Application of landsat 8 satellite imagery for estimated distribution of above ground carbon in Percut Sei Tuan forest landscape

N Sulistiyono¹,²*, AA Tarigan¹ and P Patana¹

¹Department of Forest Conservation, Faculty of Forestry, Universitas Sumatera Utara, Medan, Sumatera Utara, Indonesia.
²Center of Excellence for Mangrove, Universitas Sumatera Utara, Medan, Sumatera Utara, Indonesia.

E-mail: *nurdinsulistyono@usu.ac.id

Abstract. The use of remote sensing technology has been widely used to estimate carbon stocks above ground level, including in mangrove forest landscapes. This study aims to obtain information on the spatial distribution of above-ground carbon using Landsat 8 satellite imagery in the Percut Sei Tuan mangrove forest landscape. Ordinary least square (OLS) regression method is used to build a model of estimating the spatial distribution of above-ground carbon based on vegetation index values of normalized different vegetation index (NDVI) and green normalized different vegetation index (GNDVI). The results showed the average carbon content above ground level in the Percut Sei Tuan forest landscape was 23.55 tons ha⁻¹. The power regression model is the best estimator model for the distribution of carbon content above ground level with the equation \( y = 205.9 \times 1.2713 \) and \( R^2 \) of 72.4%.

1. Introduction
Landsat 8 is an American Earth observation satellite launched on February 11, 2013, it is a collaboration between the United States Geological Survey (USGS) and National Aeronautics and Space Administration (NASA). The satellite collects images of the Earth with a 16-day repeat cycle. Landsat data support a vast range of applications in environmental monitoring activities [1].

The utilization of index vegetation in Landsat 8 satellite imagery can be used to estimate the distribution of above-ground carbon in the mangrove ecosystem. Several studies [2-4] reported that they had succeeded in obtaining a model of estimating aboveground carbon distribution in mangrove ecosystems.

In the coastal areas, the existence of mangrove ecosystems is important as life support. Mangrove forests have economic and ecological functions [5]. One important function is to carbon sequestration. The ability of mangroves to store carbon on average, is 1023 tons ha⁻¹ and is the largest forest carbon storage in the tropics [6]. Other studies mention the average range of carbon content of mangrove forests ranging from 990 - 1074 to ha⁻¹ [7]. The objective of this study was to get information on the spatial distribution of above-ground carbon using Landsat 8 satellite imagery in Percut Sei Tuan forest landscape.
2. Materials and method

2.1. Research location
The research was conducted on the mangrove forest landscape in Percut Sei Tuan Subdistrict, Deli Serdang Regency, North Sumatra Province. The geographical position of the mangrove forest landscape in Percut Sei Tuan is located at latitude 3.68° N - 3.77° N and longitude 98.70° E - 98.83° E. The map of the research area can be seen in Figure 1.

![Figure 1. Map of the study area in Percut Sei Tuan](image)

2.2. Measurement of above ground carbon
Measurement of above-ground carbon in the field was carried out at 30x30m plot. Placement of sample plots was done by purposive sampling while still considering the distribution and representation of the sample. Measurements of above-ground biomass are carried out on vegetation with diameters more than 10 cm. The value of the above-ground carbon is 50% of the above-ground biomass. The equation developed by Komiyama is used to measure above ground biomass [8] with the equation:

\[ W_{\text{top}} = 0.25 \cdot \mu \rho D^{2.46} \] (1)
Note:

\( W_{\text{top}} \): above ground biomass (ton/ha)

\( D \): diameter of breast height (cm)

\( \rho \): wood density (g/cm³)

2.3. Vegetation index

In this study, we are used two vegetation index is NDVI and GNDVI. Values of vegetation index were obtained from images of Landsat 8 Path/Row 129/57 acquisition on February 13, 2018. NDVI [9] and GNDVI [10] formulas were calculated with the equation:

\[
\text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}} \tag{2}
\]

\[
\text{GNDVI} = \frac{\text{NIR} - \text{G}}{\text{NIR} + \text{G}} \tag{3}
\]

Note:

\( \text{NIR} \): digital number in the Near Infrared band

\( \text{R} \): digital number in the Red band

\( \text{G} \): digital number in the Green band

Estimation of above ground carbon distribution is done by regressing 45 data of above ground carbon measurement values in the field with vegetation index values. Normality tests using Kolmogorov-Smirnov test and heteroscedasticity tests were carried out to test the assumption of ordinary least square (OLS) regression. The OLS regression equation model used is:

1. Linear : \( y = a + bx \) \hspace{1cm} (4)
2. Logarithmic : \( y = a + b \ln x \) \hspace{1cm} (5)
3. Power : \( y = a \times x^b \) \hspace{1cm} (6)
4. Exponential : \( y = a \exp^{bx} \) \hspace{1cm} (7)

Note:

\( Y \): Above ground carbon (ton/ha)

\( X \): NDVI and GNDVI value

Validation tests were carried out to determine the deviation of the estimated above-ground carbon from a regression model with above-ground carbon from the field. Test of paired samples t-test is used to validation test. The number of sample plots used to validation tests is ten plots.

3. Results and discussion

3.1. Spatial model of above ground carbon

The measurement results on 45 plots show the average of above-ground carbon is 23.55 tons ha\(^{-1}\) with a range value between 1.29 - 54.83 tons ha\(^{-1}\). The results of this study are lower than the research [2] in Matang mangrove forest Malaysia, which mentions the range of above-ground carbon between 1.01 to 259.68 t C ha\(^{-1}\).

The results of statistical tests in the form of analysis of variance (ANOVA), coefficient of determination \((R^2)\) and t - paired test on the estimation model of the above-ground carbon distribution can be seen in Table 1.
Table 1. Results of testing the above-ground carbon regression model in the Percut Sei Tuan forest landscape

| Model            | Equation                          | Sig of ANOVA | $R^2$ | t-paired test |
|------------------|-----------------------------------|--------------|-------|---------------|
| Linear (NDVI)    | $y = 113.59x - 43.034$            | 0.000        | 0.557 | 0.179         |
| Logarithm (NDVI)| $y = 57.494\ln(x) + 54.602$      | 0.000        | 0.529 | 0.175         |
| Exponential (NDVI)| $y = 0.1821e^{8.0506x}$           | 0.000        | 0.693 | 0.196         |
| Power (NDVI)     | $y = 205.9x^{4.2713}$             | 0.000        | 0.724 | 0.192         |
| Linear (GNDVI)   | $y = 91.886x - 34.582$            | 0.000        | 0.550 | 0.429         |
| Logarithm (GNDVI)| $y = 50.773\ln(x) + 47.23$       | 0.000        | 0.534 | 0.417         |
| Exponential (GNDVI)| $y = 0.3454e^{6.4454x}$          | 0.000        | 0.670 | 0.474         |
| Power (GNDVI)    | $y = 115.85x^{3.7164}$            | 0.000        | 0.708 | 0.462         |

Based on Table 1, ANOVA test results show that the NDVI and GNDVI vegetation index on the Landsat 8 satellite imagery can be used as estimators above ground carbon in the eight regression models tested in this study (sig ANOVA <0.05). The relationship between vegetation index NDVI and GNDVI is directly proportional to above-ground carbon, meaning that an increase in the value of vegetation index will be followed by an increase in the value of the above-ground carbon. A scatter diagram of the relationship between the value of vegetation index with the content above ground carbon can be seen in Figure 2.

![Figure 2](image)

Figure 2. Scatter plot of above-ground carbon at each vegetation index: (a) NDVI and (b) GNDVI

The magnitude of the ability of the vegetation index variable in explaining variations in the above-ground carbon content is shown in the magnitude of the coefficient of determination ($R^2$). In the estimator model using NDVI vegetation index, the smallest coefficient of determination is in the logarithmic regression model (NDVI) with a value of 0.529 and the largest coefficient of determination on the linear model (NDVI) with a value of 0.724 whereas the estimator model uses the GNDVI vegetation index. The smallest coefficient of determination is in the logarithmic regression model (GNDVI) with a value of 0.534 and the largest coefficient of determination in the power model (GNDVI) with a value of 0.708.
3.2. Distribution of above ground carbon base on the best model

Based on Table 1, the results of the validation test using the t-paired test showed the estimated value of above-ground carbon with carbon measurement data in the field showed no significant difference (Sig>0.05). This shows the estimator regression model above ground carbon is valid for use.

The best regression model for estimating the distribution above ground carbon is a model of power (NDVI). Consideration used because the model has the highest $R^2$ value of 0.724. Furthermore, the distribution of carbon above ground level in Percut Sei Tuan can be mapped based on the power (NDVI). Regression model. The results of carbon distribution in the selected model show that the mangrove forest area still has a high carbon value, especially in coastal areas. The carbon estimation distribution map using the estimation model is seen in Figure 3.

![Image](image.png)

**Figure 3.** Spatial distribution of above-ground carbon in Percut Sei Tuan forest landscape

4. Conclusion

The vegetation index on the Landsat 8 satellite imagery can be used as an estimator spatial distribution of the above-ground carbon in Percut Sei Tuan. The best model of above-ground carbon potential estimator is the power regression model with NDVI vegetation index with the equation $y = 205.9 \times 4.2713$ with $R^2 = 0.724$.

References

[1] U.S. Geological Survey 2016 Landsat—Earth observation satellites (ver. 1.1, August 2016): U.S. Geological Survey Fact Sheet 2015–3081, 4p
[2] Hamdan O, Khairunnisa MR, Ammar AA, Hasmadi IM and Aziz HK 2013 Journal of Tropical Forest Science 25(4) p 554–56
[3] Wicaksono P, Danoedoro P, Hartono H, Nehren U and Ribbe L 2011 Proc SPIE 8174 81741B DOI: 10.1117/12.897926
[4] Winarso G, Vetrita Y, Purwanto AD, Anggraini N, Darmawan S and Yuwono DM 2015 International Journal of Remote Sensing and Earth Sciences 12(2) p 85 – 96
[5] Duke NC, Meynecke JO, Dittmann S, Ellison AM, Anger K, Berger U, Cannici S, Diele K, Ewel KC, Field CD, Koedam N, Lee SY, Marchand C, Nordhaus I and Dahdouh-Guebas F 2007 A world without mangroves? Science 317(5834) p 41-42 DOI: 10.1126/science.317.5834.41b
[6] Laffoley D and Grimsditch G 2009 The management of natural coastal carbon sinks (Gland, Switzerland: IUCN)
Acknowledgments
This study was partly supported by a TALENTA Grant 2018 (No. 2590/UN5.1.R/PPM/2018) from Universitas Sumatera Utara.