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Carbon Dioxide Sequestration Capability of Green Spaces in Bogor City

Azra Q. Hazarin, Rokhmatuloh, Iqbal Putut Ash Shidiq

¹Department of Geography. Faculty of Science, University of Indonesia, Depok Campus, 16424, Indonesia

Email: rokmatuloh@yahoo.com

Abstract. Biomass estimation can be used to estimate the stock of carbon dioxide. Bogor City is one of the hinterland of Jakarta, which has a significant increase in population growth rate, especially in 1990-2000 when the number hit 10,25% and the average 3,373 vehicles each month of increase of the which provides a significant emission of carbon dioxide. This research uses three different Vegetation Indices such as NDVI, MSAVI2 and ARVI to estimate the best index to build a biomass models with 73 in-situ measurements and convert it to carbon stock estimation. This research aim at 1) looking for vegetation index which is best to be used for urban green spaces (identification ?) and 2) estimation of carbon stock of urban green spaces in the city of Bogor. 3) carbon dioxide absorption estimation of Bogor city. The result shows MSAVI2 as the best index of 61.8% correlation with rather that NDVI (42.35%) and ARVI (43.7%) . Every districts in Bogor can not absorb its carbon dioxide emission with the total of 5,931,131 tons of carbon dioxide unabsorb.

1. Introduction

Adaptation to climate change depend on the activities carried out in urban areas, home of more than half of the population living world and the center of economic activity [1]. Although urban areas occupy only 0.51% of the total land in the world, but the ecological footprint from the reduction of natural areas from 70% to 50%, which is intended to accommodate the needs of human consumption is big [2]. Population growth and urban activities will increase greenhouse gases, these activities may include the transport sector, the industrial sector, commercial and domestic sectors. [3]

According to Business as Usual (BAU), CO₂ emissions are going to reach 906 million tonnes in 2020 [3]. It is caused by the increasing number of fossil fuel, oil, and coal utilization in human activity [4]. It is also caused by the growing number of population which leads to land-use/land-cover change [5]. Most of the changes are occurred in green areas where transformed to built-up area. Vegetated area such as green belt, parks, yards, and forest highways which are able to absorb CO₂ and produce O₂ has been converted into shops, housing, offices, recreation areas, roads and industries.

Studies on related topics in the city scale offer some challenges. The need to cover large area and obtain a large dataset spatially and temporally are some of the challenge. Therefore this study uses remote sensing technology, as it is able to provide spatial and temporal data over a medium- or large-scale area [6].

Remote sensing is capable of recording the reflectance value of a variety of objects including vegetation [7]. This interaction can be measured by algorithms in the image. Vegetation indices algorithms that are mostly utilized in the field of environment are NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index), which is used to measure the percentage of canopy cover of trees [8] the measurement of carbon stocks, biomass to carbon dioxide stored and oxygen supply. Vegetation indices used in this study is the NDVI [9], Modified Soil Adjusted Vegetation Index 2 (MSAVI2) [10], and Atmospherically Resistant Vegetation Index (ARVI) [11].

Therefore, this research is needed to determine the ability of green space to absorb the carbon dioxide emissions. This information can be used to help local governments to understand the environmental conditions of their region. Some of the value of their research interests are given the threat of human activity in the transport sector, commercial and domestic that can threaten the environment so that the



monitoring of environmental conditions, especially the vegetation needs to be done to balance the sector.

2 Methodology

2.1 Research Framework

The aim of this study is to measure the carbon dioxide sequestration capability of green space areas. To achieve that aim, carbon stocks that potentially stored in vegetation are being calculated from biomass estimated from regression model between stand parameters and vegetation indices. This research comes from the idea of green space requirements that must sustain human activities for a clean and healthy air. The variables used in this study are the NDVI, MSAVI2 and ARVI to create a model of biomass based on linkages between biomass in-situ performed by measuring trunk diameter at breast height, tree height, tree species, and the density of trees be obtained from ICRAF's Wood density. Field measurement carbon dioxide emission data were gathered from Environmental Agency of Bogor City in the year of 2017. The result is green spaces absorbing quality of carbon dioxide in Kota Bogor.

2.2 Data collection

The data used in this study is divided into primary data and secondary data. Primary data were directly collected in the field and secondary data were collected from certain sources as well as related agencies and being processed prior to the field measurement. Primary data collected in this study are type of tree, tree diameter and tree height. Determination of the sample using a multi-staged sampling, first is the determination of non-probability sampling using purposive sampling technique sampling as a control variable to separate the non-green space and green space from 82 samples which measured 6 x 6 m, identical with SPOT-7 spatial resolution, later will be called a grid. Meanwhile, secondary data used is the property of the agency or agencies such as image data SPOT-7 in 2017 from the National Institute of Aeronautics and Space (LAPAN), RBI map published by the Geospatial Information Agency (BIG) with 1:25000 scale.

2.2.1 Data processing

The first data processing is radiometric correction on SPOT-7 imagery by changing the Digital Number (DN) into Top of Atmosphere (TOA) Reflectance using FLAASH module in ENVI 5.1. After radiometric correction, the reflectance value is converted to the vegetation index by the formula as follows:

- a. Normalized Difference Vegetation Index (NDVI) (Rouse, 1973).

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

- b. Modified Soil Adjusted Vegetation Index (MSAVI2) (Huete, 1988),

$$MSAVI2 = \frac{(2 * NIR + 1 - \sqrt{(2 * NIR + 1)^2 - 8 * (NIR - RED)})}{2}$$

- c. Atmospherically Resistant Vegetation Index (ARVI) (Kaufman & Tanre, 1992)

$$ARVI = (NIR - ((2RED) - BLUE)) / (NIR + ((2RED) - BLUE))$$

The data collected is a tree trunk diameter (dbh), tree height, tree species. Biomass calculated using allometric equation belongs to the USDA 2016 written by McPherson [12]. The equation used in urban areas so as to reduce the bias that occurs than using a general allometric equations.

Calculations are based on the measurement of the volume of the converted tree with wood specific gravity value of each individual tree species. After that, the value of the biomass dry weight multiplied by 1.28 scalar factor into the total biomass. This value is then multiplied by 0.5 to be converted into a total carbon value and multiplied by the molecular weight of CO₂ that is 3.67 to estimate the value of the stored carbon dioxide. The accuracy of the results were tested using Mean Absolute Error (MAE).

2.2.2 Data analysis

This research uses spatial analysis, statistical analysis and overlay analysis. Spatial analysis is used to determine the distribution of biomass in Bogor based on the grid which divided into four classes: low, medium, high, and very high. Statistical analysis is used to determine the correlation between the results of field measurements with the field of biomass vegetation index. Overlay analysis is used to determine the absorption of carbon dioxide emissions by reducing the carbon dioxide emissions of carbon dioxide stored by the unit of analysis.

3. Result

3.1 Distribution of Biomass and Carbon Dioxide (CO₂) Stored in Bogor City

3.1.1 Vegetation Indices

The highest NDVI value in the city of Bogor is 0.729 and the smallest value is 0.208. MSAVI2 pixel values has a maximum value of the result of image processing SPOT-7 is 0.584 and the minimum pixel value is -0.077, while the maximum pixel value of ARVI in the city of Bogor, namely 0,998 and the minimum pixel value is -0,175.

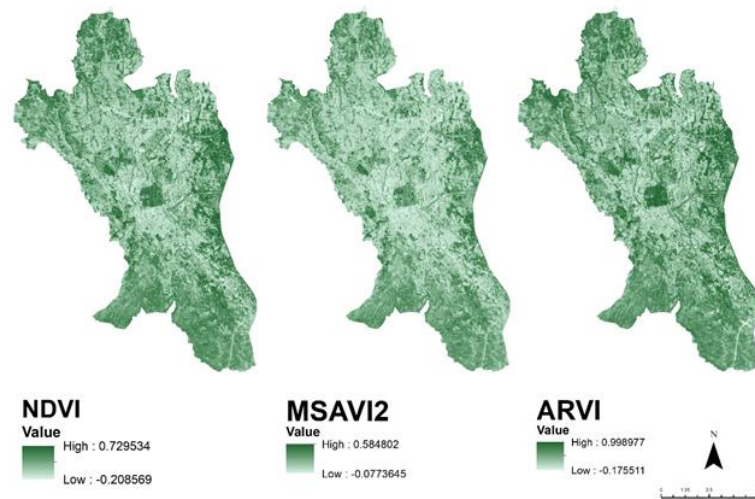


Figure 1. Map of NDVI, MSAVI2 and ARVI Bogor City

3.1.2 Land Cover

Based on the results of the classification between vegetation and non-vegetation in SPOT-7 imagery, it is known that the actual area of green space in the city of Bogor reached 45.59% with an area of 51.25 km².

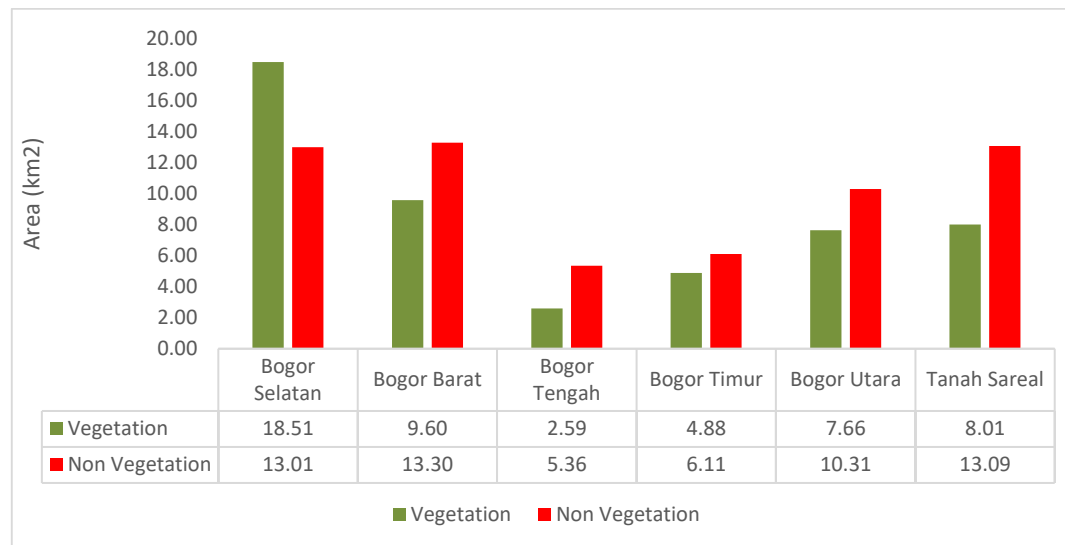


Figure 2. Chart of Non Vegetation and Vegetation Land Cover in Bogor

Bogor has six subdistricts which are Bogor Barat, Bogor Tengah, Bogor Timur, Bogor Utara and Tanah Sareal. The one which has the most are without vegetation is Bogor Barat with land cover 41.93% of vegetation and 58.07% of non vegetation, next is Bogor Tengah with 32.58% of vegetation and 67.42%, Bogor Timur 44.43% of vegetation and 55.57% of non vegetation, Bogor Utara 42.61% and 57.39% for vegetation and non vegetation, respectively. The last is Tanah Sareal with 37.97% and 62.03% for vegetation and non vegetation, respectively.

3.1.3 Biomass

The model with linier regression estimates the value of the biomass modeled after the vegetation index that has the highest Pearson correlation with the value of the actual biomass. MSAVI2 has the highest correlation with biomass ($R=0.618$) other than two variables. The second highest correlation found in ARVI correlation value as it is reached 0.437. The lowest correlation with the value of 0.423 is the NDVI variable.

Linear regression was used to build the biomass model. The model is $Y = -9827.05 + 51680.18x + C$ where Y is the biomass, and X is a pixel value of MSAVI2. The results of the regression coefficients showed positive values which means that any increase in the value of MSAVI2 then the value of the biomass will be increased. Overall test results of biomass estimation has an error value for 1.26%. The percentages show that the model is built has an accuracy of 98.74%.

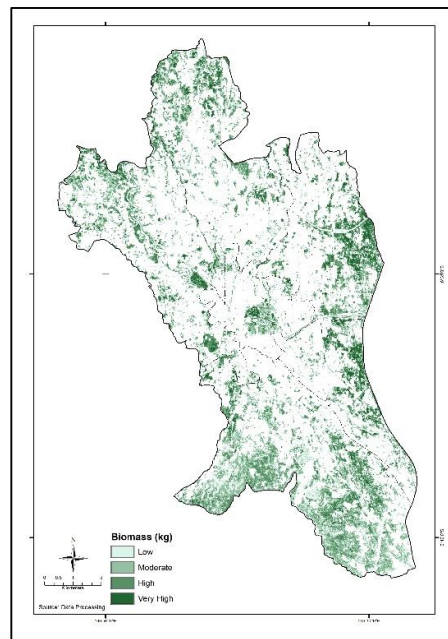


Figure 3. Biomass Map of Bogor City

Distribution of biomass in Bogor City classified by the method of natural breaks (Jenks) on ArcGIS 10.1, there are four classifications, these classifications are 80-2769 kg / grid, 2770-5305 kg / grid, 5306-8475 kg / grid, 8476-20268 kg / grid. Distribution of biomass per sub-district class can be seen in Figure 5.

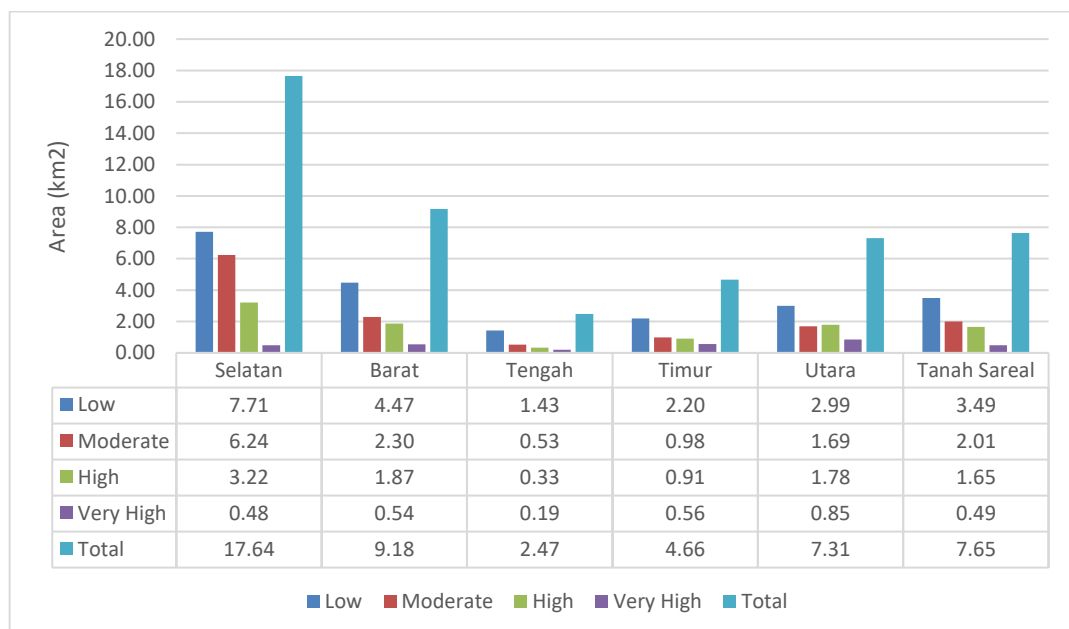


Figure 4. The area of biomass per sub-district classification

Overall low biomass value has the most extensive distribution in Bogor because their numbers are dominating compared to other classes. Bogor Selatan subdistrict has the largest biomass area of 17.64 km² and therefore has an area of low, medium and high largest among others. Very high class has the largest area in Bogor Utara which is 0.85 km²- almost half of the area in the Bogor Selatan i.e 0.48 km². Bogor Tengah subdistrict has the smallest area of biomass throughout the class because it has the

smallest area. Bogor Barat subdistrict has the low and high area of biomass after Bogor Selatan subdistrict which consists of 4.47 km² biomass, 2.30 km² of moderate, and 1.87 km² of high biomass.

3.1.4 Carbon Stored

Measurements of carbon dioxide stored in vegetation can help determine the policies of transport, the carrying capacity of the region as well as indicators of environmental quality. Carbon dioxide is a component that can harm the environment, so it should be countered with good absorption. The absorption of carbon dioxide that can be done in a massive, low cost and fast is the absorption by plants.

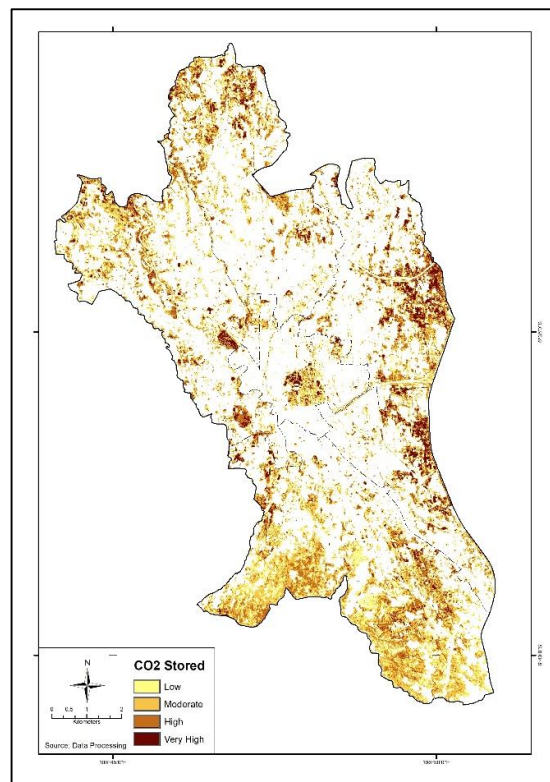


Figure 5. Carbon dioxide stored in Bogor

Distribution of carbon dioxide stored in Bogor classified by the method of natural breaks (Jenks) at ArcGIS 10.1, there are four classifications, the classifications are 1262-4549 kg / grid, 4549-9246 kg / grid, 9246-15117 kg / grid, 15117-37425 kg / grid. Carbon dioxide is stored at very high grade spread throughout the city of Bogor but most numerous are in Bogor Utara and Bogor Timur. In Bogor Tengah very high classification are in the Bogor Botanical Gardens, in Bogor Barat subdistrict the locations are in CIFOR and Balai Agroklimatologi Cimanggu

Bogor City center section is dominated by regions that do not have carbon deposits and areas that have lower carbon dioxide absorption, the region that do not have carbon dioxide tends to distribute towards the northern part of the city of Bogor, this is due to Depok and Jakarta. Areas that do not have carbon deposits also follow the pattern of major streets and areas that have high accessibility, due to developed land.

3.1.5 Carbon Dioxide Emissions

Carbon dioxide is a harmful gas that is colorless and odorless. Carbon dioxide is commonly found from incomplete combustion of natural gas and other materials containing carbon. Vehicle is the biggest contribution of carbon emissions with a percentage of 70%. Figure 7 illustrates the distribution of carbon dioxide in Bogor using IDW interpolation with the spread value is highest in Bogor Utara subdistrict, Bogor Barat and Bogor Tengah, while the smallest value contained in Bogor Barat dan Bogor Selatan subdistrict. Overall the total carbon dioxide per districts in the city of Bogor ranges between 1.097.823 to 3.937.765 ton with district which has the largest total is Bogor Selatan subdistrict.

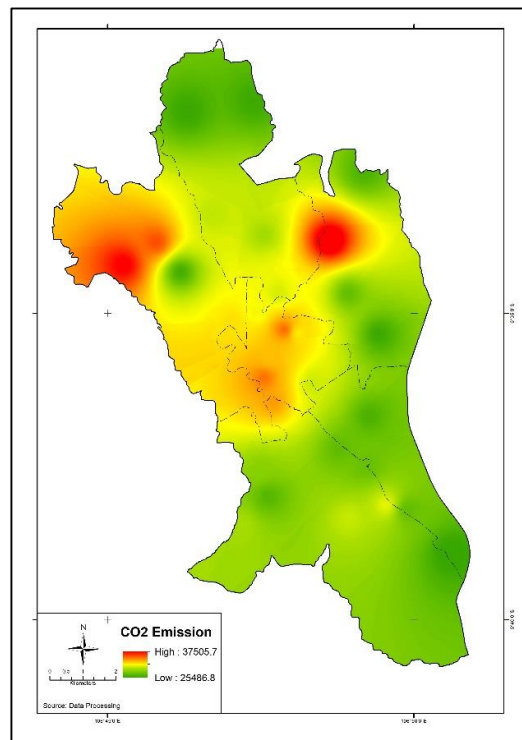


Figure 6. Carbon Dioxide Emissions of Bogor City

The absorption of carbon dioxide by green space is an important function in the presence of plants in urban areas, urban carbon dioxide emissions have a higher rate because of human activities, transportation, and industry. Therefore determine the ability of green space to absorb carbon dioxide can help understanding the capacity of the environment, the implementation of spatial plans and policies that support the health of public and private transport. The distribution of green space to the absorption of carbon dioxide emissions in the city of Bogor can be seen in Figure 8 where the absorption of vegetation are still scattered throughout the city of Bogor with total area of the territory which are able to absorb emissions is 27.34 km² and the area that is unable to absorb amounted to 79.90 km². Greatest area is in Bogor Selatan subdistrict with 10.44 km², followed by Bogor Utara, 4.39 km².

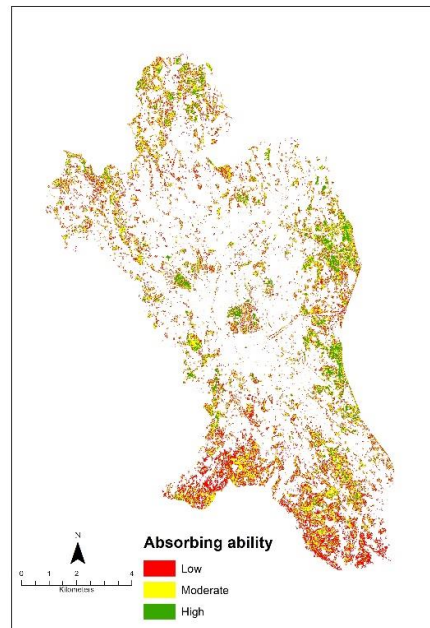


Figure 7. Map of Carbon Dioxide Absorption Bogor City

The ability to absorb carbon dioxide emissions in this research is calculated by reducing CO₂ saved with carbon dioxide emissions and divided into three classifications, namely the classification of low, medium and high. Low values has the biggest area in in the Bogor Selatan, this is because the absorption of CO₂ vegetation in this area is not too big although this region has lower emissions. Bogor Utara subdistrict has the biggest high classification area despite having a point of high concentrations of carbon dioxide emissions in its territory, this is due to stored of CO₂ that have a high value and are beyond the reach of the concentration point. The region around point concentration is in the classification of areas that are not able to absorb carbon dioxide emissions. Bogor Barat subdistrict expands absorption ability after Bogor Selatan subdistrict with a total area of 4.60 km²

Table 1. Classification of CO₂ Stored

CO ₂ Stored (kg/grid)	Grid Total	Area (km ²)
Low	372.879	13,42
Moderate	288.000	10,36
High	98.407	3,54
Total	759.286	27,33

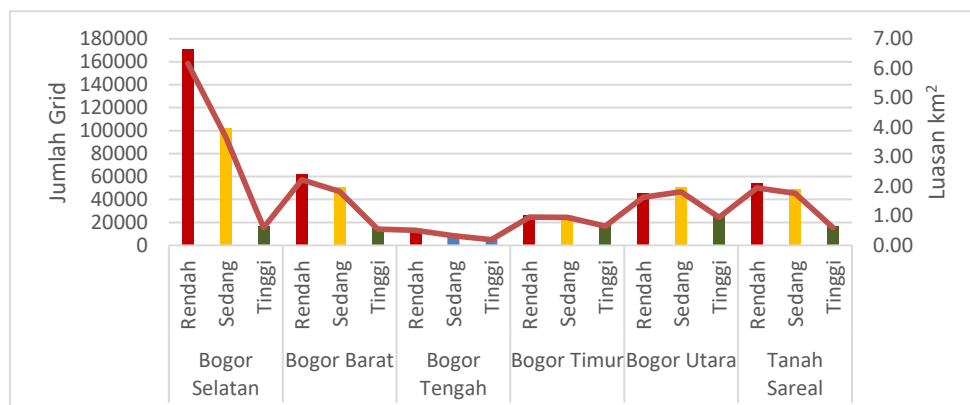


Figure 8. CO₂ Stored in Bogor City

Figure 9 shows a comparison between the stored of CO₂ and CO₂ emissions per districts in the city of Bogor. The most visible is the absence of CO₂ savings deficit in all districts. Districts that have the highest emissions is Bogor Selatan, although the CO₂ savings are also the largest in the district, but there is still a deficit of 968.849 tonnes. Tanah Sareal has a deficit of 1,309,287 tons of CO₂, Bogor Utara subdistrict have the deficit of 836.603 tonnes of CO₂, Bogor Timur subdistrict has a deficit of 452.140 tonnes of CO₂, Bogor Tengah subdistrict must absorb 729.198 tonnes of CO₂ that is not absorbed by the vegetation. The deficit is in Bogor Barat subdistrict in the amount of 1,635,053 tons of CO₂, this is due to the high amount of CO₂ emissions in these districts.

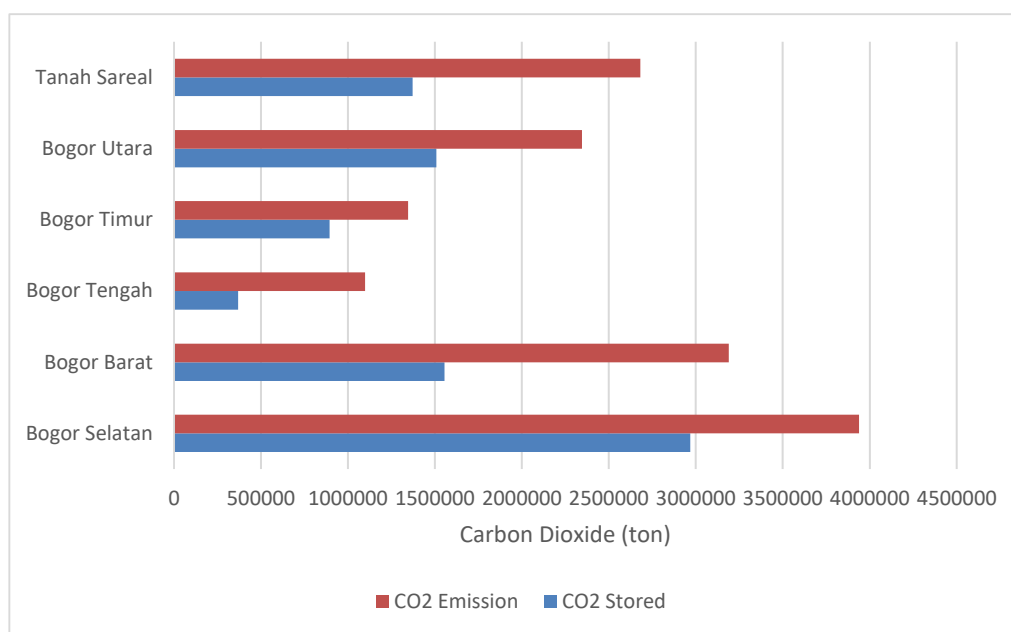


Figure 9. Comparison of CO₂ stored and CO₂ Emissions in Bogor City

If using the average uptake of CO₂ from this study which is 0.22 ton/ m² then to increase the absorptive capacity of vegetation on carbon dioxide emissions, Bogor Selatan subdistrict must add green spaces covering areas of 4.4 km², Tanah Sareal need greening of 5.95 km² of its area while Bogor Utara need to add areas of 3.8 km². Bogor Timur, Bogor Timur and Bogor Barat each need greening total area of 2.05 km², 3.31 km² and 7.43 km². Overall the city of Bogor has the capability of 8,666,259 tons of CO₂ absorption and emission amount of 14,597,390 tons, so the city of Bogor need to sustain a deficit of 5,931,131 tons of CO₂ emissions that can be done with increasing the planting of vegetation in a city park, river border, roadway borders and unused land.

4. Conclusion

The total content of green spaces biomass in the city of Bogor reached 4,102,761 tons. The biomass which has a very high class located in the north and east and high, medium and low in the southern parts. Values higher biomass in the north and east due to the denser green spaces. Low biomass value scattered throughout the city but has a high area in the center of the city of Bogor.

Modified Soil Adjusted Vegetation Index 2 (MSAVI2) (42.3%) had a higher correlation of Normalized Difference Vegetation Index (NDVI) (42.35) and Atmospherically Resistant Vegetation Index (ARVI) is worth 43.7%. The model generated estimates of biomass with MSAVI2 is the MAE value of $1:26\%Y = -9827.05 + 51680.18x + C$.

Bogor City has the capacity of 8,666,259 tons of CO₂ absorption and emission amount of 14,597,390 tonnes with very high absorption located in the north and east part. Bogor City has a deficit of 5,931,131 tons of CO₂ emissions. The area of green space that can absorb CO₂ emissions is 27.34 km², while the area which is not able to absorb its emissions is 79.90 km².

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