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Crown Density Relationship to Microclimate and Comfort Index in Telaga Sari City Forest, Balikpapan, East Kalimantan, Indonesia

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Abstract. The development of urban areas that are increasingly developing causes the area of green open space to decrease, and urban buildings that are increasingly denser result in an increase in local temperatures in the city. The presence of vegetation will provide cooler air. Furthermore, the urban microclimate is an interesting thing to correlate with the presence of vegetation somewhere. The Telaga Sari City Forest is one of Balikpapan's green open space places. This research analyz the relationship between crown density microclimate and comfort index. The method for the percentage of crown density used Habitapp App. To measure the microclimate used Thermohygrometer, and Lux Meter. From the research results, it is known that, at the Telaga Sari City Forest there is a strong relationship between crown density and microclimate, namely light intensity, temperature, humidity, and the comfort index/THI, successively the multiple R values of 0.87, 0.83, 0.78 and 0.81. The linear equations namely y = -23.677x + 1986, y = -0.0317x + 31.096, y = 0.119x + 65.891 and y = -0.0232x + 29.007. In order to create a favorable microclimate in the city and provide green open space, it required to plant trees with high canopy density values.

1. Intoduction

In urban areas, rapid population growth is followed by economic, settlement, education, and cultural developments. The rate of urbanization is accelerating, driven by the enormous attractiveness of cities for rural residents, so the resulting urban resources and environment have considerable pressure caused by an increase in the population of urban areas. The conversion of land into facilities for supporting urban activities such as roads, industry, trade, and settlements that were initially in the form of space for growing various vegetation to become urban areas is one of the effects of urban development that is characterized by an increase in population [1].

One of the impacts resulting from the need for green open space in urban areas is that people need more places to socialize with the surrounding environment, furthermore, limited green open space in urban areas can cause the pollution produced to be unable to be absorbed so that it can interfere with public health [2]. Increasingly polluted air quality is an essential reason for providing urban Green Open Space (RTH). The hot and humid climate in the tropics is an increasing discomfort problem, especially during the day, dramatically affecting activities' comfort. The problem of uncontrolled heat is caused by converting green open land into built-up areas, such as infrastructure, settlements, and other infrastructure, resulting in a problem of limited green open space. Based on the information above, These problems will certainly affect the livability level of Balikpapan City. Balikpapan City has a mission related to the city's livable one, creating a livable city and being environmentally conscious.

Balikpapan City's public green open space in 2017 was 353.2 Ha [3]. In 2018, the public green open space area was 207.48 Ha [4]. It indicates that there has been a reduction in the area of green open space in Balikpapan City by 145.72 Ha from the 2017 – 2018 period. After analyzing the need for public green open space based on meeting the needs of residents in Balikpapan City, it turns out that public green open space in Balikpapan City is still inadequate. Public green open space currently managed by the Balikpapan city government is identified as 0.57% of the total area of Balikpapan city of 50,330 ha. From these data, achieving the 20% Public Green Open Space target of 10,066 ha is still far from the requirements, so other more appropriate efforts are needed to achieve this target. Private green open spaces currently managed by private companies and the community are identified as 852.88 ha or 1.69% of the total area of Balikpapan City, which is 50,330 ha. From these data, achieving the 10% private green open space target of 5,033 ha is still far from the existing requirements, so an appropriate provision strategy is needed for Balikpapan City. Public Green Open Space still needs an additional 19.43% and Private Green Open Space 8.31%. The provision of green open space, both public and private, for the context of Balikpapan City, needs to pay attention in detail to the actual spatial conditions that can provide an overview real of the condition of green space, both open as open green space and other green spaces that can function as open green space. It should be the primary focus for the City of Balikpapan.

The city of Balikpapan still maintains a lot of green open areas, including cemeteries, city parks, green belts, city woods, and protected forests. The Telaga Sari City Forest is one of Balikpapan's green open space places. Urban forests are places in or around cities where trees are permitted to grow naturally, unmanaged, and without being arranged like a park. Reduced urban environmental degradation, improved living conditions, and aesthetics are all advantages of this green space. Urban forests are essential to counteracting urban physical growth that is becoming more crowded and reducing the amount of natural open space.

The development of urban areas that are increasingly developing causes the area of open green space to decrease, and urban buildings that are increasingly denser result in an increase in local temperatures in the city. It distinguishes the condition of the city's air temperature being hotter than the air temperature in the village. This temperature increase is essentially a reflection of changes in the microclimate; reduced vegetation will exacerbate the aesthetic appearance of the city's face to become arid and hot. However, on the contrary, vegetation will provide more relaxed air. Furthermore, the urban microclimate is an exciting thing to correlate with the presence of vegetation somewhere. How far is the relationship between canopy density and microclimate (light intensity, air temperature, relative humidity, and comfort index) is a question that will be answered through this research.

2. Material and Methods

2.1. Research sites

This research was conducted in a green open space, namely the Telaga Sari City Forest in Balikpapan City, East Kalimantan, Indonesia. Telaga Sari City Forest has an area of 93,042 m^2. Some of the visitor facilities include gazebos, toilets, and parking lots. The service is open every day except Sunday and Saturday only until half a day. Telaga Sari City Forest is a quiet visitor location despite no entrance fee. It is due to the lack of maintenance, one of which is that there are no safe tracking facilities for visitors, resulting in a lack of interest for residents to enter the location. The aerial portrait of the Telaga Sari urban forest can be seen in Figure 1.

Figure 1. Aerial Portrait of Telaga Sari City Forest

2.2. Objects, Materials, and Equipment

The objects in this study are Tree Crown Density, Light Intensity, Air Temperature, and Relative Humidity. Materials and equipment used in this study include the following: Drone Phantom 4 Pro V2.0, Software Agisoft MetashapIt is, Thermohygrometer, Lux Meter, GPS Garmin 78s, Laptop, Camera, Habitapp App, Dji Go 4 App, Pix4Dcapture App, Phiband, Survey Tape, and tally *sheet.*

2.3. Microclimate Measurement

In order to accurately measure the microclimate, the instrument is placed ±1.5 meters above the ground surface because the microclimate is the climate in the air layer near the earth's surface with a height of ±2 meters [5]. Data was retrieved thrice in the morning at 08.00-09.00 WITA, in the afternoon at 12.00-13.00 WITA and in the afternoon at 16.00-17.00 WITA, carried out when the weather is sunny.

2.4. Data analysis

Correlation and linear regression analysis between variables in this study were carried out simultaneously using Microsoft Excel software. The correlation analysis used in this study is Pearson's correlation, which produces a correlation coefficient to measure the strength of the linear relationship between the two variables. Correlation coefficient values range from -1, 0, and 1 [6]. Linear regression analysis determined the relationship between canopy density (x) and light intensity, temperature, humidity, and comfort index (y).

Table 1. Correlation Coefficient Value [7]

No	Interval Coefficient	Relationship Level
1	0,00 – 0,199	There is a correlation between the variables x and y, but very weak (negligible)
2	0,20 – 0,399	There is a weak correlation between x and y variables
3	0,40 – 0,599	There is considerable correlation between x and y variables
4	0,60 – 0,899	There is a strong correlation between x and y variables
5	0,90 – 1,000	There is a very strong correlation between the x and y variables

2.5. Processing and Analysis of Data

To determine the relationship between the level of crown density and microclimate by measuring the level of crown density and microclimatic conditions (light intensity, air temperature, and relative humidity) in the green open space. Furthermore, index analysis, correlation analysis, and linear regression were carried out. This study only analyzes the relationship between tree canopy density and microclimate (light intensity, air temperature, and relative humidity) and green open space comfort index without specifying a particular tree species.

3. Results and Discussion

3.1. Results of Crown Density Measurement

Crown density measurements in the Telaga Sari City Forest were carried out at 32 sample points. In the Telaga Sari City Forest, the types of vegetation found were more diverse, including one type, *Eusideroxylon zwageri*, an endemic Kalimantan vegetation. Crown density calculation results using the application *HabitApp* pointing to the three sample points having the highest crown density value of 81%, located at point 10 *Shorea* sp., point 24 *Pometia pinnata*, and point 25 *Acacia mangium* located not far away. Furthermore, the lowest canopy density value is found at point 26 *Acacia auriculiformis* by 48%, despite having a relatively high diameter of 42.7 cm. However, *Acacia auriculiformis* has a small leaf morphology, so the head's percentage density is lower than the vegetation at other points. To find out the density of titles at each sample point can be seen in Figure 2.

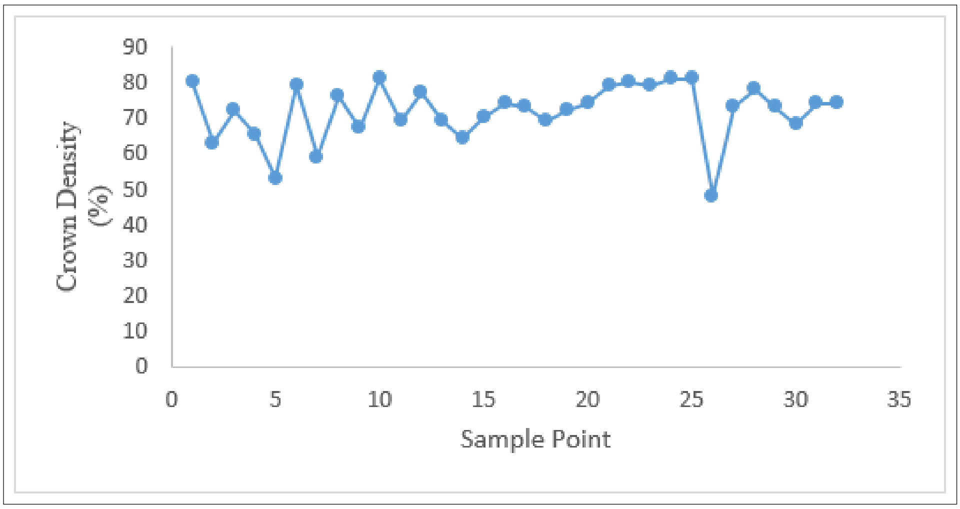


Figure 2. Crown density measurement results at 32 sample points

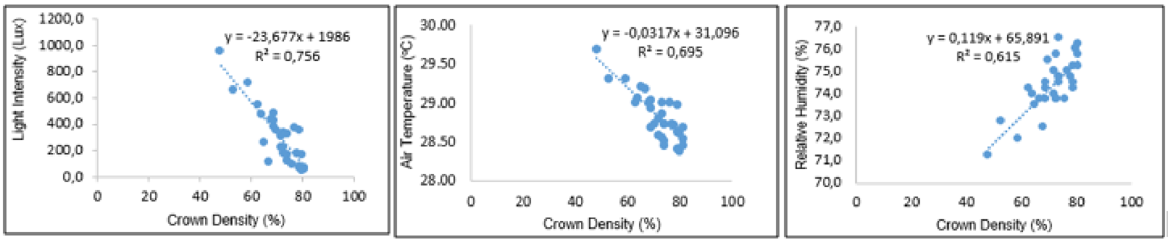
Furthermore, to find out the value of the highest crown density, it can be seen in Figure 3.

Figure 3. The highest crown density value: (a)*Shorea* sp (b) *Pometia pinnata* and (c)*Acacia mangium*

Figure 3 shows that the crown density value will be higher for trees with dense crowns. On the other hand, trees that have medium or rare crowns, the crown density value will be lower so that it will affect the solar radiation that can be intercepted. The greater the value of the heading density and the closer the heading, the greater the intercepted solar radiation.

3.2. Correlation of Crown Density with Light Intensity, Air Temperature, and Relative Humidity

The results showed that the daily light intensity was 289 Lux. The daily temperature is 28.82, and daily humidity is 74.42%. Tree crown cover affects the surrounding air temperature and relative humidity. The higher the percentage of vegetation cover, the lower the air temperature and the higher the humidity, and vice versa. Thus, samples under the canopy show lower temperature results than samples not shaded by the canopy [8]. The results of temperature measurements have a negative correlation with the results of humidity measurements; the higher the temperature, the lower the humidity [9]. The highest light intensity in the morning, and afternoon, is found at point 26 *Acacia auriculiformis* namely 750 Lux, 1,145 Lux and 964 Lux. It is known that the vegetation at that point has a crown density value of 48%, the lowest compared to other vegetation. Besides being in a reasonably open location, it also has a small leaf shape despite many branches. Furthermore, the relationship between crown and light intensity, temperature and relative humidity can be seen in Figure 4.



(a) Light Intensity (b) Air Temperature (c) Relative Humidity

Figure 4. Graph of Crown Relationship with: (a) Light Intensity (b) Air Temperature and (c) Relative Humidity

The results of linear regression show that crown density affects light intensity, air temperature, and relative humidity. Based on Figure 4, it is known that there is a strong correlation between canopy density and light intensity mark *multiple R* of 0.87. It has a negative pattern, meaning that a decrease follows every increase in the value of crown density in light intensity. Earned value *R Square* of 0.756, indicating that the canopy affects light intensity with a contribution of 76%, other factors influence the rest, and for the linear equation, it is y = -23.677x + 1986. The influence of the canopy on the microclimate is directly and indirectly related to the existence of the crown and stem. Branches and leaves reflect and absorb some solar radiation during the day, so less energy reaches the ground under the canopy [10]. The canopy is formed by the intersection of tree crowns planted in a specific pattern [11]. The size of the shaded area and the shape of the canopy are the most essential characteristics of the tree canopy in influencing the microclimate [12].

Furthermore, the relationship between crown density and air temperature has a strong correlation *R* of 0.83. It has a negative pattern, meaning that a decrease follows every increase in crown density in air temperature. R value is obtained Square is 0.695, indicating that the canopy affects temperature with a contribution of 69%; other factors influence the rest, and for the linear equation, it is y = -0.0317x + 31.096. The vegetation canopy affects the intensity of sun exposure, so more vegetation with dense and shady crowns can reduce air temperature in the microclimate [13]. Covering the tree canopy reduces radiant heat transmission and can increase the comfort of the air under the canopy [14].

The relationship of heading density with relative humidity shows a strong correlation with a mark *multiple R* of 0.78. It has a positive pattern, meaning that an increase follows every increase in the value of crown density in humidity. *R Square* of 0.615 indicates that the canopy influences humidity with a contribution of 61%, other factors influence the rest, and for the linear equation, it is y = 0.119x + 65.891. The canopy's absorbed, reflected, and transmitted radiation varies with time and place. Besides that, tree canopy architecture, plant species, size, location, and sun incidence angle can affect air temperature and humidity at a location [15]. Air humidity in urban areas is lower than in rural areas, dominated by vegetation, because the constituent materials have high conductivity and volatility.

3.3. Relationship between crown density and comfort index

The relationship between the crown and light intensity can be seen in Figure 5.

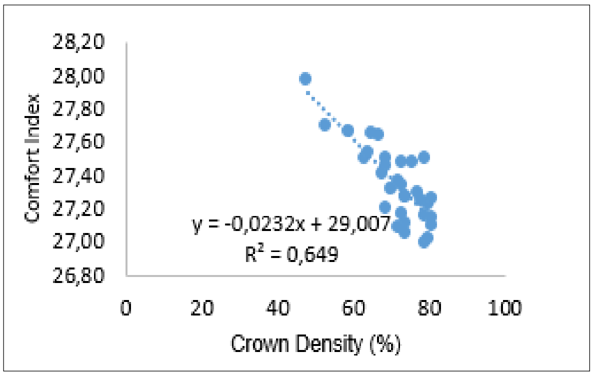


Figure 5. Header Relationship Graph with Convenience Index

Figure 5 shows that the crown density and the comfort index are strongly correlated with a mark *multiple R* of 0.81 and have a negative pattern, meaning that a decrease follows every increase in the value of canopy density in the comfort index. *R Square* of 0.649 indicates that the canopy affects the comfort index with a contribution of 65% with a linear equation of y = -0.0232x + 29.007. Furthermore, the comfort index value is 27.25 in the comfortable category. Plants or vegetation in green open spaces can beautify the environment, make people comfortable, and change the local microclimate. Although the microclimate changes produced by vegetation are insignificant, the resulting microclimate changes are felt by humans [16].

4. Conclusion

The analysis of the Pearson correlation test shows that there is a strong correlation between crown density and microclimate, namely light intensity, air temperature, relative humidity, and comfort index.

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