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THE USE OF HYPERSPECTRAL DATA TO ANALYZE CLIMATE CHANGE ACCORDING TO CARBON STOCKS AND SOUTHEAST SULAWESI BIODIVERSITY

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Abstract

Indonesian region is lately experiencing extreme weather resulting in deviant climate change. It is occurred due to the massive amount of carbon dioxide produced on this planet. As the consequence, the ozone layer protecting the earth from solar radiation becomes vulnerable and damaged. The existence of the green plants classified as forest biodiversity is expected to reduce the large amount of carbon dioxide gas by transforming it into oxygen through photosynthesis. Forest biodiversity in Southeast Sulawesi is categorized into tropical forest, savannah and mangrove forest. Each type of forest has different amount of carbon stock. Nowadays, , information in relation to carbon stocks and forest biodiversity are needed for the analysis of climate change. The main objective of this research is to analyze climate change according to carbon stocks and forest biodiversity in Southeast Sulawesi by applying hyper spectral data. In order to distinguish the forest types and to comprehend its carbon potentials, unsupervised classification method is applied and correlated with the biomass carbon. Furthermore, it is analyzed using NDVI formula to determine the extent and density of vegetation and carbon potential existing in an area. Further analysis is conducted by utilizing weather parameter of air pressure observation data, air temperature data, and weather satellite data to discover monthly average weather conditions semi-objectively. The results obtained, will enable this research to analyze climate change in order to provide early prevention efforts.

Keywords: Biodiversity, Carbon, Climate, Weather, Hyperspectral.

1. Introduction

Indonesia is developing country located in Asian continent and situated right at the equatorial line. Having such geographical condition, Indonesian certainly has a very large area of forest. One location in Indonesia with large forest area is in Southeast Sulawesi and it can be categorized into tropical, mangrove and savanna forest.

Tropical forest is inhabited by more than 50% of total species of plants in the world (Whitmore. 1990, Foody. 2003, Thomas et al 2004). However, detailed spatial

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information about composition and distribution of tree and its fauna diversity is still limited to some areas (Clark et al. 2005). Similarly, both mangrove and savanna forests occupy large distribution area and have their own roles as well. For example, mangrove plays important role on coast productivity (Analudin. 2016).

For remote sensing scientist, satellite data can be used to assess biodiversity (Lucas et al.) and to contribute on dead and living carbon assessment (Asner and Heibretch, 2002).

Based on those facts, the main objective of this research is to analyze climate change based on biomass reserve and plant diversity in South east Sulawesi. In particular, this research is aimed: (1) to estimate biomass carbon existence (2) to find out what climate change will happen by analyzing biomass existence in Southeast Sulawesi forests.

2. Material and Methods

2.1. Location

Location of this research is the whole region of Southeast Sulawesi (Figure 1) with astronomic position is between 02°45’-06°15’ South Latitude and 120°45’-124°45’ East Longitude (Biro Humas. 2013).

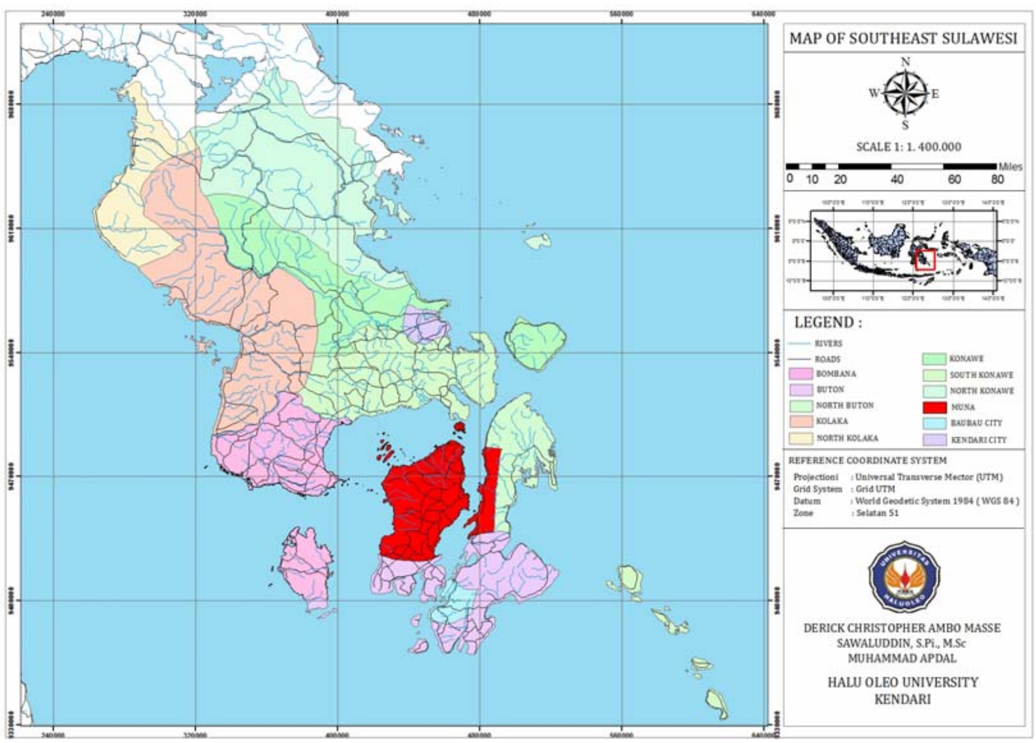

Figure 1. Southeast Sulawesi Map.

2.2. Image Processing

First stage of image processing of Landsat 8 is geometric and radiometric correction. Image correction is a conditioning operation so that the image to be used can really provide accurate information geometrically and radiometrically (Danoedoro. 1996).

After being corrected, the image will be analyzed using Normalized Difference Vegetation Index (NDVI) formula to get vegetation density point (Jensen. 1996). Next stage is a classification process to classify and separate each areas based on their own ecosystem vegetation types.

2.3. NDVI Analysis

Vegetation index can be used to measure biophysics parameter such as biomass, chlorophyll, LAI (Leaf Area Index), etc. (Jensen. 1996). To separate vegetation and non vegetation on satellite imaging, normalized difference vegetation index method is used (Gougeon and Leckie. 2003, Danoedoro. 1996), with equation as follows:

$$NDVI = \frac{IR - R}{IR + R} \tag{1}$$

Next, correlation analysis will be conducted to seek for relationship between vegetation density and area use. At this step, the new analysed image will be produced and then classified into tropical, mangrove or savannah forest. In order to interpret the relationship between two variables, the relationship power correlation criteria (Table 1) is applied (Rahmi. 2009).

Table 1. Relationship power correlation criteria

Score	Correlation relationship
0	No correlation
0.1 – 0.25	Very weak correlation
0.26 – 0.5	Medium correlation
0.51 – 0.75	Strong correlation
0.76 – 0.99	Very strong correlation
1	Perfect correlation

2.4. Biomass and Carbon Stock Estimation

Forest carbon total reserve measurement is based on biomass total content measurement and organic stuff at carbon pool (IPCC. 2003). Carbon biomass estimation on land surface is calculated by building up allometric equation (ministry of forestry. 2013). Applied allometric equation is:

$$B = Vpohon \times WD \times BEFpohon \tag{2}$$

To calculate tree volume, geometric equation is used by considering tree height and diameter data as follows:

$$V = 0{,}25\pi \times \left(\frac{D}{100}\right)^2 \times H \times F \tag{3}$$

Carbon stock estimation based on biomass needs biomass conversion factor value which is called as carbon fraction (forestry ministry. 2013), formulated as:

$$StokKarbon = FraksiKarbon \times Biomassa \tag{4}$$

Carbon fraction value applied in Equation (4) is 0.47 (IPCC. 2003).

2.5. Climate Change Analysis

Climate change is analyzed by using temperature parameters data of air and rainfall to know the average annual weather conditions on a semi-objective scale.

3. Results and Discussion

3.1. Image Correction

Image correction is the first step on preparing the data before doing analysis in order to find out the index value of vegetation density. The whole process of image correction as follows: (1) applying geometric correction of image to reflate the image within its real position; (2) applying radiometric correction to reflate pixel value that was damaged due to errors while recording the image. The result of radiometric correction can be seen at Figure 2.

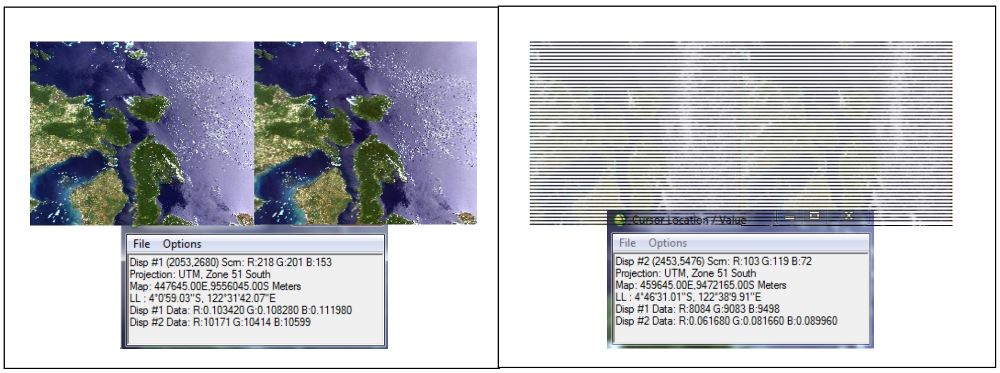

Figure 2. (a) Image pieces of Landsat Southeast Sulawesi 2016; (b) Image pieces of Landsat Southeast Sulawesi 2006

3.2. Vegetation Density Index Value and Forest Type Classification

Vegetation density index value is obtained by taking 200 samples, selected randomly in Southeast Sulawesi region through satellite imaging. In addition, its physical condition is also checked in detail by exporting existing points of investigated image into Google Earth Software. Then, analyzed vegetation physical condition is adjusted to density classification index that is already determined (Table 2).

Tabel2. Vegetation density index value classification

Density rate	Interval	Value
High density	0,8 – 1	91 – 100
Medium density	0,5 – 0,79	61 – 90
Low density	0,2 – 0,49	31 – 60
Not vegetated	-1 – 0,19	0 – 30

Point selection is conducted within two different images having 10 year time interval, i.e. Landsat 7 in 2006 and Landsat 8 in 2016. Selecting similar points is intended to see the trend of field cover change. The comparison result shows a very significant result. In 2006, vegetation density rate is 0.68005 while in 2016, it is 0.476378.

Based on the result, it can be seen that the field cover change in 10 years is 0.203674. It happened because there was added space for housing, mining, palm oil plantation and many more purposes in Southeast Sulawesi.

After finding the field cover change or vegetation trend in Southeast Sulawesi, correlation analysis is applied. In the correlation analysis, the density index value is compared to field cover change value. Correlation relationship is indicated in correlation coefficient (r) and determination coefficient (R^2). Determination coefficient shows linear relationship between NDVI result and field use value based on already determined scoring.

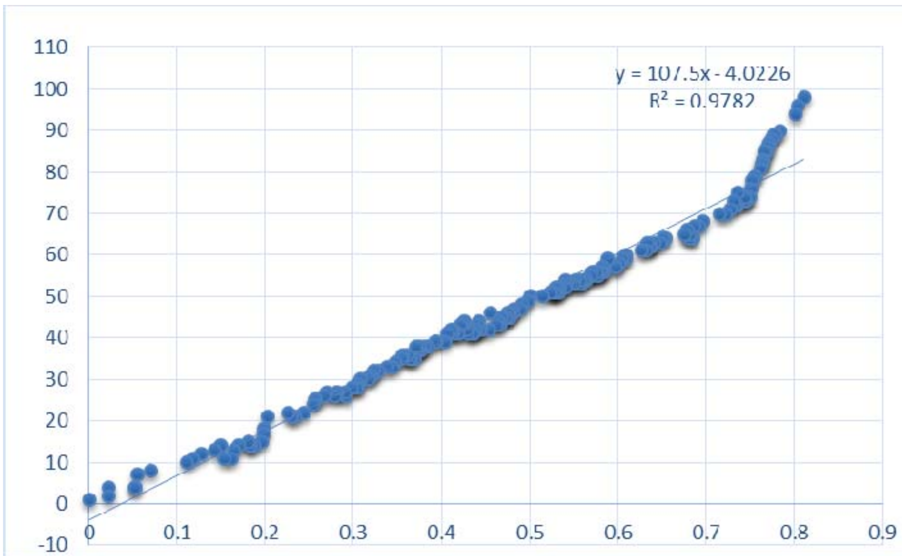

Figure 3. Index Value Of Vegetation Density in 2016.

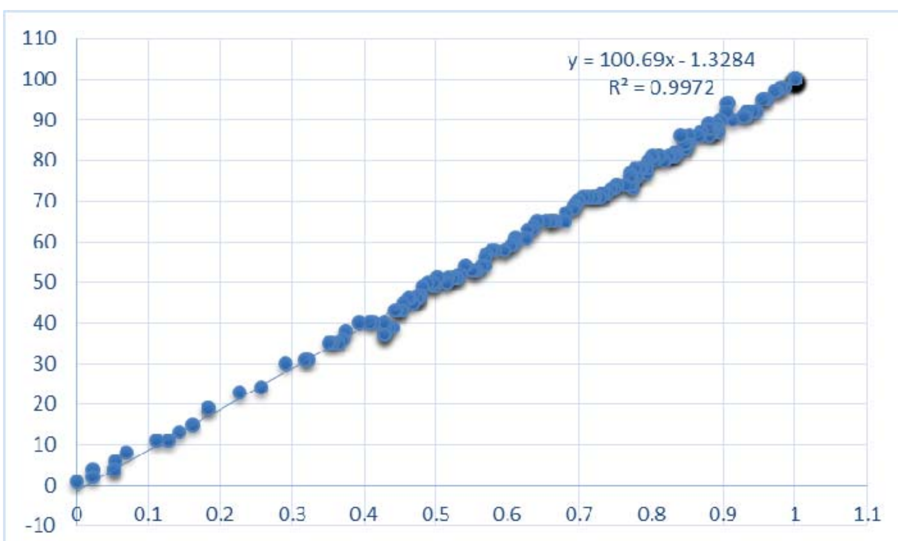

Figure 4. Index Value Of Vegetation Density in 2016.

In 2016, determination coefficient value is 0.9782, while in 2006, its determination coefficient value is 0.9972. It is obvious from the number of determination coefficient that investigated variables has a strong relationships, as can be seen on Figure 2 and Figure 3. This confirms the theory that the more determination coefficient, the stronger relationships between investigated variables (Hafish. 2013) and without considering the algebra sign, determination coefficient moves between -1 to 1.

Based on correlation analysis, it is known that determination coefficient has a very high value. Later, that value is used to predict extents for each ecosystem, i.e. tropical, mangrove and savanna forest.

3.3. Biomass and Carbon Stock

Standing Biomass calculation is conducted at each ecosystem (Tropical, Mangrove and Savanna). Both for tropical and mangrove forests, measurement is conducted as much as 3 times covering different areas. Except in savanna forest, measurement is only one time.

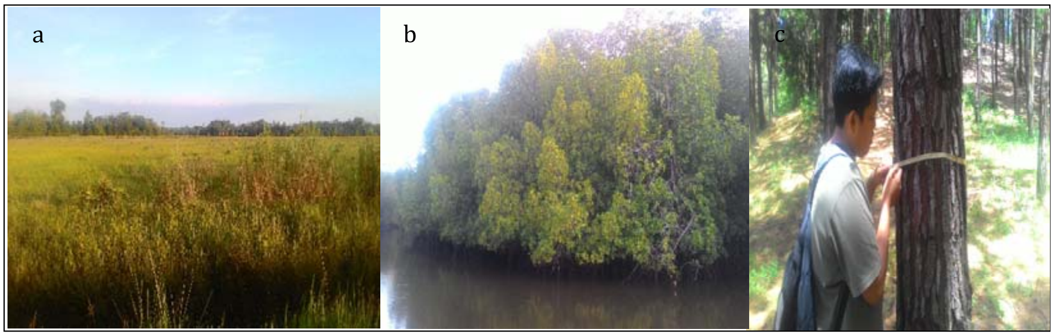

Figure 5. (a) Savanna Ecosystem; (b) Mangrove Ecosystem; (c) Tropical Ecosystem.

Standing Biomass in Plot 1, created at area of 60 m x 60 m of tropical forest ecosystem is 6 .516.08tonHa^{-1}. This result is based on the allometric formula which had been developed previously. In plot 2, founded standing Biomass based on similar formula and equal plot dimension is 7.214.45 tonHa^{-1}. While in the Plot 3 (applying similar formula and size of plot), the result of standing biomass is 6.241.79 tonHa^{-1}.

In calculating the standing Biomass of mangrove ecosystem, each plot was created at area of 30 m x 30 m. Based on the allometric formula, obtained the total biomass of plot 1 is 3.328.83tonHa^{-1}. While standing biomass for plot 2, is 4.963.75tonHa^{-1} and standing biomass for plot 3 is 3.158.48 tonHa^{-1}.

Biomass of savanna forest ecosystem is calculated by doing measurement in the field, i.e. making plot with area of 30 m x 30 m. Furthermore, recreate a new small plot (1 m x 1 m) within the aforementioned plot. In savanna ecosystem, standing biomass calculation in conducted by cutting down all individuals within the small plot 1m x 1 m and then measure the wet weight accordingly. About 300 g of the total individuals is separated and treated as wet weight sample. Furthermore, the selected wet weight sample is heated in the oven with temperature 85^0C to find out the dry weight. In order to calculate Biomass in Savanna ecosystem, the total dry and wet weights are multiplied and then it is divided with wet weight sample. The final result obtained from biomass calculation of savanna ecosystem within the selected plot is 112 ton Ha^{-1}.

Once standing biomass is known, total biomass in Southeast Sulawesi can be calculated based on the total area of each forest ecosystem type that has been set. Calculation of total biomass is conducted by multiplying the total of standing biomass with total area of each forest ecosystem type. The total biomass in Southeast Sulawesi for each forest type are as follows: (1) tropical forest ecosystem is 34.966.097.079.72tonHa^{-1}; (2) mangrove forest ecosystem is 4.611.721.676.15tonHa^{-1}; and (3) savanna forest ecosystem of biomass is 7.653.520 tonHa^{-1}.

Furthermore, based on total biomass in Southeast Sulwesi, the carbon stock can be calculated by using carbon stock formula value 0.47 as the carbon fraction value set by the Intergovernmental Panel on Climate Change (IPCC). The result shows that Carbon Stock for tropical forest in Southeast Sulawesi 16.434.065.627.47tonCHa^{-1}. In addition, Carbon Stock for Mangrove Forest is 2.167.509.187.79 ton CHa^{-1}. While, for the savannah forest ecosystem, the carbon stock is 3.597.154.40 ton CHa^{-1}. Table 3 shows the total results for biomass and Carbon Stock Calculation.

Table 3. Biomass and Carbon Stock of Southeast Sulawesi

Type of Ecosystem	Biomass Plot Area (Ton/Ha)	Total Biomass (Ton/Ha)	Total Carbon Stock (TonC/Ha)
Tropical Forest	6.516.08 7.214.45 6.241.79	34.966.097.079.72	16.434.065.627.47
Mangrove Forest	3.328.83 4.963.75 3.158.48	4.611.721.676.15	2.167.509.187.79
Savanna Forest	112	7.653.520	3.597.154.40

Based on Table 3, it can be concluded that the largest number of carbon stock in Southeast Sulawesi is at tropical forest ecosystem and respectively followed by mangrove forest ecosystem and savannah forest ecosystem.

3.4. Impacts of Biomass Carbon Stock Change to Climate Change

Climate change can be detected through temperature and rainfall which occur everyday. The following is data used in this research (Table 4) taken from Kendari Meteorology and Maritime Climatology Station and then converted into annual average climate condition. Figure 6 shows the graph of monthly average climate data. There are 3 stations in Southeast Sulawesi but the weather data is only taken from Kendari Station to represent other parts of Southeast Sulawesi region, as there is no significant weather differences among parts of the aforementioned region.

Table 4. Weather Annual Average in Kendari Municipality

Year	Annual Average of Temperature	Annual Temperature Max	Annual Rainfall
2008	27.04	31.21	7.48
2009	26.58	31.02	5.85
2010	26.68	31.07	6.79
2011	26.90	31.40	4.80
2012	27.21	31.04	4.74
2013	27.34	31.52	4.67
2014	27.12	31.68	2.99
2015	26.89	31.60	5.48

According to data from Kendari Station, during the last 8 years, there is a rising trend in the average annual temperature. This is due to deforestation activities happening across Southeast Sulawesi Region. Deforestation is the main cause of climate change because it reduces the number of forest plants functioning to absorb carbon dioxide. As the result, the ozone layer at the atmosphere becomes damaged.

According to Biomass Carbon Calculation that has been done, Southeast Sulawesi forests can only absorb and temporarily save less that 18 billion tonnes of carbon. There is a significant difference as compared to forest condition in Southeast Sulawesi from 10 years ago. The satellite imaging applied for this research also confirms that there is significant change of land cover condition within the last 10 years.

As can be seen from Table 4, the maximum temperature in Kendari Municipality has increased by 0.1^{0}C per year. Meanwhile, the rainfall experiences a downturn every year. This research brings up consequences to the upcoming years that Southeast Sulawesi Region will experience more dryness, particularly in Kendari Municipality.

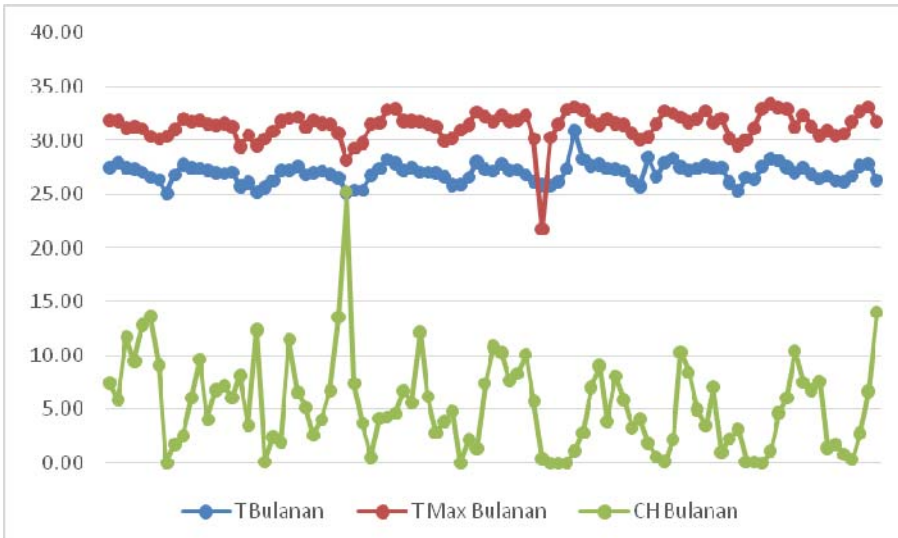

Figure 6. Monthly Average Weather Condition of Kendari Municipality.

Besides dryness, seasonal change also becomes uncertain. As can be seen in 2014, the Southeast Sulawesi region experienced prolonged EL Nino condition causing some parts in the region suffered due to dryness. In addition, in 2013, the prolonged La Nina caused floods in some parts of Southeast Sulawesi region, including Kendari Municipality.

According to the climate change projection from IPCC, the global temperature will rise by 2^{0}C in 2050. This prediction might happen faster due to fast deforestation practices causing less forest area. Therefore, it is predicted that hydro meteorological hazards in Indonesia will increase.

In conclusion, the choice in the future toward change climate issues is how to do mitigation or risk reduction as well as to adapt with the change on earth. There are several promising programs can be done, such as Carbon Bank, reforestation, or finding new invention to reduce the rate change of land cover. However, the most important thing is commitment of all people to prevent global warming.

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