Vegetation index-based biomass model and Land Surface Temperature (LST) from urban green spaces in Bandung City derived from multispectral imageries

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Abstract. Bandung City is the largest metropolitan city in West Java Province, with a population of more than 2.5 million people in 2019. With the vast number of population, the need for land that is inevitable. The need for land in this area continuously increased, but the balanced is not meet with the availability of land. Further, it will encourage the conversion of natural land such as green spaces into a built-up form such as settlements. A disturbed vegetation cover would have an impact on the carbon sequestration capabilities and, on the other hand, might increase the land surface temperature. The goals of this study are to determine the carbon sequestration capabilities of tree biomass in urban green space and to examine the relationship between biomass content and land surface temperature (LST). Some vegetation indices include NDVI, ARVI, and SAVI, derived from multispectral Sentinel 2B are being correlated with allometric-based biomass value to generate biomass estimation models. Spatial analysis is useful to provide information about the value of biomass in the tree canopy and spatial distribution of biomass in the City of Bandung. It results that NDVI provides a better correlation than SAVI and ARVI. The amount of Biomass in the UGS vegetation in Bandung City is 4098.504 ton. Spatial distribution of high-value biomass is located in the north of Bandung, while low-value biomass is spread spatially in the south of Bandung. Large-sized trees with high vegetation density are in areas with high biomass values. While LST values range from 0 to 34.73 °C. If there is a correlation between biomass and LST, it produces an inverse correlation of 0.33 with a moderate relationship.

Keywords : Biomass model, vegetation indices, LST, urban green space, Sentinel 2B

1. Introduction
The existence of Urban Green Space (UGS) as the lungs of the city is indispensable by a city or region. Based on the UU No. 26 of 2007 on Spatial Arrangement requires the area of Green Open Space (UGS) in urban areas at least 30% of the city area with proportional 20% public UGS and 10% private UGS [1]. While The City of Bandung currently has a public UGS of only 8.61% calculated from the area of Bandung city as a whole which is 3183.76 Ha. In addition, Bandung is the largest metropolitan city in West Java with a population of more than 2.5 million people in 2019 [2].

So it has an impact on the wider land needs. The growing need for land in Bandung will encourage transform green land into a built-up. Furthermore, this will encourage the conversion of natural land such as green open land into land built like settlements. The disrupted vegetation cover will have an impact on carbon absorption capabilities and on the other hand, can increase ground surface temperature. Land conservation on UGS causes UGS area to decrease. The lack of UGS in Bandung makes it incompatible with the regulations that have been formulated while on the other hand the existence of UGS on a micro-regional scale has an ecological function in terms of regulating air temperature, so any policy of changing UGS will change the air temperature [3].

According to [4] the total amount of material living above the surface on a tree can biomass define and expressed with a unit of dry weight of area. Biomass will experience growth and development as plants absorb carbon dioxide (CO₂) from the air and convert these compounds into organic matter through the process of photosynthesis. The result of the process of photosynthesis in the form of oxygen (O₂) that can be beneficial to human beings, animals, and plants. Biomass
estimation in this study was conducted with 3 approaches create a model, field measurement, and remote sensing. Approach in the form of modeling can be done by calculating allometric equations on UGS, field measurements can be done to find information about the value of biomass in tree headers and the amount of CO₂ absorbed by vegetation by measuring Diameter at Breast Height (DBH), height, and plant species.

While the approach with remote sensing is used to know the best vegetation index that will be used into biomass. The vegetation index is NDVI (Normalized Difference Vegetation Index) with consideration of chlorophyll value, ARVI (Atmospherically Resistant Vegetation Index), and SAVI (Soil Adjusted Vegetation Index). The selection of vegetation index is based on different characteristics. NDVI is obtained from the peak of reflectance that is susceptible to chlorophyll in absorbing light energy for photosynthesis, SAVI is a greenness index whose variability is greater due to soil reflectance [5]. While ARVI is obtained based on consideration of the presence of aerosols in the atmosphere [6]. Therefore, the purpose of this study is to spatially analyze biomass estimates using allometric models with the best vegetation index in urban Urban Green Space (UGS), and describe whether it has a relationship with the surface temperature.

2. Methods

2.1. Study Area

Bandung is the largest metropolitan city in West Java Province. Geographically the area of Bandung is between 07°31'57" - 107°45'55" E and 6°49'37" - 6°56'36" S. Based on DPKP3, about 8.61% of the area of Bandung is urban green space with UGS border (river, road, railway, airport, sutet, toll road), UGS Park Environmental Unit/city, UGS Forest City, UGS nature preservation, UGS cemetery, UGS private, and UGS Plasma Nutfah eks. Situ Protection Area (Fig. 1) The UGSpredominated Artocarpus heterophyllus, Casuarinaceae, Mangifera, Swietenia mahagoni, and Samanea saman.

2.2. Geospatial Information System Data Processing

Secondary data in this study is Sentinel-2B imagery obtained on 06-13-2020 for vegetation index and landsat imagery obtained on 07-27-2020 for Land Surface Temperature (LST) path/row 122/65 with cloud content of <10%. LST calculation uses band 10 on imagery. Before processing with vegetation and LST index equations, imagery is first corrected to cut cloud values and geometric corrections to cut position distortion. The acquisition of the NDVI (Normalized Difference Vegetation Index) vegetation index (Equation 1), the ARVI (Atmospherically Resistant Vegetation Index) (Equation 2), and the SAVI (Soil Adjusted Vegetation Index) (Equation 3). The values obtained from the vegetation index range from -1 to 1.

\[
N = \frac{N - R}{N + R} \quad (1)
\]
To get the value of the surface temperature obtained from the thermal waves that are in the image. In Landsat-8 OLI/TIRS band 10 imagery is get land surface temperature values can using a thermal band. The calculation process in obtaining the first value is to do radiometric correction through the conversion of Digital Number (DN) to spectral radiance [7]. Then change the spectral value that has been obtained to the temperature value. And the last is to change the celvin temperature value to Celsius temperature. So that the LST equation is obtained (Equation 4). To adjust the plot size of the biomass estimation, the LST pixel is re-sample to 100 x 100 m. The choice of band 10 is due to the LST value in Band 10 is not contaminated with stray light so Band 10 recommend using quantitative analysis.

\[ L = \frac{K_2}{K_1} - 272.15 \]  

Where LST is Land Surface Temperature (°C), L is spectral radiation (Watts/(m² * sr * μm)) K1 is a Band-specific thermal conversion constant from the metadata and K2 dalah Band-specific thermal conversion constant from the metadata.

### 2.3. Field Sample Method and Data Accuracy Test

The average ABG value of plants can be known by the creation of a plot measuring 100 x 100 m (1 ha). Because according to [8] that a large plot is able to accommodate the diversity of biophysical parameters it represents but will take a lot of time and cost and the manufacture and measurement is getting longer. The selection of samples for the field was randomly conducted in the Urban Green Space (UGS) as much as 80 plots or equal to 10 x 10 pixel sizes with a 90% confidence level agree slovin rules. In this study the biophysical parameters of trees measured were Diameter at Breast Height (DBH), height, and tree species. Then, biomass estimation is based on allometric equations from the USDA in species. If there is no species, then frequency variations are based on broadleaf tree groups (Equation 5), conifer trees (Equation 6), and palm trees (Equation 7).

\[ V_{\text{Broadleaf Tree}} = 0.0001967 \times \text{dbhcm}^{1.951853} \times \text{htm}^{0.664255} \]  
\[ V_{\text{Conifer Tree}} = 0.0000426 \times \text{dbhcm}^{2.24358} \times \text{htm}^{0.64956} \]  
\[ DW_{\text{Palm}} = (6 \times \text{htm} + 0.8) + (0.8 \times \text{htm} + 0.9) \]

Based on equations 5 and 6 above that V is the volume of broadleaf and conifer tree groups, dbhcm is the diameter at Breast Height (DBH) with centimeters, htm is the height of a tree with a unit of meters. In equation 7, DW is a Dry Weight group of palm trees with a unit of kilograms. To be found DW value as AGB, the group of broadleaf and conifer trees multiplied by the density of tree species based on USDA and Wood Density ICRAF[9,10] with reference to tree species located in tropical Asia.

\[ \text{NMAE} (%) = \frac{1}{R} \sum_{i=1}^{R} \left| \frac{y_i - \hat{y}_i}{x} \right| \times 100 \]  

The data used in the biomass equation is 60% of the field measurement results and 40% is used for Normalized Mean Absolute Error (NMAE).which corresponds to the quadratic regression. NMAE is used to check prediction methods (Equations 8). Each error or residual are squared. It is then summed up and added with the number of observations. Where yi is the prediction and \( \hat{y}_i \) is reduced of observations.

### 2.4. Data Correlation Analysis
To compare the correlation between LST and biomass values, 95 plots measuring 100 x 100 m were selected with a 90% sample based on slovin rules that were assumed to represent the overall population information. LST data analysis is calculated based on statistical analysis to measure correlation or LST with biomass estimation value using Pearson Product Moment (Equations 9).

\[ r_x = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}(\sum_{i=1}^{n}(y_i - \bar{y})^2)} \]  

(9)

Where \( r_x \) is the correlation coefficient between variables x and y with x is a free variable and y is a bound variable. This calculation will have a value of 0 to 1. The strength of the \( r \) value is as follows:

1. \( r < 0.25 \) : Both variables have no relationship
2. \( 0.26 < r < 0.50 \) : Both variables have moderate relationships
3. \( 0.51 < r < 0.75 \) : Both variables have strong relationships
4. \( 0.76 < r < 0.1 \) : Both variables have perfect relationships

3. Results and Discussion

Urban Green Space (UGS) Data obtained from existing RDTR sourced from the Dinas Tata Ruang (DISTARU) of Bandung city has an area according to table 1.

| UGS Category                        | Area (Ha) |
|-------------------------------------|-----------|
| UGS Forest City                    | 25.29     |
| UGS Plasma Nutfah eks. Situ Protection Area | 11.67 |
| UGS Nature Preservation            | 538.00    |
| UGS Cemetery                       | 131.42    |
| UGS Park Environmental Unit/city   | 166.75    |
| UGS Private                        | 60.80     |
| Airport Border                     | 53.21     |
| Road Network Border                | 15.27     |
| Railway Border                     | 54.83     |
| River Border                       | 229.64    |
| SUTET Border                       | 93.34     |
| TOLL Border                        | 68.80     |

Source: Dinas Tata Ruang Kota Bandung

UGS Bandung category is dominant in the local RTH Protection area of 1449.09 ha of the total area of RTH Bandung. UGS Spatial distributed local protection in the northern part of Bandung with the dominance of plant species during field surveys in RTH Bandang is Artocarpus heterophyllus, Casuarinaceae, Mangifera, Swietenia mahagoni, and Samanea saman.

The vegetation index is obtained from sentinel image processing 2B. The result of vegetation index values in the form of NDVI, ARVI, and SAVI has different minimum, maximum, and average values according to table 2.

| Vegetation Index | Min  | Max  |
|------------------|------|------|
| NDVI             | -0.16| 0.79 |
| ARVI             | -0.36| 0.78 |
| SAVI             | -0.05| 0.56 |

Source: Data Processing Results
The above vegetation index has varying maximum and minimum values. The spatial distribution of vegetation indexes in the form of NDVI, ARVI, and SAVI is the dominant maximum value in the northern part of Bandung, and the low vegetation index value is in the southern part of Bandung (fig.2). The maximum vegetation index value is in *Samanea saman* species with a high biomass estimate based on the results of field measurements.

The value of the vegetation index is then regressed with the biophysical measurement of trees in the field to produce a correlation and error biomass estimation.

| Vegetation Index | Pearson Correlation (%) | Biomass Estimation Model | NMAE (%) |
|------------------|-------------------------|--------------------------|----------|
| NDVI             | 60.2                    | Y = 110.04 - 3622.71x - 14055.44x^2 + 17549.45x^3 | 2.63     |
| ARVI             | 64.6                    | Y = 339.14 + 529.13x - 3112.56x^2 + 7364.37x^3 | 2.33     |
| SAVI             | 76.2                    | Y = -31.68 + 7830.68x - 38852.08x^2 + 68390.27x^3 | 1.67     |

Table 3: Correlation and error biomass estimation using each vegetation index formula

Source: Data Processing Results

Table 3 shows that SAVI has a better correlation to biomass values than other vegetation indices, with the least error being 1.67%. In contrast, NDVI has the lowest correlation with the highest number of error reaching 2.63%. In addition, ARVI showed a sized correlation percentage value of about 64.6% with an error of about 2.33%.

This study used qubic regression to get biomass guessing models with field sampling data. Thus, SAVI was chosen as the best vegetation indices because it has the highest correlation with biomass (76.2%) with relatively low errors (1.67%). The figure 3a shows a biomass distribution map in Bandung that is integrated using biomass and SAVI guessing models.
Biomass values range from 0.00126 to 5.46821 ton and the amount of biomass in the UGS vegetation in Bandung City is 4098.504 ton. Spatial distribution of high-value biomass is located in the north of Bandung, while low-value biomass is spread spatially in the south of Bandung. Large-sized trees with high vegetation density are in areas with high biomass values. If it is correlation to the land surface temperature of Bandung city, then there is a relationship inversely. In the southern part of Bandung has a low biomass value with high LST and in the northern part of Bandung has a high biomass value with low LST, evidenced by a correlation value that is minus and by 0.33 with variable biomass estimation and LST has a moderate relationship. This can be because the northern part of Bandung city is distributed spatially dominant vegetation protection category as precise and natural protection, while the southern part of Bandung city is distributed spatially dominant non-vegetation such as settlements.

In Indonesia the excess heat is not evenly known as the hot pole city. Hot poles are formed if some vegetation is replaced by asphalt and concrete for roads, buildings and other structures necessary to accommodate high population growth. The surface of the soil will absorb more of the sun's heat and reflect it, causing the city's surface temperature to rise [11]. So that the southern region that there are many buildings has a high LST value, while the northern part of the area that there is a lot of vegetation land has a low LST value.

4. Conclusion
Sentinel 2B imagery is used to map the spatial distribution of biomass in Bandung. Various vegetation indexes including NDVI, ARVI and SAVI are used to produce biomass. While the LST algorithm on Landsat imagery is used to produce LST spatial distribution. It concluded that NDVI provides a better correlation than SAVI and ARVI. The amount of Biomass in the UGS vegetation in Bandung City is 4098.504 ton. Spatial distribution of high-value biomass is located in the north of Bandung, while low-value biomass is spread spatially in the south of Bandung. While LST values range from 0 to 34.73 °C. If there is a correlation between biomass and LST, it produces an inverse correlation of 0.33 with a moderate relationship.

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