Estimation of Carbon Stock Stands using EVI and NDVI vegetation index in production forest of lembah Seulawah sub-district, Aceh Indonesia

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Abstract - This study aims to determine the distribution of the vegetation indexes to estimate the carbon stocks of forest stands in the Production Forest of Lembah Seulawah sub-district. Aceh Province, Indonesia. A non-destructive method using allometric equations and landscape scale method were applied, where in carbon stocks at the points of samples are correlated with the index values of each transformation of the vegetation indexes; EVI and NDVI. Results show that EVI values of study area from 0.05 to 0.90 and NDVI values from 0.17 to 0.85. The regression analysis between EVI with carbon stock value of sample locations equation is $Y = 151.7X-39.76$. with the coefficient of determination (R^2) is 0.83. From this calculation, the total carbon stocks in the Production Forest area of Lembah Seulawah sub-district using EVI is estimated 790.344.41 tonnes, and the average value of carbon stocks in average is 51.48 tons per hectare. Regression analysis between NDVI values at the research locations for the carbon stack measured samples *is $Y = 204.Xx-102.1$* with coefficient of determination (R^2) is 0.728. Total carbon stocks in production forest of Lembah Seulawah sub-district using NDVI is estimated 711.061.81 tones. and the average value of carbon stocks is 46.32 tons per hectare. From the above results it can be concluded that the vegetation indexes: EVI and NDVI are vegetation indexed that have a very close correlation with carbon stocks stands estimation. The correlation between EVI with carbon stock and the correlation between NDVI with carbon stock is not significantly different.

Keywords: Vegetation index. Production Forest, Carbon stock, EVI and NDVI

Introduction

Nowadays, global warming is an environmental problem commonly discussed both in academic and nonacademic situations. Global warming is defined as the recent and ongoing rise in the global average temperature near Earth's surface (Environmental Protection Agency. 2007). Intergovernmental Panel on Climate Change (2007) has indicated that most of the observed areas in the world have shown that an increasing of global average temperatures since the mid-20th century is most likely due to the increase in anthropogenic greenhouse gas concentrations. The greenhouse effect is a result of rising concentrations of carbon dioxide (CO_2) and other gases in the atmosphere. The increase concentration of CO_2 is caused by the combustion of organic materials that exceed the capabilities of vegetation and sea to absorb them. Vegetation in the tropic, especially tropical forest vegetation has significantly contributed to reduce global

warming and associated with climate change has provided useful information for the complex coupling of the biosphere and the atmosphere (Piao *et al*, 2014).

Tropical forest vegetation has a strong role in local and global climate change. and plays a prominent role in the global C cycle (IPCC. 1996; Dixon *et al*.. 1994). Vegetation absorbs CO_2 in the atmosphere (carbon sink) through photosynthesis and stores the carbon in plant structures (Dixon et al.. 1994). The flow of carbon from the atmosphere and vegetation is a two-way flow with fixation of carbon into biomass through photosynthesis and carbon is released to the atmosphere through decomposition and combustion processes (Lasco. 2002).

However deforestation in tropical regions is considered as the second largest source of greenhouse gas emissions (IPCC. 2007) and it is believed to remain the main source of emissions in the future (Millennium Ecosystem Assessment. 2005). Deforestation and forest degradation can result in more carbon emissions expelled to the atmosphere, thus affecting the global climate and environmental changes (Achard *et al*.. 2004; Frolking *et al*.. 2009; Hansen *et al*.. 2013). On the other hand, the possibility of expanding carbon sequestration in forests has been identified as a potential way to mitigate climate change (FAO. 2001; DeFries *et al*.. 2000).

Aceh Besar district has an extensive production forest area about 68.506.97 Ha. Aceh province is currently in a period of moratorium logging. As a result, the main function of forest product production is as a producer of timber and non-timber forests cannot run optimally. Under these conditions, the production forest can be used as a carbon sink as part of to reduce global warming.

Currently a concern of global changes and ecosystem functions requires accurate estimates of biomass and the monitoring of the dynamics of amendments (Le Toan et al.. 2011). Methods of field measurements at plot level are considered to give a fairly accurate value. However, when applied to a large area it becomes less efficient. The technique based on field measurements is the most accurate but difficult to do over large areas and has proven to be very expensive, labor-intensive and time-consuming (De Gier. 2003). Thus there is a need for a developed method of estimation and monitoring changes in carbon stocks in a more efficient way. One of these methods is by using remote sensing technology. Retrieval of vegetation properties such as leaf area index and indices using remotely sensed data is an efficient method compared to ground measurement (Fernandes *et al.* 2002; Mayr and Samimi, 2015)

Remote sensing technology is a technology that has been utilized in various fields of science and one of them is the forestry field. Currently, remote sensing has been widely used for gathering information about forest biomass (Drake *et al*. 2003. Le Toan *et al*.. 2004. 2011. Maynard *et al.*, 2007; Lu. 2006). Parameter of satellite imagery used in the process of estimating the biomass is vegetation index. Vegetation index is an index obtained through mathematical operations such as subtraction, addition and the ratio between the near infrared band with a red band of satellite imagery. The use of vegetation indices commonly used to estimate the biomass of which is normalized difference vegetation Index (NDVI) (*Rouse et al.* 1973) and enhanced vegetation index (EVI) *(Huete et al.* 1999).

Material and Methods

The research was conducted in the production forest in Lembah Seulawah sub-district, Aceh Province Indonesia for collecting field data. Ground checks and field data collection was conducted from April to July, 2016.

A handheld GPS, a compass, a Phi Band (Band diameter), a tape measure and a clinometer were used during the field data collection. Landsat 8 OLI Path 131 Row 56 date acquired on 18 January 2015 were utilized and tally sheet for dimensional measurements of trees containing the following information: species, number of trees, tree height diameter at above the ground

height (DBH) approximately 130 cm above the ground were used to calculate the carbon stock for selected stands of the Production Forest, Lembah Seulawah, Aceh.

A non-destructive method using allometric equations and NDVI and EVI indexes was performed. Non-destructive method is the method of calculation of the biomass measuring the diameter and height without the damaging of trees. Calculation of biomass with this method was carried out by using the allometric formula. Landscape scale method (NDVI) is a method of estimation of carbon stocks which utilizes satellite imagery. Image analysis can produce EVI and NDVI values for each selected study sites. The value of the EVI and NDVI were correlated with the calculated of the biomass measured in the fields. Spatial distribution maps of carbon stock and index value were performed. Selection of the sample areas based on the value of vegetation index distribution was carried out. Based on the index value, we selected 19 plots of the sample area.

Image Processing

Cropping and radiometric corrections were carried out for the Landsat image of the location. The following equation was used to convert DN values to TOA reflectance for OLI data:

$\varrho\lambda' = M_\varrho Qcal + A_\varrho$ ....(1)
where:
$\varrho\lambda'$ = TOA planetary reflectance, without correction for solar angle. Note that $\varrho\lambda'$ does not contain a correction for the sun angle
M_ϱ = Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x. where x is the band number)
A_ϱ = Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x. where x is the band number)
Q_{cal} = Quantized and calibrated standard product pixel values (DN)

Furthermore, the image of the sun's angle was corrected to eliminate the difference in the DN values caused by the position of the sun. The position of the sun to the earth changes depending on the recording time and location of the object to be recorded. The equation for correction with the angle of the sun, as follows:
$\varrho\lambda = \varrho\lambda'/(\cos(\theta SZ)) = \varrho\lambda'/(\sin(\theta SE))$
where:
$\varrho\lambda'$ = ToA reflectance
θSE = Local sun elevation
angle. The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION)
θSZ = sun zenith angle.
$\theta SZ = 90° - \theta SE$

A WGS 1984 datum of Universal Transverse Mercator (UTM) projection in Zone 46 N was selection to geo-referenced of the image of the location samples.

Vegetation Index

Normalized Difference Vegetation Index (NDVI)

To obtain the pixel values associated with biomass, the NDVI equation was used (*Rouse et al.* 1973)

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

NDVI : Normalized Difference Vegetation Index
NIR   : Near Infrared Band
Red   : Red Band

Enhanced Vegetation Index (EVI)
To compare the indexes distribution values for the research area, the EVI index equation was utilized *(Huete et al.* 1999):

$$EVI = 2.5x \frac{(NIR - RED)}{(NIR + C1 \times Red - C2 \times Blue + L)}$$

EVI   : *Ehnanced Vegetation Index*
NIR   : *Near Infrared Band*
Red   : Red Band
Blue   : Blue Band
C1   : values as coefficients for atmospheric resistance
             Value 6
C2   : values as coefficients for atmospheric resistance
             Value 7
L   : value to adjust for canopy background

Both NDVI and EVI indices are correlated with the calculation of carbon stock of the production forest of Lembah Seulawah sub-district. A determined coordinates of the sample plots were created to the image sample plots according to the field check. After the vegetation index image data was obtained then correlation was calculated with the results of the field data measurement.

Field Data Collection

Random plots of the area were made to collect the field data in the production forest. The number of plots in this study was 24 plots each with a size of 30 X 30 m, a similiar plot with the image used.

Biomass of stands' calculation.

Calculation of tree biomass using allometric equations is as follows. (Chave et al. 2005):

W = 0.0509 x ϱ x DBH^2 x T
W = the total biomass (kg)
DBH = diameter at above the ground (aproximately 130 cm)
ϱ = wood density (gr / cm3)
T = height (m)
In this allometric equation components or dimensions of the trees required is the diameter and height, and the weight information of each type of the wood. For the measurement of the diameter, the phi-band and the diameter were utilized to measure the tree diameter at above the ground height (± 130 cm) (D/DBH) and the measurement of tree height used a hagameter, while for calculating biomass in this study used a specific density of average wood 0.68 gr/cm3.

For the calculation of natural forest biomass, the average wood density in the area used the value of 0.68 g per cm^3 (Rahayu *et al.*. 2006). This value index number is based on the climate of

the research area where the precipitation in this area is 1500-2000 millimeter per year and it is classified as a humid climate (rainfall of 1500-4000 millimeter per year). This is consistent with the finding of Rahayu *et al.* (2006) and Samsoedin *et al.* (2009), both researchers used similar calculation for natural forest biomass with the average wood density of 0.68 gram per cm^3.

Based on the results of measurements of the diameter and height of stands on each plot sample, calculations of biomass were carried out, and then the entire calculation of biomass stands per hectare use following equation:

$$W = \frac{\sum_{i=1}^{n} Wpi}{A} \times 10.000$$

W   : Total Biomass (ton/ha)
Wpi   : Tree Biomassa (ton)
A   : Plot size (m^2)
n   : number of trees

Estimation of Carbon Stock

The content of carbon in forest vegetation can be inferred from forest biomass, by the equation as follows (Brown et al.. 1 996):
Y = W * 0.5
Y = above the ground carbon (t / ha)
W = Total of biomass per hectare (t / ha)

The biomass stands were calculated using allometric equations developed by Chave *et al.* (2005).

Correlation Model Between Carbon Stock Value with NDVI dan EVI Value.

Based on calculations of the carbon stocks estimation of the modeled correlation between carbon stocks and the value of NDVI and EVI was carried out. The correlations were calculated by the linear regression equation; y = a + bx. the values of a and b can be calculated using the following formula (Walpole. 1992):

$$b = \frac{n\sum_{i=1}^{n} x_i y_i - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}$$

$$a = \frac{\sum_{i=1}^{n} y_i}{n} - b\frac{\sum_{i=1}^{n} x_i}{n}$$

x = NDVI/EVI value
y = Carbon value

And then, the correlation analysis is calculated using the following Pearson correlation test equation:

$$r = \frac{n\sum\limits_{i=1}^{n} x_i y_i - \left(\sum\limits_{i=1}^{n} x_i\right)\left(\sum\limits_{i=1}^{n} y_i\right)}{\sqrt{\left[n\sum\limits_{i=1}^{n} x_i^2 - \left(\sum\limits_{i=1}^{n} x_i\right)^2\right]\left[n\sum\limits_{i=1}^{n} y_i^2 - \left(\sum\limits_{i=1}^{n} y_i\right)^2\right]}}$$

r = Coefficient correlation
n = Number of Plot
x = NDVI/EVI Value
y = Carbon Value

Based on the above calculation, a Pearson correlation of the carbon value with the NDVI and EVI were calculated to estimate the total carbon stock in the Production Forest of lembah Seulawah, Aceh.

Result and Discussion

Carbon Stock of the Plot Samples

The average of biomass and carbon stocks for each plot is presented in Table 1 below:

Table 1. The quantity of biomass for each plot of the research area based on the Allometric Equation calculation.

No. Plot	Biomass (kg/plot)	Biomass (kg/ha)	Biomass (ton/plot)	Biomass (ton/ha)
1	6,878.03	76,422.57	6.88	76.42
2	10,664.04	118,489.28	10.66	118.49
3	13,042.04	144,911.51	13.04	144.91
4	9,406.83	104,520.35	9.41	104.52
5	9,202.43	102,249.22	9.20	102.25
6	11,218.70	124,652.18	11.22	124.65
7	9,923.52	110,261.38	9.92	110.26
8	9,047.48	100,527.60	9.05	100.53
9	11,922.83	132,475.92	11.92	132.48
10	10,615.85	117,953.89	10.62	117.95
11	11,040.99	122,677.68	11.04	122.68
12	10,542.47	117,138.56	10.54	117.14
13	8,154.04	90,600.49	8.15	90.60
14	12,149.14	134,990.44	12.15	134.99
15	11,259.93	125,110.33	11.26	125.11
16	10,179.31	113,103.49	10.18	113.10
17	14,475.07	160,834.07	14.48	160.83
18	9,439.65	104,885.05	9.44	104.89
19	4,260.21	47,335.64	4.26	47.34
20	9,448.53	104,983.70	9.45	104.98

No. Plot	Biomass (kg/plot)	Biomass (kg/ha)	Biomass (ton/plot)	Biomass (ton/ha)
21	8,011.46	89,016.24	8.01	89.02
22	8,711.24	96,791.51	8.71	96.79
23	8,219.17	91,324.08	8.22	91.32
24	12,455.36	138,392.85	12.46	138.39
	240,268.32	**2,669,648.02**	**240.27**	**2.669.65**

The amount of forest biomass of the forest stand is shown in Table 2. Table 2 shows that the value of the smallest total carbon is in plot 19 with a value of 2.13 tons, equal to 23.67 tonnes/ha, while the highest biomass is obtained at plot number 17 with the value of 7.24 tons or equal to 80.42 ton per hectare.

Table 2: Carbon stock total for each sample plot of study area

Plot No.	Biomass (ton/plot)	Biomass (ton/ha)	Carbon ton/plot	Carbon (ton/ha)
1	6.88	76.42	3.44	38.21
2	10.66	118.49	5.33	59.24
3	13.04	144.91	6.52	72.46
4	9.41	104.52	4.70	52.26
5	9.20	102.25	4.60	51.12
6	11.22	124.65	5.61	62.33
7	9.92	110.26	4.96	55.13
8	9.05	100.53	4.52	50.26
9	11.92	132.48	5.96	66.24
10	10.62	117.95	5.31	58.98
11	11.04	122.68	5.52	61.34
12	10.54	117.14	5.27	58.57
13	8.15	90.60	4.08	45.30
14	12.15	134.99	6.07	67.50
15	11.26	125.11	5.63	62.56
16	10.18	113.10	5.09	56.55
17	14.48	160.83	7.24	80.42**
18	9.44	104.89	4.72	52.44
19	4.26	47.34	2.13	23.67*
20	9.45	104.98	4.72	52.49
21	8.01	89.02	4.01	44.51
22	8.71	96.79	4.36	48.40
23	8.22	91.32	4.11	45.66
24	12.46	138.39	6.23	69.20
	240.27	**2,669.65**	**120.13**	**1,334.82**

Vegetation Index Transformation

Vegetation index is a value obtained from a specific combination of several spectral bands from remote sensing imagery. Vegetation indices used in this study is Enhanced Vegetation Index (EVI) and Normalized Difference Vegetation Index (NDVI).

***Enhanced Vegetation Index* (EVI)**

Image processing algorithms of EVI result in the vegetation index values of the study area between 0.05 and 0.93. The distribution of EVI value in the area is as presented in Table 3:

Table 3. The Distribution of EVI Values of the study area

EVI Value	Area (ha)	Percentage (%)
0 – 0.20	7.83	0.05
0.21 – 0.40	497.17	3.24
0.41 – 0.60	6.893.15	44.90
0.61 – 0.80	7.912.16	51.54
0.81 – 1.00	41.07	0.27
Total	**15,351.38**	**100.00**

Spatial distribution of EVI values of Production Forest, Lembah Seulawah, Aceh is shown in Figure 1.
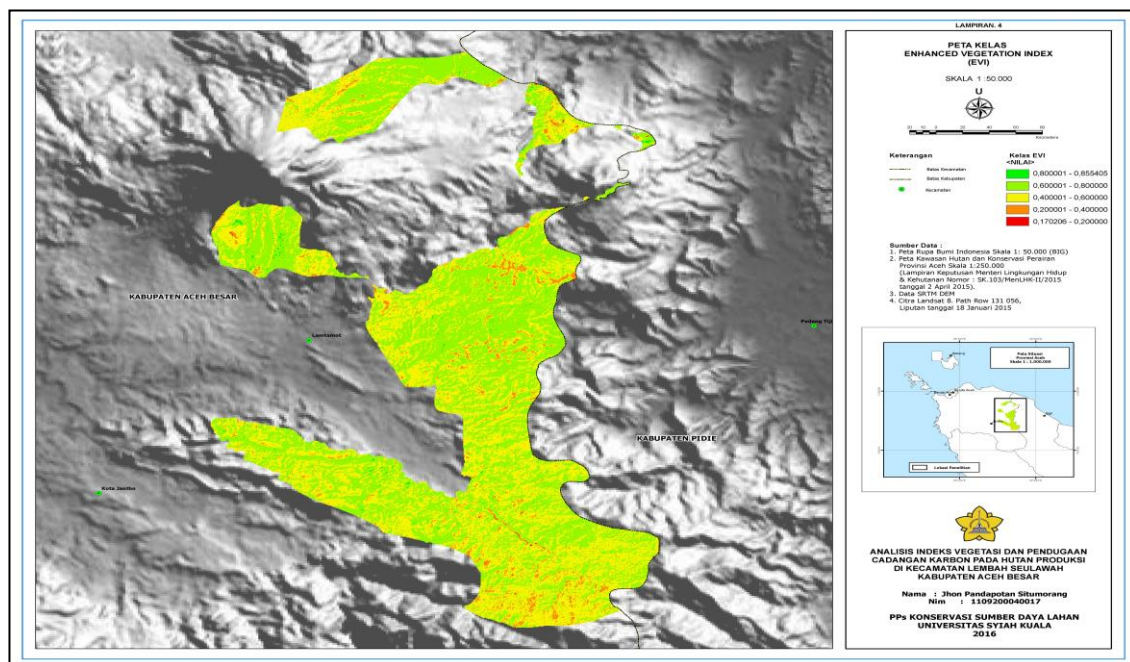
Figure 1. Spatial Distribution of EVI Values of Production Forest. Lembah Seulawah, Aceh.

Normalized Difference Vegetation Index (NDVI)

The NDVI algorithms for the Landsat image of the study area produced the values of vegetation index between 0.17 and 0.85. If we refer to the results obtained, it is known that

133

almost all the research areas were covered with vegetation. Distribution of NDVI value of the research area is presented in table 4:

Table 4. Total area based on the distribution of NDVI value in the study area

NDVI value	Area (Ha)	Percentage (%)
0 – 0.20	0.27	0.002
0.21 – 0.40	13.82	0.090
0.41 – 0.60	422.44	2.752
0.61 – 0.80	1,.764.49	83.149
0.81 – 1.00	2,150.36	14.008
Total	**15,351.38**	**100.000**

Spatial distribution of NDVI value in the Production Forest of Lembah Seulawah Sub-district, Aceh is shown in Figure 2.
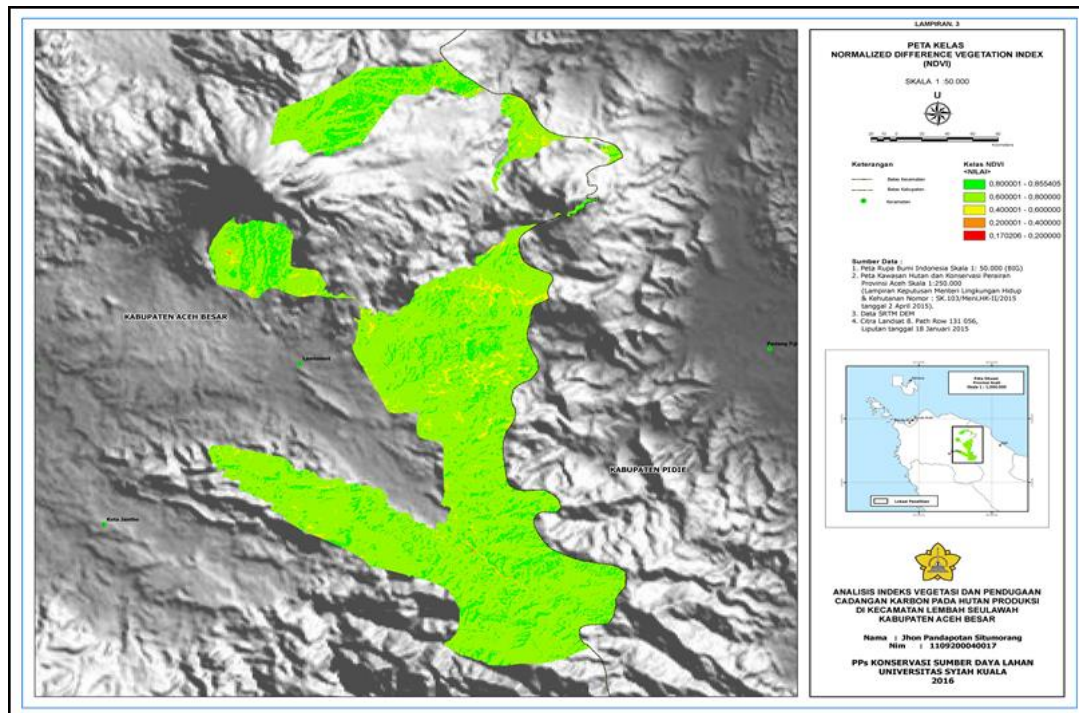
Figure 2. Spatial distribution of NDVI values of production forest, Lembah Seulawah, Aceh.

Vegetation Index Relationship With Value Content of Carbon Stock

Correlation between EVI and Carbon Stock of Stands

Regression analysis between EVI and the carbon value to determine the correlation between EVI and carbon stocks was obtained by using each value, represented by X (EVI index) and Y (carbon stock) values respectively. The regression analysis between EVI values and carbon obtained a model equation of *Y = 151.7X-39.76* with the coefficient of determination (R^2) = 0.83. This indicates that 83.0% of the value of carbon can be explained by EVI through a linear relationship. The relationship between EVI and carbon values is shown in Figure 3.
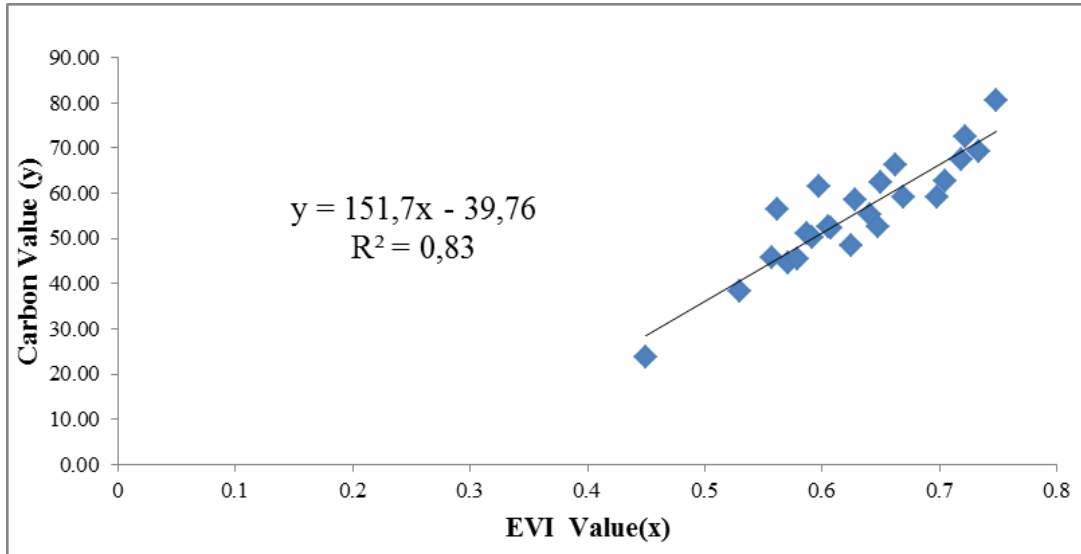
Figure 3. Linier correlation of EVI with the carbon stands total in Lembah Seulawah, Aceh

Correlation between NDVI and Carbon Stock of Stand Forest

Regression analysis was conducted to correlate the NDVI value with the carbon stock value at the research sample plots. Estimation of carbon stock (Y value) and NDVI value (X variable for each plot were then used as input data to calculate the regression analysis of NDVI and carbon stock. The regression analysis between NDVI values and carbon stock using the linear regression equation of y = a + bx obtained a model equation of *Y = 204.3X-102.1* with the coefficient of determination (R^2) = 0.728.

The value of coefficient of determination (R^2) = 0.728 indicates that 72.8% of the carbon value can be explained by the NDVI through a linear regression obtained. The relationship between NDVI and carbon values is shown in figure 4.
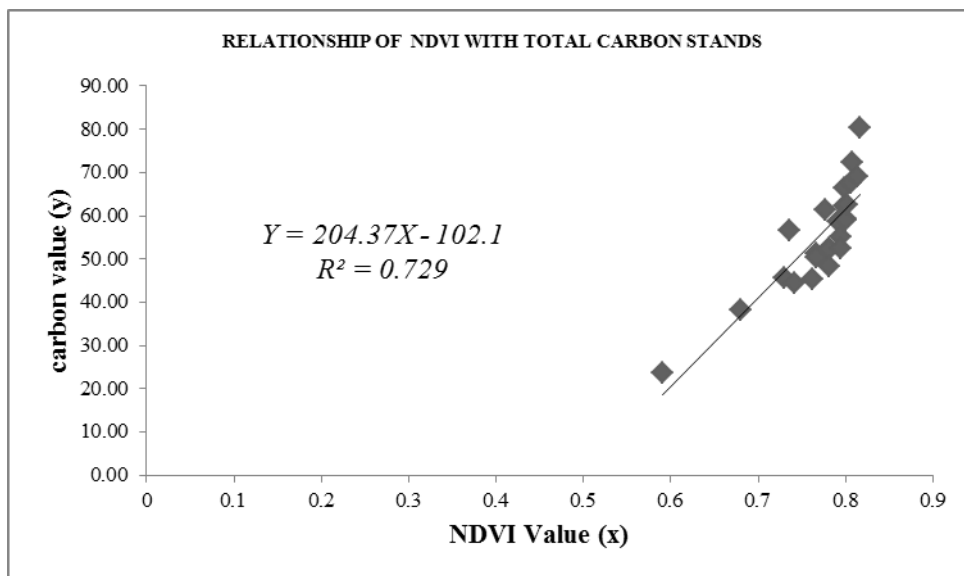

Figure 4. Linier correlation between NDVI and carbon stock in the Production Forest Area, Lembah Seulawah, Aceh.

135

Estimation of 1 Carbon Stock Total

Through the results of linear regression analysis the relationship between carbon stocks by value of Vegetation Index was obtained. Through these equations, carbon stocks of the research area can be estimated.

Estimation of Total Carbon Stock based on EVI value

Carbon Stock using EVI in the production forest of Lembah Seulawah district was calculated using the regression analysis equation $y = 151.7x-39.76$, with a coefficient of determination (R^2) that is equal to 0.83. From the calculation results obtained, the total carbon stocks in production forest of Lembah Seulawah, Aceh was 790.344.41 tonnes, and the average of carbon stocks is 51.48 tonnes per hectare. The distribution of carbon stocks using EVI vegetation index is presented in figure 5.
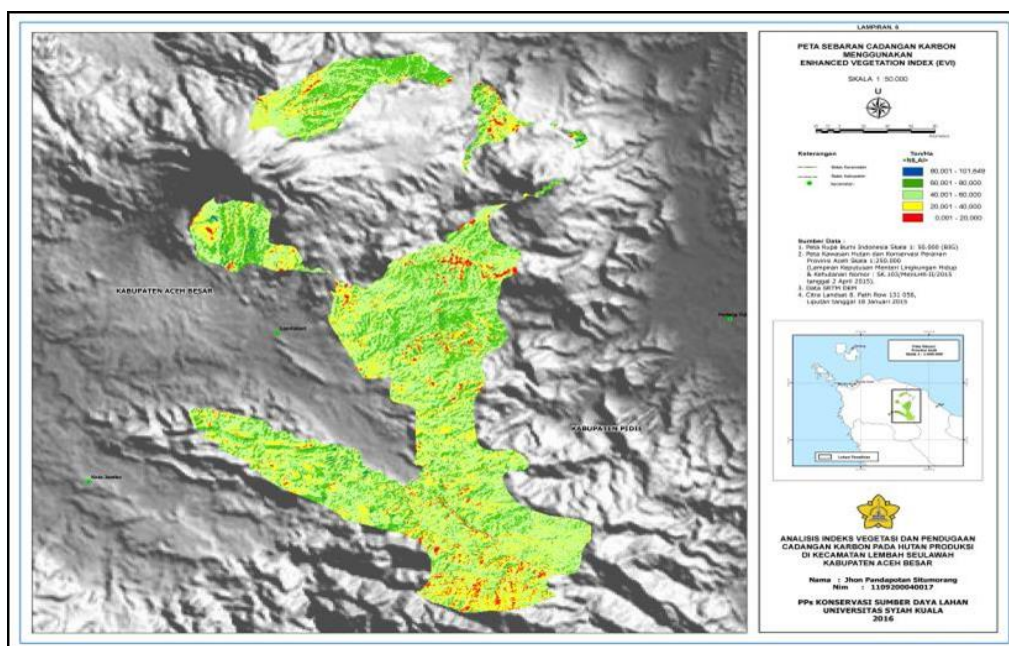

Figure 5: Spatial distribution of Carbon Stocks Stand in Lembah Seulawah. Aceh based on EVI value

Estimates of Total Carbon Stock based on NDVI value

Carbon Stock Value using NDVI in production forest in lembah seulawah district was calculated using the regression analysis equation 204.3x-102.1 with the coefficient of determination (R^2) that is equal to 0.728.

From the calculation obtained that total carbon stocks in production forest of lembah seulawah district using NDVI is 711.061.81 tons. and the average value of carbon stocks per ha is found to be 46.32 tonnes / ha. The distribution of carbon stocks by using NDVI vegetation index is presented in Figure 6.
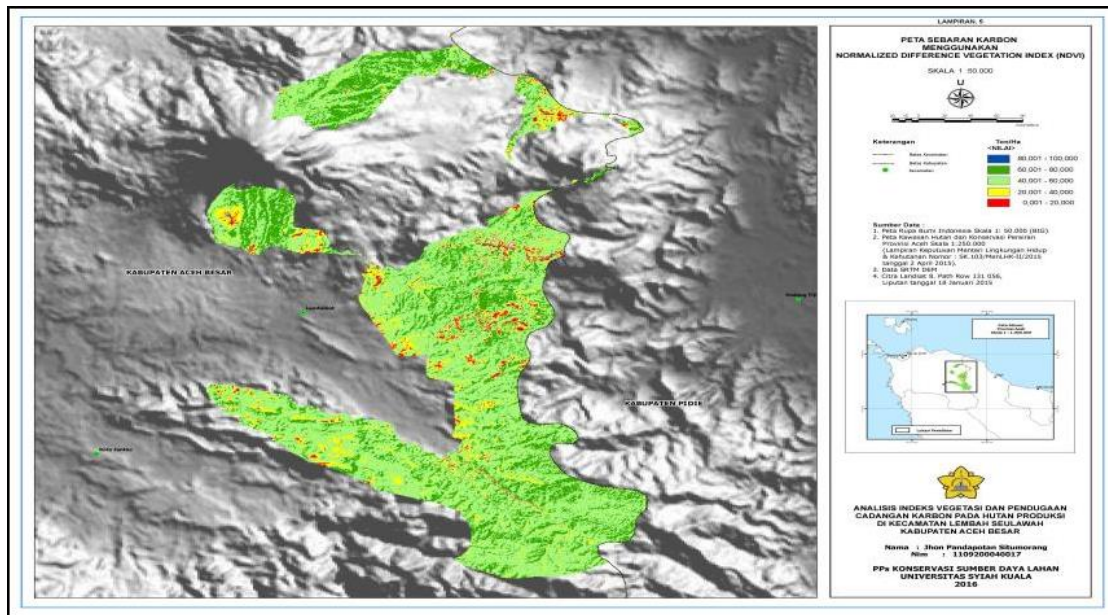
Figure 6: Spatial distribution of carbon stock in the Production Forest, Lembah Seulawah. Aceh based on NDVI value

Conclusions

Estimation of carbon stock using vegetation indices (EVI and NDVI) in the production forest area of Lembah Seulawah, Aceh Indonesia has been proposed in this research. The EVI value in the production forest of Lembah Seulawah was from 0.05 to 0.93 and NDVI value from 0.16 to 0.85. These findings indicate that the vegetation cover in the area varies, from sparse to very dense vegetation.

The linier regression of carbon stock with EVI value can be estimated using linier correlation of $Y = 151.7X-39.76$; where Y as carbon stock total and X is the EVI value. Using this finding, the total carbon stocks in the production forest of Lembah Seulawah Aceh is approximately 790.344.41 tonnes, and the average of carbon stocks is 51.48 tonnes per hectare.

Estimation of carbon stock using NDVI value of the area can be approached using linear regression of $Y = 204.3X-102.1$. Through this equation, the total carbon estimation in the production forest of Lembah Seulawah is 711.061,81 tonnes, with the average of 46.32 tonnes per hectare.

The EVI and NDVI vegetation indices have shown a close correlation with stands of carbon stocks estimation. Both indices approaches show a correlation coefficient of NDVI and EVI are 0.85 and 0.91 respectively, and the coefficient of determination of NDVI and EVI is 0.72 and 0.82. Both EVI and NDVI show no significant difference in term of correlation with the total of carbon stock stands.

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