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Outlook for carbon stock of tropical forest in the context of climate change

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Abstract. There has been a large increase in understanding the relationship between aboveground forest biomass and climate change in recent years. Aboveground Biomass (AGB) estimation is very important in understanding the contribution of forests to the regional carbon cycle. AGB in tropical forest areas is often carried out by utilizing the transformation of the vegetation index because the value obtained is a combination of several channels in the image to highlight the appearance of vegetation. Difficulties in field surveys due to tropical forest field conditions transform the vegetation index calculation is an effective alternative approach to estimate biomass. The purpose of this study is to estimate biomass by utilizing remote sensing data to estimate carbon stock. The study was conducted on tropical forests in Solok Regency, West Sumatra Province. The method used is calculating the surface biomass content with the index value of each transformation of the vegetation index type. The results of this study show the level of accuracy and total carbon content of each transformation of the vegetation index type (NDVI, TNDVI, RVI, TRVI). NDVI is the best accuracy for estimating biomass density with R^2 of 60%. The surface biomass estimates in Solok Regency as 115.6 tons/ha. The amount of stored surface biomass varies, depending on the level of greenness and the age of the vegetation.

1. Introduction

Accurate estimation of tree biomass is crucial to understand the process of carbon cycles in the forest [1]. Remote sensing has provided an important understanding of the relationship between aboveground forest biomass (AGB) and climate change through AGB mapping using the remote sensing [2]. Remote sensing has proven its ability to collect spatial and spectral data with good resolution. Remote sensing also allows researchers to study at different depths of scale through satellite observations of large areas with more frequent frequencies [3].

Many researchers use vegetation index analysis to estimate the biomass of forest areas. The field survey measurement methods take much time and costly while using the remote sensing processing it provides a cost-effective approach. It can be used to detect the changes in vegetation for a wide spatial scale [4]. Information about AGB is needed to estimate ecosystem activity and the carbon cycle that results from changes in vegetation [5].

Photosynthesis in the forest must not be disturbed because it will affect the cycle of CO_2 and O_2 (carbon cycle) in the atmosphere [6]. Indonesia has abundant forest resource potential as one of the largest in the world. Forests have an essential role in maintaining climate stability in the world. Indonesia must be able to maintain the carbon cycle as ideal as possible. Solok Regency is located in the Province of West Sumatra; this region is one of the regencies that have a large forest area. The Solok Regency



government is also committed to maintaining the quality of tropical forests by doing proper planning [7].

The REDD is a concept that provides incentives for developing countries to reduce deforestation and keep carbon emissions within reasonable limits. It is hoped that the concept of REDD can withstand the pace of climate change [8]. Forest change affects the carbon cycle globally, then influences the climate and biodiversity in it [9].

Materials and Methods

1.1. Study area

The research location was conducted in Solok Regency, West Sumatera Province, Indonesia. Geographically, Solok regency lies between $00^{\circ} 32' 14''\text{S}$ and $01^{\circ} 46' 4''\text{S}$ and $100^{\circ} 25' 00''\text{E}$ and $101^{\circ} 41' 41''\text{E}$. The topography of the region varies significantly between plains, valleys, and hills, with altitudes between 329 meters – 1,458 meters above sea level [10]. The area of Solok regency is 373,800 hectares that consist of 14 district and 74 villages. The landscape is varied with the highlands in the south to center and the lowlands in the north. The natural landscape of the central part of Solok is a mountainous and hilly area that stretches from southwest to southeast. In general, the areas in the highlands is above 1,400 meters above sea level between Alahan Panjang and Nanam River. While the relatively sloping area is on the slopes of Mount Talang starting from Guguk, Batu Bajanjang, Bukit Sileh to the north until Koto Anau, Koto Laweh, Dilam, Parambah. Furthermore, the lowland areas are Koto Baru, Muara Panas, Bukit Tandang, Kinari, Panyakalan, Selayo, Solok, Gaung, Saok Laweh, Sumani, and Singkarak. In the southern most of Solok Regency, there are also many lowlands. This is especially the area of Sungai Pagu which is the estuary of the Batang Kerasi flow. The wavy area stretches from Liki to Lubuk Gadang. The area is a tropical climate with a temperature range of $18\text{-}30^{\circ}\text{C}$ and an average rainfall of 2,054 mm per year [7].

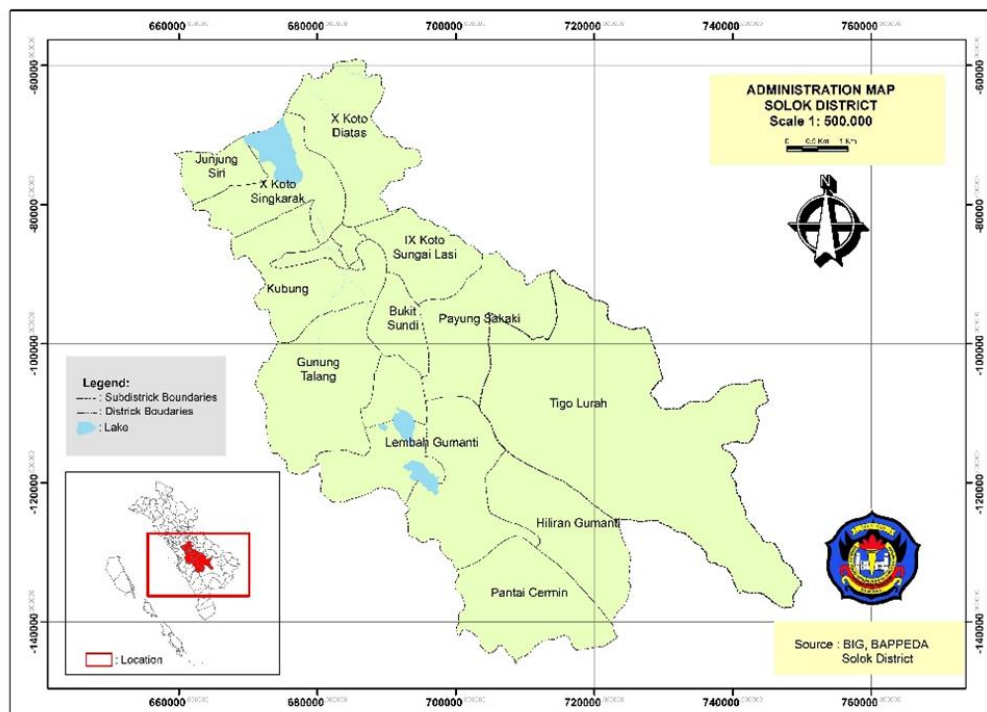


Figure 1. Administrative map of Solok Regency.

The border of Solok Regency at the north is Tanah Datar Regency while in the south with Pesisir Selatan Regency and Jambi Province. It also has a border with the City of Padang in the west and

Sijunjung Regency in the east (Figure 1). This position puts Solok Regency into a strategic area because it is a connecting area for several cities in West Sumatra and Jambi such as Padang Panjang, Padang, Sawah Lunto, Muaro Bungo, and Sungai Penuh.

1.2. Tools and Material

This study uses a tool in the form of ENVI 5.2 and ArcGIS 10.4 software for processing satellite image data. Ms. Office Word and Ms. Office Exel are used for processing and analyzing data attributes. Garmin 64s GPS and field checklist for Ground check purposes. The material used are the Indonesian Basic Map for Solok Regency (Sheet: 0715-34, 0815-13, 0814-14, 0815-11, 0815-12, 0815-21, 0814-43, 0814-44, 0814-53, 0814-42, 0814-51, 0814-52) Scale 1:50,000, Landsat 8 OLI (Path 127 row 60 dan Path 127 Row 61) recording on August 7, 2016.

2. Methods

The method used in this research is visual and digital remote sensing image interpretation. The stages of this research include radiometric correction, geometric correction and vegetation index formulation. The radiometric correction needs to be done for processing of Landsat 8 OLI imagery because the characters possessed on the sensors that record the digital number [11]. Landsat 8 also has two instruments, such as The Operational Land Imager and The Thermal Infrared Sensor [12]. There are three stages of the radiometric correction process. The correction is done to make the digital number of each pixel into a unit of radiance sensor ($W/(m^2 \cdot sr \cdot \mu m)$). The second stage is the conversion from radiance sensor to a reflectance sensor; the use is to reduce the variability between images. The final radiometric correction stage is the conversion of sensor reflectance to surface reflectance to conduct relative atmospheric correction.

The Landsat 8 OLI TIRS acquisitions are precision terrain corrected. Geometric correction using ground control and using a DEM to correct parallax error due to local topographic relief [13]. The geometric correction of Landsat 8 has not been processed using the image to image method but is preferably using another image which geometric correction has been done.

Processing of Landsat 8 OLI image after the radiometric and geometric correction was carried out by transformation of the vegetation index. The value obtained is a combination of several spectral bands to highlight the value of the vegetation. The vegetation index is an optical measurement of the greenness level of vegetation canopy, composite properties of leaf chlorophyll, leaf area, structure and vegetation canopy cover [14,15]. Accuracy tests are also carried out to compare the values of the surface carbon content. In the accuracy level test process, regression equations (Table 1) have been obtained from each used index [16].

Table 1. Vegetation index formula.

Formula	Vegetation Index Type	Formula	Source
NDVI	Normalized Different Vegetation Index	$\frac{(NIR - Red)}{(NIR + Red)}$	[17]
TNDVI	Normalized Different Vegetation Index	$\left(\left[\frac{(NIR - Red)}{(NIR + Red)} + 0,5 \right] \right)^{\frac{1}{2}}$	[17]
RVI	Ratio Vegetation Index	$\frac{NIR}{Red}$	[18]
TRVI	Transformed Ratio Vegetation Index	$\left(\frac{NIR}{Red} \right)^{\frac{1}{2}}$	[18]

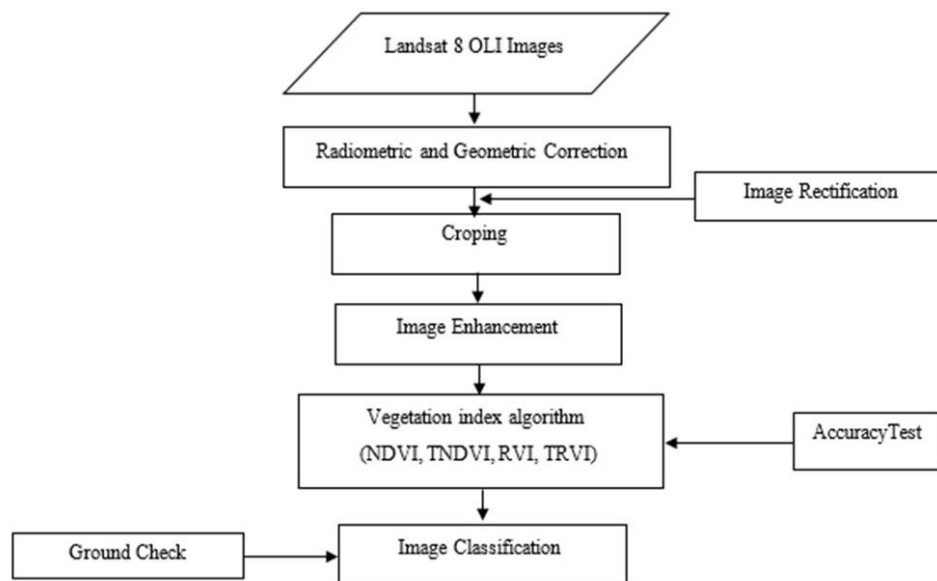


Figure 2. Workflow analysis.

3. Results and Discussion

3.1. Land Use of Solok Regency in 2016

Based on the interpretation of Landsat 8 OLI imagery of 2016, it was identified that there are nine types of land use. They are Primary Forest, Secondary Forest, Paddy Field, Settlement, Mixed Plantations, Crop Fields, Water Bodies, Bushes, Plantations. The area of each land use type describes in table 2 [19].

SolokRegency is cover with forest for more than 50% of its area. Forest areas are spread evenly throughout the western and southern regions, then spread quite widely in the southeast part of Solok Regency. In the forest, there are plants or trees that are long-lived and large-sized so that they can be a storage place for biomass above and in the soil. Based on the area of Solok regency, which is mostly forested, this study is more focused on analyzing forest areas. Spatial distribution of land use in Solok Regency presented in figure 3.

Table 2. Land use classification in Solok Regency.

No	Land use	Area (ha)	Percentage
1	Primary Forest	159,544	47.31
2	Secondary Forest	14,679	4.35
3	Paddy Field	45,591	13.52
4	Settlement	3,963	1.18
5	Mixed Plantations	76,478	22.68
6	Crop Fields	27,489	8.15
7	Water Bodies	6,690	1.98
8	Bushes	2,165	0.64
9	Plantations	620	0.18
Total		337,220	100

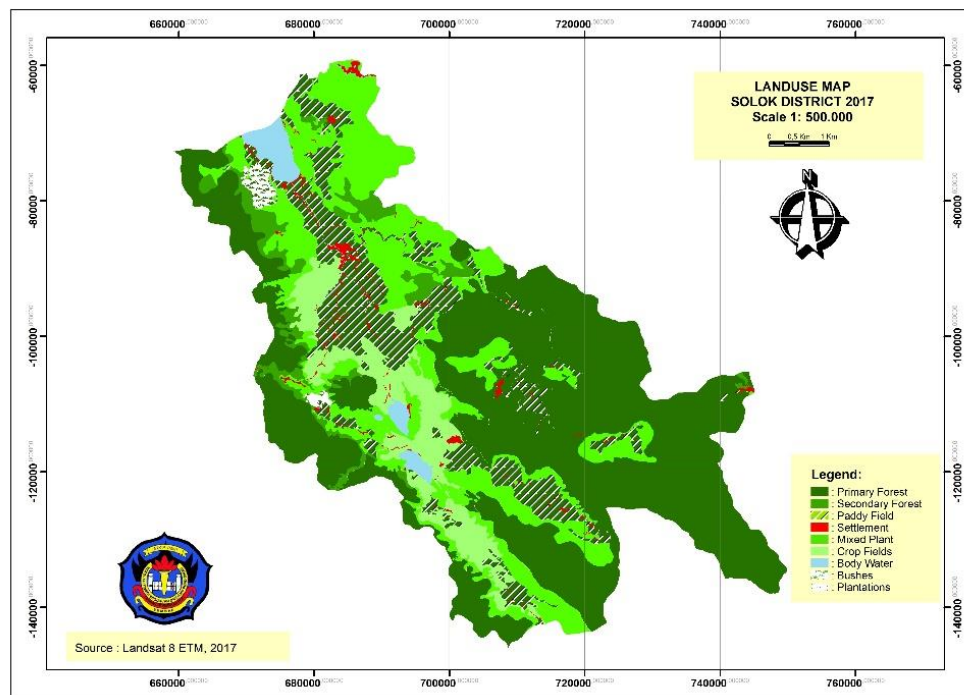


Figure 3. Land use map of Solok Regency.

3.2. Vegetation Index

Vegetation Index spectral value then used to calculate a regression equation that as a parameter between the four vegetation index methods. The result of the regression formula and R^2 for each vegetation index presented in table 3. The R^2 value is the value that gives instructions to determine the correlation between the variables that are connected. Based on the 8 regression equation models obtained, then the highest regression model is selected. Further can be seen in the table of regression equations and the coefficient of determination of each vegetation index in table 3.

Table 3. Correlation and Equation of vegetation index.

Correlation	Equation	R^2
Biomass-NDVI (Average)	$y = -189,4x^2 + 440,3x - 105,1$	0.607
Biomass-NDVI (Median)	$y = -80,65x^2 + 318,2x - 72,30$	0.583
Biomass-TNDVI (Average)	$y = -638,6x^2 + 1694,x - 995$	0.506
Biomass-TNDVI (Median)	$y = -257,4x^2 + 939,2x - 605$	0.501
Biomass-RVI (Average)	$y = 62,75\ln(x) - 23,95$	0.473
Biomass-RVI (Median)	$y = 61,72\ln(x) - 22,84$	0.472
Biomass-TRVI (Average)	$y = 122,6\ln(x) - 18,95$	0.471
Biomass-TRVI (Median)	$y = 121,5\ln(x) - 17,65$	0.470

In general, the relationship between biomass and the vegetation index will be in the shape of a curve as shown in Figure 4, provided that there is only one type of plant in the forest and a different age.

However, the analysis result curve is not yet perfect. This is most likely due to the heterogeneous type of plant in the forest in Solok Regency, and the data used is less representative. In this study, the range of NDVI values was at 0.22-0.72. Provided that if there is a value below 0.22, it will be assumed to be 0.22. Moreover, if there is a value of more than 0.72, it will be assumed to be a value of 0.72. This is done to avoid estimation values that are lacking or excessive.

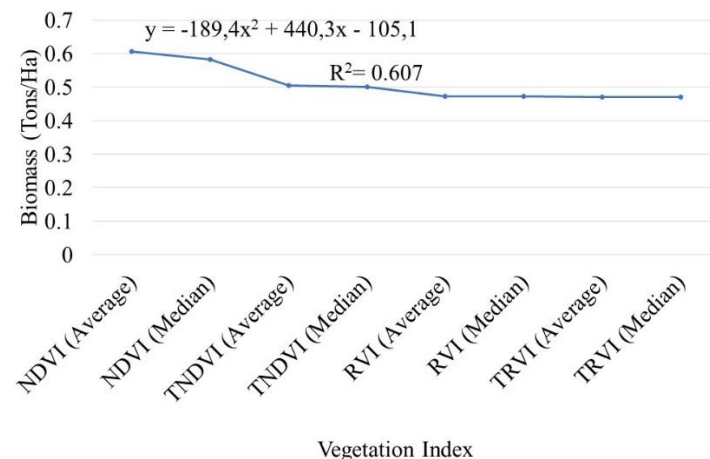


Figure 4. Estimation of biomass from different types of vegetation index.

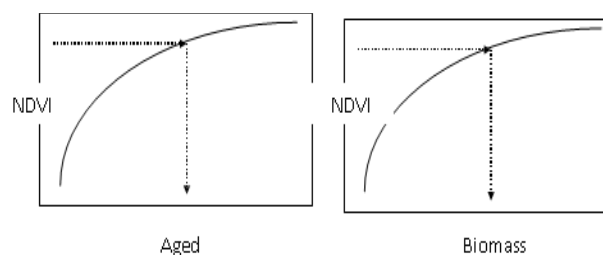


Figure 5. NDVI Curve with Tree Aged and Biomass.

Based on the results of regression analysis between NDVI with carbon values in forest areas in Solok Regency with the coefficient of determination (R^2) of 0.607 or it can be said that 60% of carbon values can be explained by the NDVI variable. Based on this, the total carbon value obtained using the NDVI vegetation index is 115.6 tons/ha. Research conducted [20] shows that the value of biomass in forests is 104.1 tons/ha. The acquisition of forest biomass values is relatively the same as the estimation results in this study.

4. Conclusions

There are nine of land use type in Solok Regency with dominantly cover by forest area. The forest area is spread on the west to the south side; then the forest area is also quite wide in the southeast with varied topography. NDVI becomes the best vegetation index formulation for carbon estimation. The total carbon value obtained using NDVI vegetation index is 115.6 tons/ha.

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