower the AVI value, it indicates that the area is not vegetation area / open land and is marked with a faded green color. In areas covered by clouds, the AVI value is known as 0 or NaN.

3.2. Result of Bare Soil Index (BI)

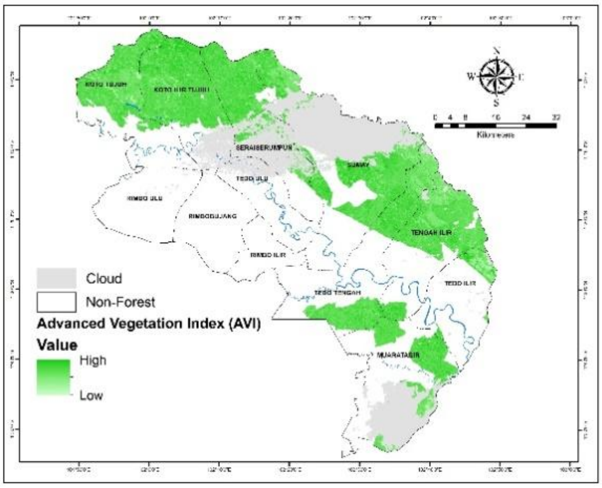
Based on formula (2) BI results are obtained as shown in Figure 4. A high BI value in the study area proves that the study area is dominated by open land / no vegetation marked in red. A low BI value indicates that the area is an object of vegetation cover that is marked in green. A low BI value indicates that a high FCD value. To validate the results we compare it with the google earth satellite imagery on the same years.

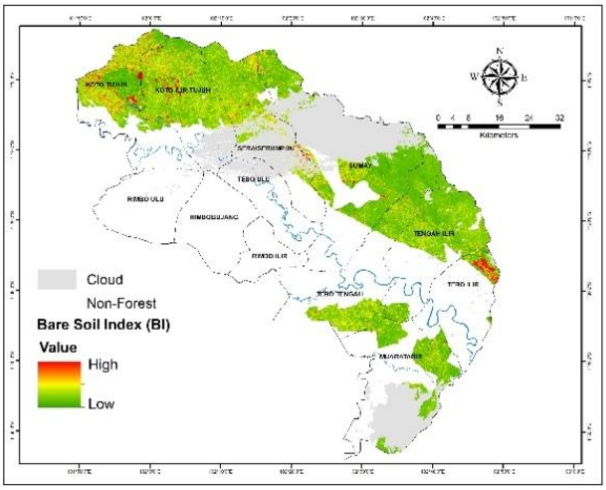
3.3. Result of Shadow Index (SI)

Based on the formula (3) the SI results are obtained as shown in Figure 5. A high SI value in the study area proves that the area shows vegetation objects and is characterized by dark tones. The lower the shadow value will indicate that the object is in the form of grassland or open ground. A low SI value is characterized by a slightly bright hue. In areas that have clouds, SI will be worth 0.

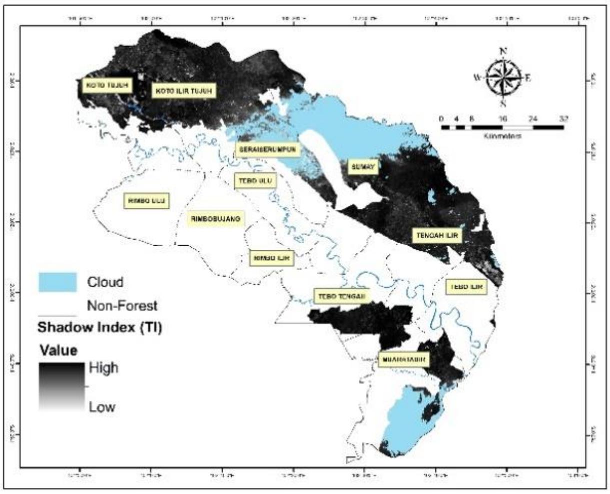
3.4. Result of Thermal Index (TI)

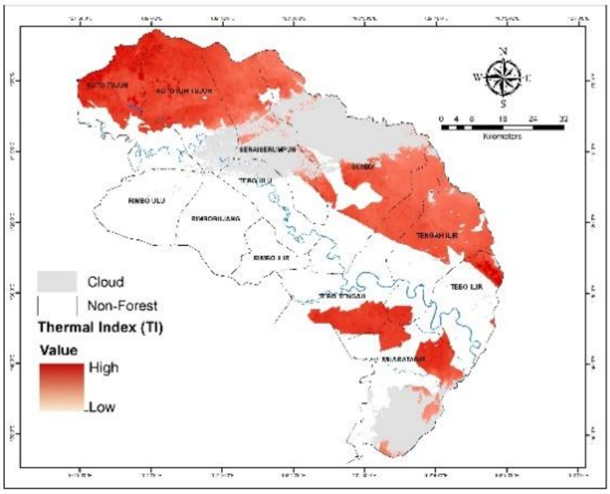
Based on formula (4) TI results are obtained as shown in Figure 6. High temperatures are found on non-vegetation / exposed soil objects and marked in red. The higher the temperature value proves that the location is an object of vegetation / open land. Low temperatures are found on vegetation objects that are marked with pink. The lower the temperature, the higher the FCD value. The lower the temperature, the darker the color and it proves that the point is an object of vegetation. In areas covered by clouds they do not have a temperature value because at the time of the cloud masking process the cloud value is changed to 0.





(3) **4)**



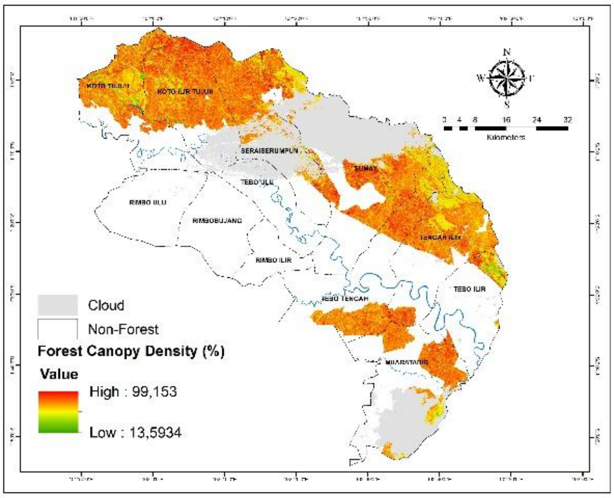


(5) **(6)**

Figure 3. Advanced Vegetation Index (AVI) results; **Figure 4.** Bare Soil Index (BSI) results; **Figure 5.** Shadow Index (SI) results; **Figure 6.** Thermal Index (TI) results

3.5. Result of Forest Canopy Density (FCD) and Canopy Density Classification

FCD value (Formula 7) and class classification are obtained after getting the VD (Formula 5) and SSI (Formula 6) values obtained as shown in Figure 7. FCD mapping uses forest canopy density as an essential parameter in characterizing forest conditions. FCD data can indicate the degree of forest condition that can be known from the quality of forest stands, and can indicate the intensity of rehabilitation treatment that may be needed (Rikimaru, 2002). The Forest Canopy Density (FCD) value in 2019 has a vulnerable value of 13.59 to 99.15. The higher the value of the FCD it means more dense the canopy of the forest. With the lowest FCD value around the body of water (river). Can be seen in Figure 7.



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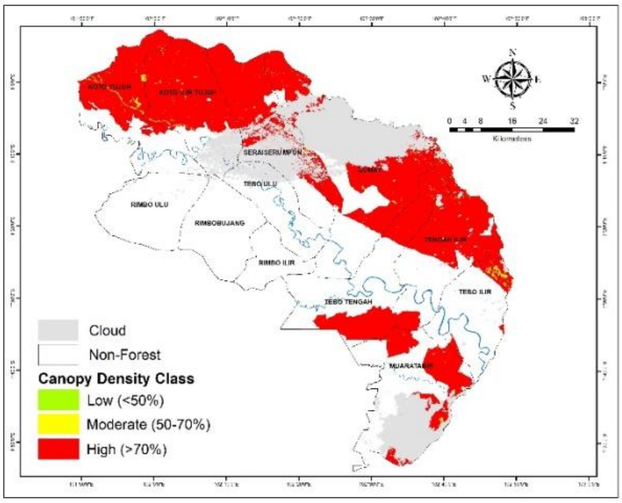

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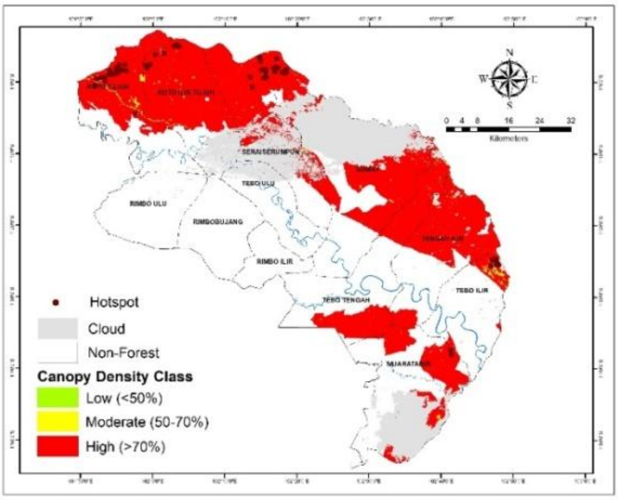

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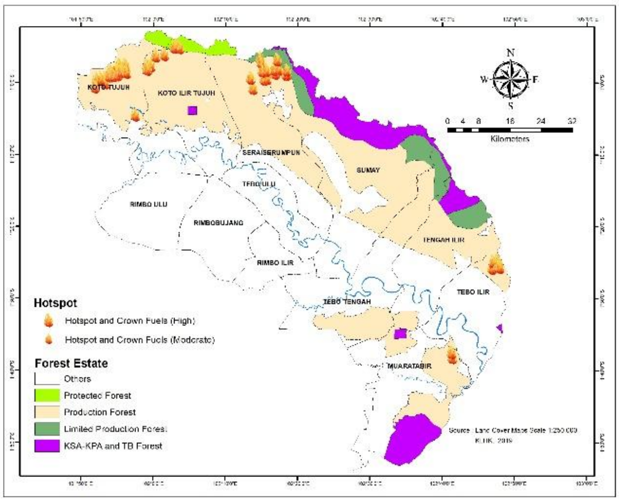

(10)

Figure 7. Forest Canopy Density (FCD) results; **Figure 8.** Forest Canopy Density (FCD) classification; **Figure 9.** Hotspot in the canopy density classification; **Figure 10.** Hotspot in the forest district

3.6. Result of Forest Canopy Density (FCD) Classification

Low density is characterized by a low FCD value (≤50%) and visualized with green. The brighter the color, the lower the FCD value and the lower the forest density. At moderate densities, the FCD values range (50% -70%) and are visualized in yellow. Moderate density is indicated by the FCD value with a range (50% -70%). Whereas the high density is marked by the FCD value with a range (> 70%) and visualized in red (Department of Forestry, 2004). In 2019 the most vulnerable FCD value is in the high class at 84.384% of the total area of Tebo Regency Forest Area. This illustrates that the forest density in Tebo Regency is high.

3.7 Hotspots and Forest Canopy Density in the Forest Estate of Tebo Regency, Jambi Province

Hotspots locations in Tebo Regency in 2019 dominate the areas that have high FCD values. This is evidenced by the presence of hotspot point in the high FCD class totaling 58 points, moderate FCD class 1 point, and no hotspot points in the low FCD class. Can be seen in **Table 1.**

Table 1. Number of Hotspots in the Canopy Density Class in Tebo District in 2019

Density Class	Hotspot 2019
Low	0
Moderate	1
High	58

Table 2 shows that almost all hotspot points in the high density class type are in the Production Forest Area, which is 50 points. Then there are in the Protection Forest and Limited Production Forest, each with 4 hotspots. For hotspots in the medium density type is 1 and is in the Production Forest Zone.

The high number of hotspot in the production forest indicates that human activity could triggered the emergence of hotspot that can grow into the forest fires. Especially area with High canopy density and the presence of hotspots enable the possibility for land and forest fires, especially the crown fuels forest fires consisting of biomass at the top of the tree (tree canopy), if the fire has reached the crown fuels then this fire will spread very easily through the canopy of interconnected trees in the forest.

Table 2. Tebo Regency's Number of Hotspot in FCD Class 2019

Forest Estate	Hotspot on Density Class Type	
	Moderate	High
Protected Forest	0	4
Production Forest	1	50
Limited Production Forest	0	4
KSA-KPA and TB Forest	0	0

4. Conclusions

High canopy density with the type of production forest area is dominated by hotspot points. Production forest areas that are mostly interfered with by humans, including land use change and supported by hotspots are possible to cause land and forest fires, moreover production forest areas have high density, this causes pforest fires potential, especially in crown fuels, ie fires that occur at the top of the tree. As a result, fire fighting is difficult, so with this research it is hoped that the government can further review the area in order to prevent forest fires.

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