The Application of Forest Cover Density (FCD) Model for Structural Composition of Vegetation Changes in Part of Lore Lindu National Park, Central Sulawesi Province

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Abstract. One method that is considered to be more accurate for the identification of forest density related to the structural composition of vegetation is using a FCD model. However, the FCD model needs to use terrain correction in the identification of structural compositions. The aims of this study are to analyse the ability of Landsat image in FCD model to map structural composition of vegetation and to study the rate of changes. Remote sensing imagery used in this study is the Landsat 7 ETM + in September 2002 and Landsat 8 OLI in September 2015. Based on the results of this study concluded that the FCD model and multitemporal Landsat imagery can be utilized for the identification of structural composition without and with terrain correction. Result of identification structural composition of vegetation in 2002 and 2015 have an accuracy respectively equal to 67.2% and 78.3%. Changes in the structural composition of vegetation without terrain correction consisted of decrease is 66,255.5 ha. In addition, the result of the structural composition of vegetation with terrain correction in 2002 and 2015 has an accuracy of 75.3% and 79.4%. Changes in the structural composition of vegetation with terrain correction consisted of a decrease is 45,456.8 ha.

Keywords: FCD, vegetation, Landsat 7 ETM+

1. Introduction

Rapid technological developments produce a science and method that is considered capable of identifying various problems. Remote sensing is the result of these technological developments. Remote sensing is the science and art of obtaining information about an object, region, or phenomenon through analysis of data obtained by means without a direct contact [1]. Remote sensing applications have an important role in helping the process of monitoring forest changes, especially the structural composition of vegetation. Periodic measurements of forest changes can be obtained with remote sensing applications and are capable of providing the best accuracy [2]. With remote sensing, information related to geosphere phenomena can be quickly obtained and analyzed systematically.

In digital analysis related to spectral transformation there is Forest Cover Density (FCD) model. According to [3] explains that FCD is the development of spectral transformation in density estimate...
and tropical forest vegetation structure. The FCD model was developed by [4] which became the model of vegetation mapping used by the International Timber Trade Organization (ITTO). The FCD model has advantages over other generic vegetation indices. The superiority of the FCD model is the vegetation structure density information in the form of vegetative structural composition obtained from four FCD modeling index comprising AVI (Advanced Vegetation Index), BI (Baresoil Index), SI (Shadow Index), and TI (Thermal Index). The FCD model utilizes various remote sensing imagery bands from the visible band to the thermal infrared band of Landsat satellite imagery.

The result of FCD model is forest density information both vertically and horizontally (structural composition). For example, there is case of changes in forest structural composition in Lore Lindu National Park area. This study aims to analyze the ability of Landsat's image capability in the Forest Cover Density (FCD) model to map structural composition of vegetation and to study the rate of change in the class of vegetation structural composition.

2. Study Area
The research was conducted in part of Lore Lindu National Park, which is administratively located in Sigi Regency, Central Sulawesi Province. The study area has an area of ± 97,204,7 ha that stretches from north to south in the western part of Lore Lindu National Park area and consisting of eight districts. Climatic characteristics of the study area that has a rainfall between 2000 - 4000 mm/year with climate type A to climate type D. Elevation in the study area ranges from ± 100 - 1900 mdpl which is dominated by mountain morphology.

3. Data
The data used in the extraction of structural compositions is Landsat 7 ETM+ recording of September 28, 2002 and Landsat 8 OLI recording image dated September 8, 2015. Landsat 7 ETM+ has 8 spectral bands meanwhile Landsat 8 OLI contains 11 spectral bands. In addition, SRTM image data is also used for slope extraction and aspect in terrain correction. The RBI map is also used as a reference for the pre-processing stage, as well as the Zoning Map of the Lore Lindu National Park Area as the reference for the study area.

4. Methods
4.1. Transformation of FCD (Forest Cover Density) Model
The transformation of the FCD model is the method used to identify the structural composition of vegetation. This model uses four kind of index calculation: vegetation index using Advance Vegetation Index (AVI), soil index using Bare Soil Index (BI), Shadow Index (SI) and temperature index using Thermal Index (TI). Here are the formulas of the four indices [5].

\[
\text{AVI} = \left(\frac{\text{NIR Band} \times (256 - \text{Red Band}) \times (\text{NIR Band} - \text{Red Band}) + 1}{3}\right)^{1/3} \\
\text{BI} = \frac{((\text{SWIR Band} + \text{Red Band}) - (\text{Blue Band} + \text{NIR Band}))}{((\text{SWIR Band} + \text{Red Band}) + (\text{Blue Band} + \text{NIR Band}))} \\
\text{SI} = ((256 - \text{Blue Band}) \times (256 - \text{Green Band}) \times (256 - \text{Red Band}))^{1/3} \\
\]

The determination of the surface temperature values obtained from the thermal infrared bands is changed from the following radians values.

\[
L_\lambda = (\text{Gain} \times \text{DN}) + \text{Bias} \\
T = K2 / \ln \left(\frac{K1}{L_\lambda} + 1\right)
\]
Information:
- \( L_\lambda \) = Radians value watt/(m² * m*ster*µm)
- Gain = \( L_{max} - L_{min} / DN_{max} - DN_{min} \)
- DN = Digital number
- Bias = \( L_{min} \)
- \( T \) = Surface temperature value (C)
- \( K_1 \) = 666.09 watt/(m² * m*ster*µm)
- \( K_2 \) = 1282.71 watt/(m² * m*ster*µm)

A high FCD value that is a forest appears if the vegetation index and the shadow index are high. A low FCD value that is a shrubs object appears if the ground index and thermal index are moderate. Grassland objects have a high vegetation index and a low shadow index. If the vegetation index and the shadow index are low then the visible object is open ground. Based on the appearance so that it becomes the basis of the relationship between the indexes that build the FCD model. The following combinations of four index characteristics in the FCD are presented in Table 1.

|        | Forest | Shrubs | Grass | Soil |
|--------|--------|--------|-------|------|
| AVI    | High   | Middle | High  | Low  |
| BSI    | Low    | Low    | Low   | High |
| SI     | High   | Middle | Low   | Low  |
| TI     | Low    | Middle | Middle| High |

Source from [4]

The results of the index are then downgraded to the values of vegetation density (VD) and Scaled Shadow Index (SSI). VD is a derivative of a combination of Advance Vegetation Index (AVI) and Bare Soil Index (BI). While SSI is derived from a combination of Shadow Index (SI) and Thermal Index (TI). The next stage to get FCD is by integration between VD and SSI using the following formula.

\[
FCD = (VD \times SSI + 1)^{1/2} - 1
\]

4.2. Changes Detection

According to [6] explained that the study of change is capable of producing data and information that is (1) changing zones / regions as well as the rate of change, (2) the spatial distribution of changes, (3) the stages of change, (4) the accuracy of the results of the change study. The change study is a step to see changes in vegetative structural composition resulting from FCD models in 2002 (early) and 2015 (end) monitoring. To identify such changes through algorithms available in digital image processing software and geographic information systems. Generally, the method used is the overlay method is a method that operates by overlapping the map to produce a map of the object changes studied. Through integration of FCD maps of early and final year yields result an information on changes in the vegetation structural composition as well as study changes in the study area.

The field check step is done by observing / checking the existing condition in the field. Checking was done on crown density, tree height and vegetation composition using 30 sample points. The accuracy test process in this research uses the accuracy test method with Standard error of estimation and Confidence level analysis to test the result of the vegetative structural composition of the FCD model. Selection of this method because the result of image processing that is map of structural composition of vegetation is ordinal data with certain range.
Figure 1. Flowchart of research
5. Result and Discussion

5.1. Structural Composition of Vegetation

The structural composition is a description of the horizontal density and the vertical density of vegetation in relation to the layer structure of vegetation. The structural composition is the result of the extraction of the Forest Cover Density (FCD) model consisting of several indices. Vegetation index, bare soil index, shadow index and thermal index as the parameters that make up the FCD model. The relationship between vegetation index and bare soil index shows negative correlation. So also in the shadow index and temperature index also showed negative correlation. The correlation is derived from a principle component analysis (PCA) which in principle aims to reduce the dimensions of information that can provide more complete new information. The principle component analysis (PCA) on the vegetation index with open soil index formed the percentage of vegetation density (VD), meanwhile principle component analysis (PCA) on shadow index and thermal index formed a scaled shadow index (SSI). Next step is integrating VD and SSI to produce FCD that shows structural composition of vegetation. The vegetative structural composition of the FCD model results is illustrated in the vegetation layer structure associated with the percentage of vegetation density from low to high that can be interpreted from grass, shrubs, bush, bushes and forest.

![Structural composition of vegetation in part of Lore Lindu National Park](image)

Figure 2. Structural composition of vegetation without terrain correction

The structural composition of vegetation in 2002 presented 5 classes dominated by forest classes with a range of values between 214 - 255 which has an area of 59,838.1 ha. Based on Figure 2. the appearance of the forest class is spread over the topography of the surface from flat (plains) to very steep (mountain), but the majority of the appearance lies on the topography of the steep surface.
Table 2. Structural composition of vegetation classes in 2002

| Class Structural Composition | Area (ha) | Percentage |
|------------------------------|-----------|------------|
| Floor/Ground Layer (Grass)   | 190.8     | 0.2%       |
| Shrub Layer (Shrubs)         | 421.9     | 0.4%       |
| Understorey (Bush)           | 2,270.9   | 2.3%       |
| Midstorey (Bushes)           | 31,001.4  | 31.9%      |
| Upperstorey (Forest)         | 59,838.1  | 61.6%      |

Source: Data Analysis, 2016

The result of the vegetative structural composition of the FCD model transformation on Landsat image 2015 also shows 5 classes. The shrub class with a range of values 132 - 173 dominates the area of study which has an area of 41,686.3 ha. In general, the class is scattered throughout the northern and central parts of the study area that the majority lies on the topography of the surface from flat to very steep.

Table 3. Structural composition of vegetation classes in 2015

| Class Structural Composition | Area (ha) | Percentage |
|------------------------------|-----------|------------|
| Floor/Ground Layer (Grass)   | 1,137.6   | 1.2%       |
| Shrub Layer (Shrubs)         | 7.124     | 7.3%       |
| Understorey (Bush)           | 41,687.3  | 42.9%      |
| Midstorey (Bushes)           | 37,198.4  | 38.3%      |
| Upperstorey (Forest)         | 9,902.9   | 10.2%      |

Source: Data Analysis, 2016

Figure 3. Structural composition of vegetation with terrain correction
The structural composition of vegetation with terrain correction in 2002 also featured 5 classes dominated by forest classes with a range of values between 214 to 255 which has an area of 50,949.7 ha. Based on Figure 3, the appearance of forest class is the most dominant class located on the topography of the surface from flat to very steep.

Table 4. Structural composition of vegetation classes with terrain correction in 2002

| Class Structural Composition | Area (ha) | Percentage |
|-----------------------------|-----------|------------|
| Floor/Ground Layer (Grass)  | 2.281,7   | 2,3 %      |
| Shrub Layer (Shrubs)        | 5.248,1   | 5,4 %      |
| Understorey (Bush)          | 11.152,4  | 11,5 %     |
| Midstorey (Bushes)          | 24.456,6  | 25,2 %     |
| Upperstorey (Forest)        | 50.949,7  | 52,4 %     |

Source: Data Analysis, 2017

The result of the vegetation structural composition of the FCD model transformation with terrain correction in Landsat image 2015 also shows 5 classes. The result of the structural composition with terrain correction is dominated by shrub class with a value range between 173 to 214 and has an area of 54,923 ha. The majority of the vegetation structural composition classes that dominate the study area lie on the steep surface topography.

Table 5. Structural composition of vegetation classes with terrain correction in 2015

| Class Structural Composition | Area (ha) | Percentage |
|-----------------------------|-----------|------------|
| Floor/Ground Layer (Grass)  | 1.596,2   | 1,6 %      |
| Shrub Layer (Shrubs)        | 3.991     | 4,1 %      |
| Understorey (Bush)          | 11.328,1  | 11,7 %     |
| Midstorey (Bushes)          | 54.923    | 56,5 %     |
| Upperstorey (Forest)        | 21.441,6  | 22,1 %     |

Source: Data Analysis, 2017

The next step after obtaining the map of the vegetation structural composition is the accuracy test. The accuracy test used standard analysis of estimation and Confidence level analysis on the vegetation structure composition map of 2002 and 2015. The accuracy test result is the accuracy value of map of vegetation structure composition both in 2002 and 2015 with field observation data. Accuracy on the map of structural composition obtained by 67.2% in 2002 and 78.3% in 2015. In addition, the accuracy test conducted on the structural composition of vegetation FCD model with terrain correction in 2002 and 2015 each has a value Amounted to 75.3% and 79.4%.

5.2. Structural Composition of Vegetation Changes

The multitemporal study is one of the hallmarks of remote sensing making it possible to see changes in the object of study. The study of changes in this research resulted in a map of changes in the vegetation structural composition of each pixel of the FCD model transformed map. The map of the change is a map compiled based on overlay techniques on the structural composition of the vegetation map of 2002 and 2015. All pixels on both maps are arranged to see how the changes and extent of the changes are. The assumptions constructed in the consideration of changes in vegetation structural composition are changes in the composition layer and vegetation structure in relation to the density and height of vegetation structure stands.

The change in the structural composition of vegetation is evident with the visualization of a 30-class change map that is 30 possible from changes in the structural composition of vegetation. The change is an assumption of changes in every class such as grass, bush, bushes, shrub and forest as well
as non-vegetation objects that indicate changes in the structural composition of vegetation is reduced and increased, for example from forest class to shrub class. In addition there are 5 classes of vegetation structural composition that is not changed.

Based on data analysis and map of change of structural composition of vegetation, it can be explained that the total area of class of vegetation structural composition change is decreased 66,255.5 ha, while the class of change of vegetation structural composition is increased 10,699.9 ha and vegetation structural composition class still have area of 20,249.3 ha. The majority of the class changes in the structural composition of vegetation encountered in the class is reduced especially in the forest class into a shrub with an area of 31,712 ha. The class of vegetation structural compositional changes is increasing which has the largest area of the shrub class into a forest with an area of 5,673.6 ha.

![Structural composition of vegetation changes](image)

**Figure 4.** Structural composition of vegetation changes in part of Lore Lindu National Park
6. Conclusions
Transformation of FCD model can produce data and information structural composition of vegetation. Class structural compositions consist of 5 classes based on layers or layers of vegetation structures. The accuracy test on the result structural composition of vegetation using FCD model in 2002 was 67.2%, while the accuracy test of FCD model 2015 was 78.3%. The accuracy test of vegetation structural composition with terrain correction using FCD model in 2002 was 75.3%, while the accuracy test of the FCD model in 2015 was 79.4%. Accuracy to the structural composition of vegetation includes the intermediate level due to the difference in radiometric resolution of the image used. Decreasing in the structural composition of vegetation is 66,255.5 ha. On the other hand, the increasingly changing class has is 5,673.6 ha, while stable structural composition of vegetation is 20,249.3 ha. Decreasing in the structural composition of vegetation with terrain correction is 45,456.8 ha. In addition, the increasingly changing class is 20,866.7 ha, while stable structural composition of vegetation with terrain correction is 30,881.2 ha.

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