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An assessment of high carbon stock and high conservation value approaches in mining area

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Abstract. The impact of forest degradation due to open-pit mining activities causes sustainable ecological damage. Mining activities that are not organized due to the mineral exploration process have resulted in many forest areas experiencing degradation. This degradation certainly reduces the level of carbon sequestration in the area, impacting the sustainability of environmental functions around the mining area. The high carbon stock (HCS) approach is a way to help companies implement their 'no deforestation' commitments. The high carbon stock approach will identify forests that must be protected and land that can be developed. Forests with high carbon stocks are maintained because they function as carbon stores, habitats for biodiversity, and provide the necessities of life for local communities. Therefore, this study aims to obtain data on the potential for carbon stocks and create a spatial model for distributing carbon content in the concession area of PT. Vale Indonesia can later be determined as high conservation value (HCV) areas using the high carbon stock approach. Measurement of carbon content in the study used an allometric equation that has been developed, then the distribution of carbon was made using the spatial vegetation index model obtained from Sentinel 2 imagery. The results showed an area of 30,526.49 (42.97%), which had high carbon stock with an average carbon stock of 106.09 ton/ha, which needed to be maintained as an area of high conservation value in the mining area of PT. Vale Indonesia.

1. Introduction

The impact of forest degradation on open-pit mining activities causes sustainable ecological damage [1–4]. Mining activities that are not organized due to the mineral exploration process have resulted in many forest areas experiencing degradation. This degradation certainly reduces the level of carbon uptake in the area, which impacts the sustainability of environmental functions around the mining area. The

increase in the land's ability to absorb carbon can be seen by calculating the carbon pool. [5] described at least four assessed areas, including above-ground biomass, subsurface biomass, inanimate matter, and soil carbon. According to [6], forest biomass content describes the relationship between forest stand conditions and forest management processes as well as natural disturbances. The canopy structure is a fundamental forest ecosystem parameter that affects microclimate, runoff, decomposition, nutrient cycling, forest disturbance, biodiversity, and carbon storage [7]. The approach to measuring carbon biomass content can estimate forest destruction due to deforestation and forest degradation [8].

There are four ways to calculate biomass which include sampling by harvesting (destructive sampling), sampling without a harvest (non-destructive sampling), estimating through remote sensing, and modelling [5]. In general, these methods are divided into two things, namely terrestrial methods and spatial analysis through remote sensing approaches [9]. The terrestrial method is used to obtain accurate data in the field, while the remote sensing method is used to simplify and streamline data collection time, for example, by using satellite imagery. The use of satellite imagery in estimating biomass has been widely used through vegetation index analysis. The method for analyzing the vegetation index that is generally used is NDVI (Normalized Difference Vegetation Index) [10].

Estimating biomass using remote sensing is carried out through data analysis on the calculation of the vegetation index from satellite image waves. Remote sensing image data that can be used are multispectral image types such as Sentinel-2 imagery (S2). S2 is an image that can be accessed for free so that mining companies can use this data to monitor the condition of mining areas, one of which is to estimate the value of carbon stocks from changes in land conditions over time. Currently, the calculation of the value of carbon stock has become one of the instruments for assessing areas with high conservation value in a company concession using the high carbon stock (HCS) approach.

The High Carbon Stock approach is a way to help companies implement their "no deforestation" commitments. The high carbon stock approach will identify forests that must be protected and land that can be developed. Forests with high carbon stocks are maintained because of their function as carbon storage, habitat for biodiversity, and the necessities of life for the community. Therefore, this study aims to obtain data on the potential for carbon stocks and create a spatial model for the distribution of carbon content in the concession area of PT. Vale Indonesia (PTVI) can later be determined as high conservation value (HCV) areas using the high carbon stock approach.

2. Materials and Methods

2.1. Study area
This research was conducted in the mining area of PT Vale Indonesia Tbk (PTVI), located in the Sorowako Block, and administratively located in East Luwu Regency, South Sulawesi Province. This company's concession area is 71,047.24 ha, where there are 20 village administrative areas within it and is surrounded by several conservation areas; those are the natural tourism park of Lake Mahalona, Lake Matano and Lake Towuti. According to the Decree of the Minister of Environment and Forestry of the Republic of Indonesia No. 362 of 2019 regarding the forest area of South Sulawesi Province, the PTVI area consists of 58.70% protected forest, 24.22% limited production forest, 0.67% conservation area and the remaining 16.42% is cultivation area.
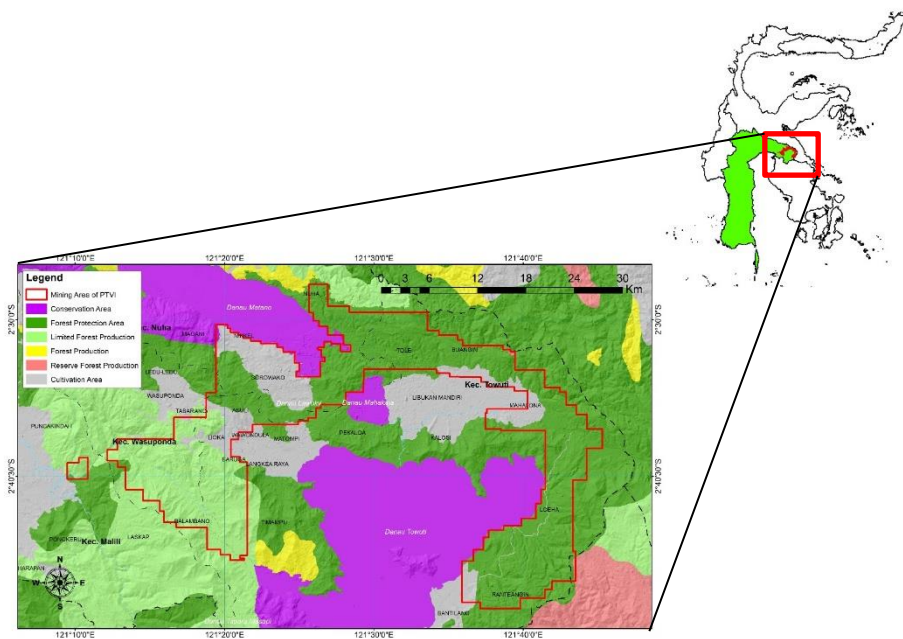
Figure 1. PTVI mining area.

2.2. Satellite data processing

One of the stages in this research is knowing the land cover condition in forested areas in the study area. The approach used is to use remote sensing methods. The remote sensing method is used to simplify and streamline spatial-based data collection [11, 12], using Sentinel-2 (S2) satellite imagery. The S2 image data acquisition used is the recording data between month 9 and month 10 of 2019, where the recording time selection is only based on a clean cloud image in the study area. Before further processing, the S2 image is processed through several stages, namely radiometric correction and band combination, to map the land cover using a 4-3-2 (true color) band combination by distinguishing objects' visual appearance based on the color hue produced by the image composite [13, 14]. In addition, the corrected image is also used to calculate the vegetation density index in the area, which will later be interpreted as forest in the mining area. The vegetation index used is the normalized difference vegetation index (NDVI) [15–18]; this index will also use to distribute the biomass distribution value in the study area. The NDVI vegetation index on Sentinel-2 imagery calculated using the following formula [19]:

$$NDVI = (\rho nir - \rho red)/(\rho nir + \rho red) \tag{1}$$

where:
ρnir : NIR band reflectance value
ρred : RED band reflectance value

2.3. Carbon stock estimation

In the HCS assessment phase, estimates of the carbon stock per hectare are calculated from biomass data collected from field plots using an allometric equation model. The biomass value is then converted into its carbon value so that the carbon storage for each vegetation stratification is known. The parameter equation used is general for all vegetation found in the study location. All DBH information from the measured vegetation is then used to calculate the biomass value for each vegetation. If each type of vegetation found in the field has been identified, both the species name and the scientific name will then search for the allometric equation formula. Each type will use its allometric formula. However, if it is not possible or there is no research on this subject for a particular type, the allometric equation formula is as follows [20]:

$$B \ (ton) = 0{,}11 \ x \ \rho \ x \ (DBH)^{2.62} \tag{2}$$

where: B = biomass, ρ = wood density, DBH = measurement of tree diameter.

The consideration in using this formula is its suitability for use in tropical forest types. Some things that must be considered using allometric equations are the density of the wood. The density of wood can view on the wood hardness database released by the World Agroforestry Centre (WAC) with a web address http://db.worldagroforestry.org/wd. If only the genus is known, the wood hardness density of the wood used is the average value at the genus level. If unknown, use standard values of 0.55 tones/m3 for tropical tree species and 0.247 tones/m^3 for palm species [21]. After knowing the biomass value, then the carbon stock value is calculated based on the following equation [22]:

$$C \ (ton) = 0.47 \ x \ biomass \tag{3}$$

The estimation of the distribution of carbon stocks is prepared based on the results of regression analysis. Regression analysis is one of the parameters analysed to analyze the relationship between the independent and dependent variables [23]. In this study, regression analysis was used to build and determine the best estimator model. The results of carbon calculations on the observation plot were the dependent variable and the NDVI vegetation index as the independent variable. Model estimation can be done by using several regression models, including linear regression models.

$$Y' = b_0 + b_1 X \tag{4}$$

where:

Y   : dependent variable
X   : independent variable
b_0 : constant
b_1 : regression coefficient

Therefore to obtain the validity of the model, it is necessary to test the model building variables. The normality test is performed using the Scatter Plot test. The validated estimator model is used later to obtain a map of the distribution of high carbon stocks, which can be used to determine areas with high conservation value. The processing of high carbon stock distribution maps is carried out using QGIS software.

3. Result and discussion

3.1. Interpretation of vegetation cover

The results of land cover interpretation using S2 images in the PTVI mining area obtained several land cover classifications, where for natural forest covering an area of 46,664.06 ha or 65.68%, reclamation forest covering an area of 972.24 ha or 1.37%% and shrubs covering an area of 2,686.15 ha or 3.78% of the total area mining concessions. The area with forest cover is then analyzed further to describe the level of vegetation density. The vegetation index describes the level of vegetation density. The spectral transformation of S2 images in the PTVI mining area obtained the NDVI index value in the range -0.5 - 0.8. Furthermore, matching this index value with the land cover condition, information is obtained that in the range <0.5 is the non-vegetation cover, 0.5 - 0.6 is shrubs, and > 0.6 is forest cover [24–27].

The NDVI index values in forest areas were then classified to obtain information on forest density levels. The index values of 0.6 - 0.65 were low-density forests, 0.65 - 0.7 were medium density forests and> 0.7 were high-density forests [24]. The classification of the NDVI index in the forest area, the area of high-density forest cover in the PTVI mining area was 30,526.49 ha or 42.97% of the total concession area, medium density forest was 9,985.64 ha or 14.05%, and the low-density forest was 6,151.93 ha or 8.66% as the distribution showed in figure 4.
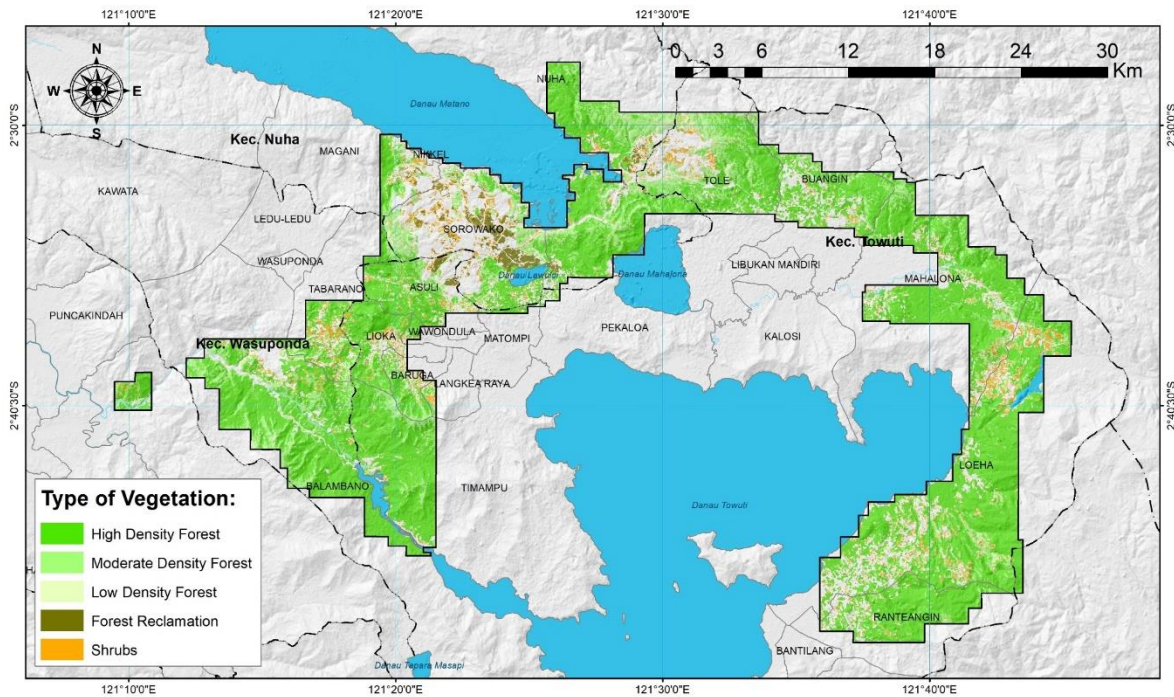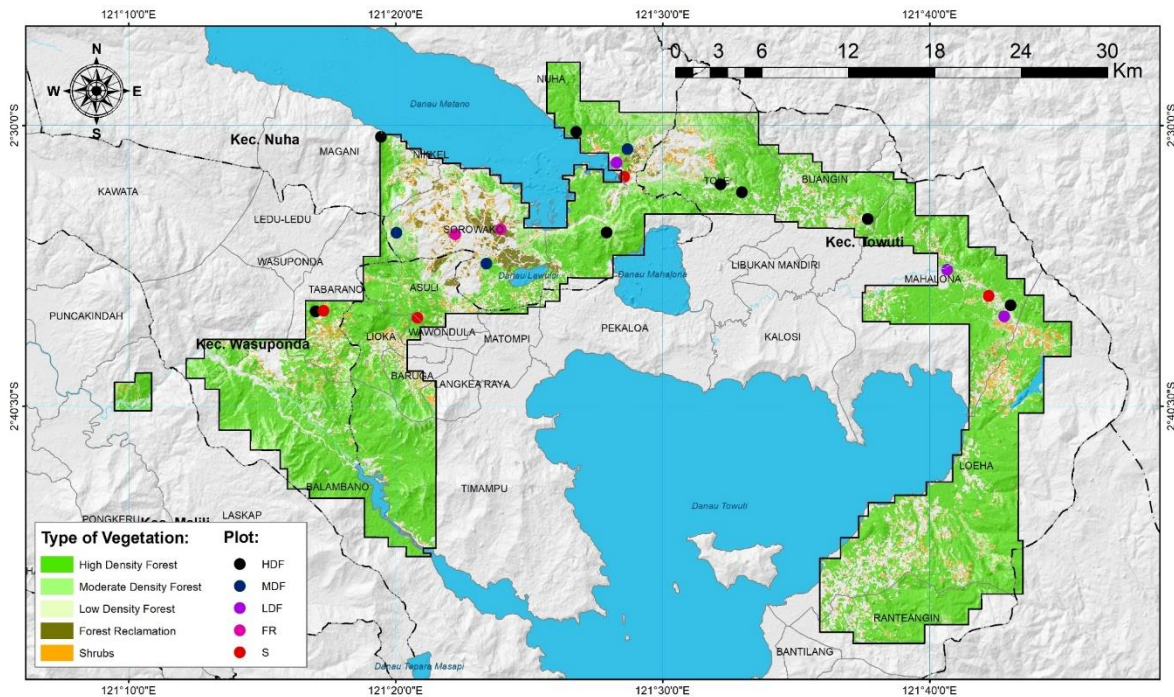
Figure 2. Vegetation cover in PTVI mining area.

3.2. Carbon stock estimation

Carbon stock is the amount of carbon in a pool [28]. The carbon stock referred to in this study is the amount of carbon stored in tree and pole-level plants recorded in each observation plot. The observed observation plots were observed in the study area as many as 20 clusters, where each cluster represents 5 observation plots scattered in each vegetation cover classification. The distribution of the observation plots in the study area presented as follows.

The calculation of carbon stock is based on the value of standing biomass in each observation plot. The problem with the terrain and the number of stands in each cluster resulted in only 18 clusters where stand data were available (both trees and poles). The results of biomass calculations for each observation plot are described as follows.

Figure 3. Distribution of observation plots in PTVI mining areas

Table 1. Biomass reserves in each observation plot

| Vegetation Type	Cluster	Biomass (kg)		Biomass (ton/ha)		
		Tree	Pole	Tree	Pole	Total
High Density Forest	1	66,614.77	1,088.89	133.23	2.18	135.41
	2	58,358.78	1,965.13	116.72	3.93	120.65
	5	95,057.69	1,333.02	190.12	2.67	192.78
	6	61,674.79	1,241.21	123.35	2.48	125.83
	7	66,529.54	2,277.77	133.06	4.56	137.61
	8	38,929.24	2,230.75	77.86	4.46	82.32
	16	55,410.48	2,572.72	110.82	5.15	115.97
Medium Density Forest	10	78,772.40	910.83	157.54	1.82	159.37
	11	98,098.94	2,105.58	196.20	4.21	200.41
	13	40,215.78	2,314.86	80.43	4.63	85.06
Low Density Forest	14	103,602.77	980.78	207.21	1.96	209.17
	4	30,825.31	4,098.57	61.65	8.20	69.85
	9	46,596.77	1,048.42	93.19	2.10	95.29
Reclamation Forest	12	25,627.40	1,311.54	51.25	2.62	53.88
	15	82,552.45	1,644.77	165.10	3.29	168.39
Shrubs	17	2,491.93	856.75	4.98	1.71	6.70
	18		932.27		1.86	1.86
	19	16,246.25	67.50	32.49	0.14	32.63

The results of the biomass calculation above are the basis for the preparation of the carbon distribution model. The model developed uses regression analysis between variable Y (biomass

calculation) and variable X (the NDVI vegetation index value obtained from the transformation of the S2 image value in 2019). The model used is y = 959.73x - 472.95 with a coefficient of determination (R2) of 65.39% (0.6539). A good model is a model that has a high coefficient of determination (R2). Sarwono stated that if the R2 value is in the range> 0.5 - 0.75, then the analyzed variables have a strong relationship [29]. The data normality test also illustrates that the data being analyzed is spread or normally distributed. Normal data can be seen based on a straight-line graph. figure 4 shows the results of the normality test based on the scatter plot.
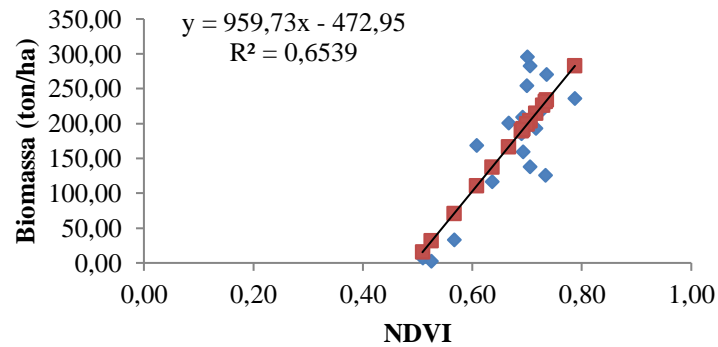
Figure 4. Normality test based on the scatter plot.

The prediction model that has tested is then processed using a GIS approach to distribute the biomass value for each pixel of the NDVI raster data for forests and shrubs. The value of the biomass scattered in each pixel is then converted to calculate the carbon stock, where the assumption is that 47% of the biomass value is the value of carbon stock. The conversion results obtained the value of the distribution of carbon stocks in the vegetation cover in the study area. The results of the distribution of carbon stocks in the study area presented in figure 5 below.
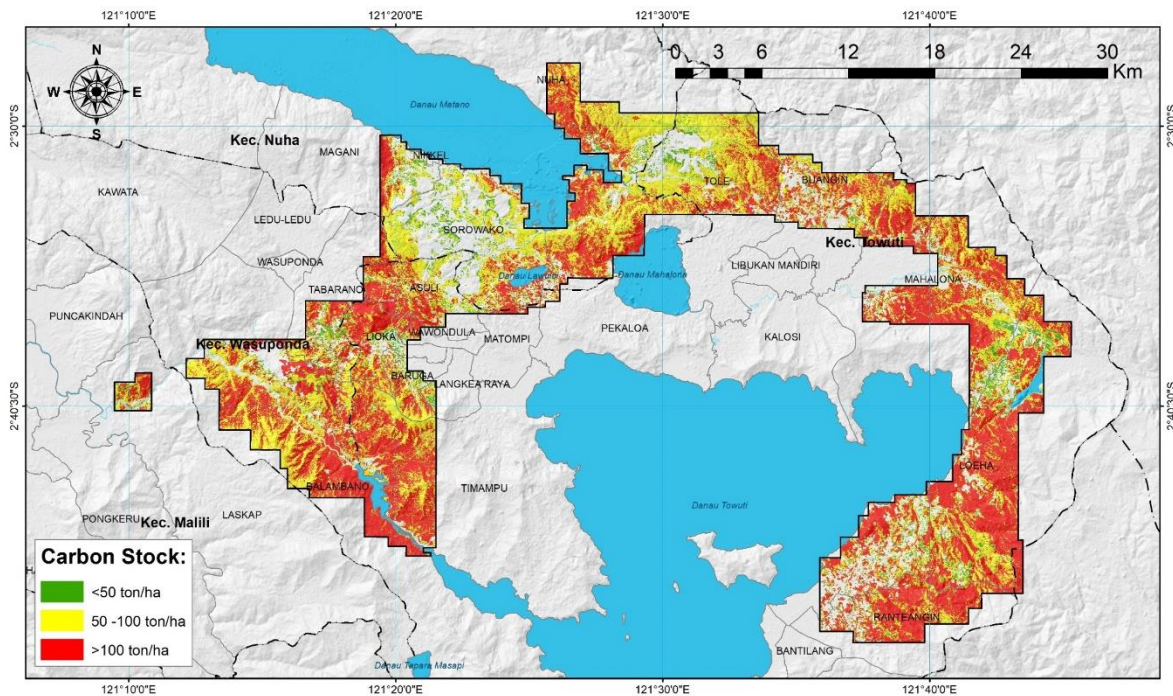
Figure 5. Distribution of standing carbon stocks in the PTVI mining area.

The biomass calculation results from the stand measurement data can describe the condition of carbon stocks in the entire study area. The high average standing carbon found in the high-density forest vegetation cover where the average value of carbon stock was 106.09 tones/ha. The description presented in table 2 below.

Table 2. Calculation of standing carbon stocks in the PTVI mining area.

Vegetation Type	Number of Observation Clusters	Number of Stands / Ha	LBDS (m^2)/ha	Average carbon stock (tones/ha)
High Density Forest	8	903	17.79	106.09
Medium Density Forest	3	1015	13.06	81.90
Low Density Forest	3	757	14.68	60.84
Reclamation Forest	2	750	12.43	77.20
Shrubs	4	368	3.99	35.20

The high carbon stock in high-density forest illustrates that natural forest with a high vegetation density level has a high absorption rate. This confirmed by Masripatin and Rusdiana's statement that carbon stock tends to get bigger with increasing vegetation development and its density [28,30]. The potential for high carbon absorption in this mining area needs to be maintained because it can function to reduce the concentration of carbon releases in the atmosphere due to the mining industry's activities. Apart from the high-density forest, reclamation forest in the PTVI mining area also gives positive values where the carbon stock level is above low-density forest and is almost close to a medium-density forest. This illustrates that the results of post-mining land revegetation activities in PTVI have approached a succession of natural forest conditions. The average value of reclaimed forest carbon stock is 77.20 tones/ha; this value has increased from the results of Witno research in the PTVI reclamation area, where the average value of reclaimed forest carbon stock was 62.66 tones/ha [31].

The area with high carbon stock in the PTVI mining area can designate as an area of high conservation value. Where in the HCV assessment instrument, high carbon stock is HCV 7. Where HCV 7 includes areas that have the function of areas that have high carbon stocks and must protect with degraded lands that can develop. The high carbon stock approach will identify secondary forest that must be protected and degraded to develop. Secondary forests should be maintained because they function as high carbon storage, a habitat for biodiversity, and provide the necessities of life for local communities. If determined based on the results of this study, an area can be maintained as HCV in the PTVI mining area because it has high carbon reserves of 30,526.49 ha or 42.97% of the overall concession area. The distribution presented in figure 6 below.
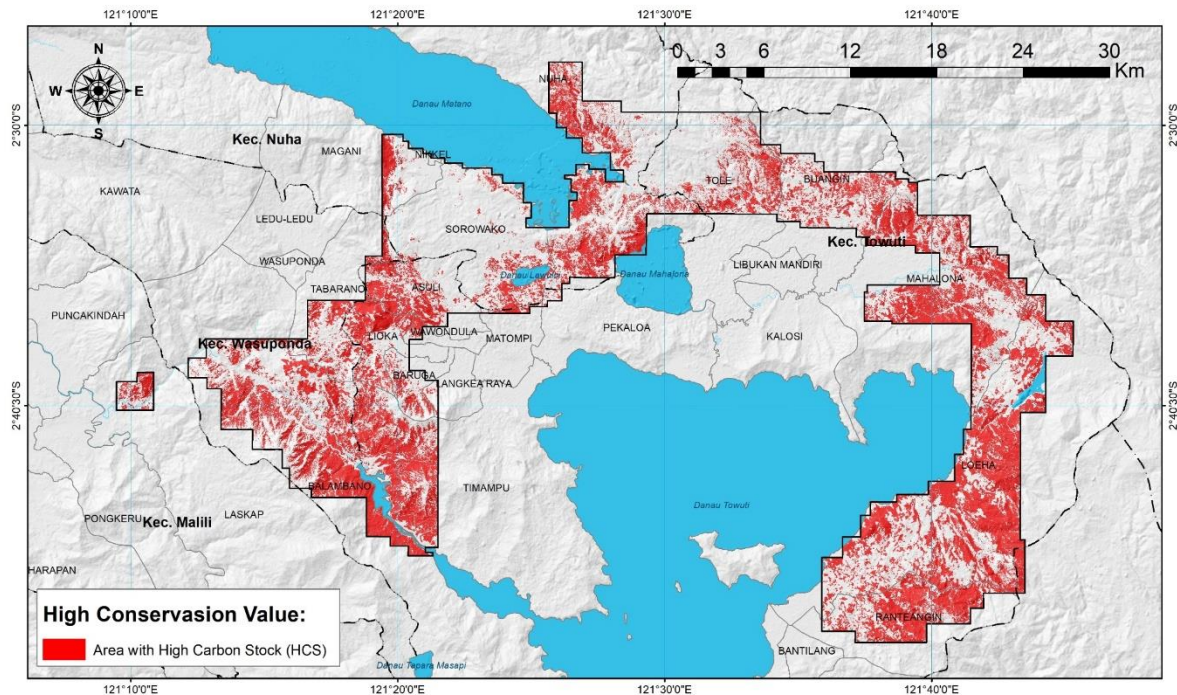
Figure 6. High carbon stock area in PTVI mining area

4. Conclusion
The assessment of carbon stock areas in the mining area can be estimated using remote sensing technology by analysing the results of field measurements with vegetation index analysis from Sentinel-2 imagery. This approach can estimate areas with high carbon stock, which is a parameter in determining areas with high conservation value in a concession.

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