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The green open space functions as a water catchment area and a source of thermal comfort

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Abstract. The Kalijodo green open space has an area with a 48% vegetation area. The ideal green open space has a vegetated area of 80 to 90%. This can affect its function as a water catchment area and a source of thermal comfort. This research examines the water absorption capability and the value of the thermal humidity index in the Kalijodo green open space. The method used in this research is descriptive analysis. Based on the research results, the water absorption capability that is owned is 54.56%. The optimum value of water absorption capability is about 75 to 95%. The value of the thermal humidity index obtained was 30.75, and it was in a very uncomfortable category. The comfortable category of thermal humidity index is less than 29. The Kalijodo green open space does not properly function as a water catchment area and thermal comfort source. Therefore, it is necessary to improve the Kalijodo green open space condition, especially in terms of vegetation conditions.

1. Introduction

The Kalijodo green open space is an area with a design plan dominated by vegetated land built-in 2017 on land formerly a prostitution area to help prevent flooding, as a means of social interaction for the community and increasing the aesthetic value of the city. The ideal green open space has some functions to help absorb rainwater or surface water on the ground, thereby increasing water availability in the ground and overcoming flooding [1,2]. The ideal green open space also has other functions to reduce air temperature and reduce the effects of urban heat, thus creating an excellent urban ecology for activities and a place for social interaction and recreation [3,4,5].

Regarding the ideal green open space, which has a minimum vegetated area of 80 to 90% of the total area of green open space, based on observations from high-resolution image interpretation results through the GIS application, Kalijodo green open space only has a vegetated area of 48%. This result will affect the Kalijodo green open space’s function, especially as a water catchment area and a source of thermal comfort. Vegetation can maintain and increase soil permeability to absorb water properly and increase the water infiltration in the soil. Vegetation can also absorb heat radiation from the sun so that it can lower the surrounding air temperature and stabilize the thermal humidity index value.

Previous research about the function of green open spaces as water catchment areas was carried out by Andini (2016) in the Kapuas square park, Pontianak. The results of observations related to the description of the green open space area show that the composition of the area of the vegetation is only 22% of the total area of the green open space, and this is a condition that is also not ideal. Based on research related to water infiltration, the results show that the water absorption capacity that can be
done by the Kapuas square park is only 37% [6]. The ability to absorb water is still far from the ideal value that a city park should do, which is 75 to 95% [7]. This indicates that the Kapuas square park is not functioning correctly as a water catchment area.

Research related to the function of green open space as a source of thermal comfort has also been conducted by Sanger et al. (2016) in the city park of Bitung, North Sulawesi. The area of vegetated land-based on observations related to the area's description is 70% of the total area of the green open space. The area of vegetation is still less than 10% of the ideal green open space criteria. The research results related to the value of the thermal humidity index in Bitung city park shows that the value is 29.39, and this value is included in the uncomfortable category [8].

Based on the results of observations and preliminary discussions on several previous studies, this study was conducted to examine and analyze the water absorption capability, in its function as a water catchment area and the value of thermal humidity index, in its function as a source of thermal comfort in the Kalijodo green open space.

2. Method

2.1. Location
This research was conducted in a green open space in Kalijodo, located in the Pejagalan Village, Penjaringan District, North Jakarta Administrative City, DKI Jakarta Province. This research was conducted from June to July 2020.

2.2. Data collection technique
To obtain the data about water absorption capability discharge, the initial step that must be done is to measure the infiltration rate. Infiltration rate measurements were carried out at 3 points, with information shown in Table 1.

| Measurement Location | Location Coordinates | Location Description |
|----------------------|----------------------|----------------------|
| X-1                  | 06° 08’ 17,59” S     | The grass land, without cover (canopy) |
|                      | 106° 47’ 14,92” E    |                      |
| X-2                  | 06° 08’ 26,07” S     | The grassless land, without cover (canopy) |
|                      | 106° 47’ 19,09” E    |                      |
| X-3                  | 06° 08’ 18,30” S     | The grassland, under the tree canopy |
|                      | 106° 45’ 15,40” E    |                      |

One of the equipment used to obtain infiltration rate data is using a Double Ring Infiltrometer. After obtaining the infiltration rate data, then calculating the absorption coefficient value. The obtained absorption coefficient data are used to calculate the discharge from the potential water infiltration, determining the water absorption capability in the Kalijodo green open space. The formula for calculating the discharge from potential water infiltration [6] can be seen below:

\[
\text{Potential Water Absorption Discharge} (Q) = P \times A \times R = P \times A \times (1 - C) \quad (1)
\]

Information:  
- \(P\) = Average annual rainfall in the last 10 years (mm/year)  
- \(A\) = The total area (m\(^2\))  
- \(R\) = Absorption coefficient  
- \(C\) = Runoff coefficient

The activity to obtain data related to the thermal humidity index's value was carried out by measuring temperature and humidity using the Kestrel 5000 tool for five days at 5 location points in
Kalijodo green open space. Measurements were made in 3 sessions per day, namely in the morning session (07.00 to 08.00 A.M.), the noon session (12.00 A.M. to 1.00 P.M.), and the afternoon session (4.00 to 5.00 P.M.). The Information about the location of temperature and humidity measurements in the Kalijodo green open space can be seen in Table 2.

| Measurement Location | Location Coordinates | Location Description |
|----------------------|-----------------------|----------------------|
| TP-1                 | 06° 08’ 16,80” S      | The grass land, under the Tree canopy |
|                      | 106° 47’ 15,00” E     |                      |
| TP-2                 | 06° 08’ 21,60” S      | The road (made of cement), without cover (canopy) |
|                      | 106° 47’ 16,20” E     |                      |
| TP-3                 | 06° 08’ 35,80” S      | The road (made of cement), under the tree canopy |
|                      | 106° 45’ 19,20” E     |                      |
| TP-4                 | 06° 08’ 29,40” S      | The skateboard arena made of asphalt, without cover (canopy) |
|                      | 106° 45’ 21,60” E     |                      |
| TP-5                 | 06° 08’ 31,80” S      | The grass land, without cover (canopy) |
|                      | 106° 45’ 24,00” E     |                      |

After measuring the air temperature, the measurement data is calculated to get the the value of thermal humidity index. The formula used to calculate the value of the thermal humidity index [9], can be seen below:

\[
THI = 0.8T + \frac{RH \times T}{500}
\]  

Information:  
 THI = Thermal Humidity Index  
 RH = Rate of air humidity  
 T = Air temperature

2.3. Data analysis technique
All of the data that has been obtained and calculated using the formulas determined, then analyzed. The analysis method used in this research is descriptive analysis. Descriptive analysis is a statistic used to analyze data by describing or describing the collected data as it is, without intending to make generalized conclusions or generalizations [10]. Descriptive analysis carried out in this study was carried out by describing and explaining the calculations’ results obtained on the factors or causal variables that existed in previous theories or studies.

3. Results and discussion

3.1. Location description
Based on the observations, the Kalijodo green open space has 48 % vegetated land cover, and the remaining 52 % consists of various kinds of facilities and infrastructure. More detailed information regarding the extent of land cover types in the Kalijodo green open space can be seen in Table 3.
Table 3. The types of land cover in the Kalijodo Green Open Space.

| No. | Types of Land Cover                  | Area (m²)     |
|-----|--------------------------------------|---------------|
| 1   | Vegetation                           |               |
|     | The Grass                            | 15,885.42     |
|     | The Trees                            | 1,013.99      |
|     | Sub-total                            | 16,899.41     |
| 2   | Non-vegetation                       |               |
|     | The road (made of cement)            | 11,820.01     |
|     | The building                         | 3,171.04      |
|     | The Built-up land (made of asphalt)  | 2,564.08      |
|     | The pedestrian path (made of cement) | 816.28       |
|     | Sub-total                            | 18,371.41     |
|     | Total Area                           | 35,270.82     |

Table 3 shows the total area of the Kalijodo green open space, which is 35,270.82 m². There are two types of land cover, namely vegetated and non-vegetated land cover types. The vegetated land cover consists of grass and trees. Meanwhile, the non-vegetated land area consists of major roads, buildings, built-up land, and pedestrian paths. The total area of vegetated land cover is 16,899.41 m². The total area of land cover types that are not vegetated is 18,371.41 m². This clearly shows that the area of vegetated land is smaller than the land area that is not vegetated.

3.2. Water absorption capability

The Kalijodo green open space's water absorption capability is obtained based on the results of calculations from various indicators. These indicators, namely the value of the infiltration rate, the average rainfall per year, the green open space area, and the coefficient of absorption and runoff.

Measurements to obtain infiltration rate data in the Kalijodo green open space were carried out at three points (X-1, X-2, and X-3) based on pavement and canopy cover types. The measurement location point X-1 has a grass pavement type, without any canopy. The X-2 measurement location point has a type of non-grass pavement (bare soil) without any cover (canopy). The X-3 measurement location point has a grass pavement type and is under a tree canopy. The activity of measuring the infiltration rate will be carried out on June 17th, 2020. The time to measure the infiltration rate was carried out in the dry month or dry season phase and was only done once. The infiltration rate value is obtained by calculating the measurement data using the Horton model formula. The infiltration rate values that have been obtained are classified according to Kohnke (1980), ruling for further analysis. The infiltration rate values of the three measurement location points can be seen in Table 4.

Table 4. The value of infiltration rate in the Kalijodo Green Open Space.

| Measurement Location | Infiltration Rate (mm/hour) | Classification (Kohnke, 1980) |
|----------------------|-----------------------------|-------------------------------|
| X-1                  | 90.43                       | Medium Fast                   |
| X-2                  | 18.79                       | Medium Slow                   |
| X-3                  | 284.39                      | Very Fast                     |
| Average Value        | 131.5                       | Fast                           |

From the three measurement points, soil samples were taken. Soil samples from each measurement location point are taken to the laboratory for testing related to permeability, moisture, and soil composition. The laboratory test results of the three soil samples at the location of the measurement of the Kalijodo green open space's infiltration rate can be seen in Table 5.
Table 5. The result of soil sample test.

| Location | Permeability (mm/hour) | Water Content (%) | Soil Texture (%) | Type of Soil           |
|----------|------------------------|-------------------|------------------|------------------------|
| X-1      | 6,2                    | 31,15             | 12 32 56         | Latosol                |
| X-2      | 6,0                    | 29,34             | 11 31 58         | (Dark Reddish Brown)   |
| X-3      | 6,8                    | 34,20             | 14 35 51         |                        |

Table 4 shows that the X-1 measurement location has an infiltration rate of 90.43 mm/hour. This infiltration rate is in the medium-fast category based on the classification of Kohnke (1980). The pavement is one of the factors that can affect the infiltration rate. Vegetation (the grass and the trees) has a function to increase soil permeability [1]. The laboratory tests result from soil samples were taken at the point where the measurement of the infiltration rate X-1 showed a value of 6,2 mm/hour (Table 5). The enlargement of soil pores causes increased permeability in the soil. Soil pores also play a role in the infiltration of surface water into the soil. According to Rawls et al. (1993), where the soil is overgrown with grass, it has a better infiltration rate than non-vegetated soil and processed soil. Soils that are not vegetated and processed soils have the potential to increase soil compaction and pavement so that it has the potential to cause scale on the soil and even erosion [12].

The infiltration rate value at the point of measurement location of the infiltration rate X-2 is smaller than the location X-1 and X-3. According to Kohnke's (1980) classification, the X-2 measurement location's infiltration rate falls into the medium-slow category, with a value of 18,79 mm/hour (Table 4). The soil's surface layer is not covered by various types of vegetation (grass and trees), causing the condition to look arid. This arid condition causes the appearance of a scale on the soil layer. The soil layer scale is caused by a compaction process, which can reduce the soil's ability to infiltrate water [12]. The laboratory test results of soil samples taken from the X-2 infiltration rate measurement location point showed a permeability value of 6,0 mm/hour, and the smallest among other soil samples (Table 5). The soil's low ability to infiltrate water can cause standing water above the ground and potentially create flood conditions.

The infiltration rate at the X-3 infiltration rate's measurement location has a value of 284,39 mm/hour and is the largest compared to X-1 and X-2. Based on the classification of the infiltration rate by Khonke (1980), the infiltration rate value at the X-3 measurement location is included in the high-speed category. The conditions at the X-3 infiltration rate measurement location point with the surrounding land cover, full of various types of vegetation, such as grass, flowers, and trees. Variations of this type of vegetation can increase better soil permeability because of grassroots presence combined with plant and tree roots so that the soil pores are getting bigger and bigger. This is evidenced by the soil sample test results, which states that the permeability value of the soil at the measurement location of the X-3 infiltration rate has a value of 6,8 mm/hour, and this is the largest compared to X-1 and X-2 (Table 5). The X-3 infiltration rate measurement location is perfect for draining water into the ground so that it can avoid surface waterlogging (zero runoff). Based on table 4, the average value of the Kalijodo green open space's infiltration rate is 131.5 mm/hour. According to Khonke's (1980) infiltration rate classification, the average value of the Kalijodo green open space's infiltration rate is in a fast category.

The value of the average infiltration rate of the Kalijodo green open space then calculates other data such as the annual average rainfall intensity in DKI Jakarta province in the last 10 years (2010 to 2019), which is 1,970 mm/year, the total area of vegetation is 16,899,41 m². The total area of the Kalijodo green open space is 35,270,82 m². The calculation of all the data shows that the absorption coefficient (R) in the Kalijodo green open space is 281. If the coefficient value obtained is more than 1 (one), then the value is still calculated 1 [6]. This shows that the Kalijodo green open space's infiltration rate is greater than the intensity of rainfall, so the amount of water that can be infiltrated at 100 %. The absorption coefficient value is then calculated on the annual average rainfall intensity data in the province of DKI Jakarta for the last 10 years (2010 to 2019) with a value of 1.970 mm/year and
the total area of Kalijodo green open space, amounting to 35,270.82 m², to obtain data in the form of potential water absorption that can be owned by the Kalijodo green open space, which is as much as 69,484 m³/year. The value of the potential for water infiltration is the maximum result if the Kalijodo green open space has a vegetated area of 100%.

Water infiltration discharge is the volume of water owned by the Kalijodo green open space in one year. In comparison, water runoff discharge is the water volume discharged by Kalijodo green open space in one year. Water infiltration discharge and water runoff discharge in the Kalijodo green open space (RTH) were obtained based on calculations from the percentage and area data of land cover and its type, absorption coefficient (R), and runoff coefficient (C) of each type of pavement [11], as well as data on the intensity of annual average rainfall in the province of DKI Jakarta in the last 10 years (2010 to 2019). The calculation of the water infiltration discharge and water runoff discharge in the Kalijodo green open space can be seen in table 6.

### Table 6. The calculation of infiltration discharge and runoff discharge.

| Land Cover | Types    | Area (m²) | R  | C  | Rainfall Intensity (mm/year) | Infiltration Discharge (m³/year) | Runoff Discharge (m³/year) |
|------------|----------|-----------|----|----|-----------------------------|----------------------------------|----------------------------|
| Pavement   | Asphalt  | 2.564,08  | 0.05| 0.95| 1.970                       | 252.5                            | 4.798,6                    |
|            | Cement   | 12.636,29 | 0.05| 0.95| 1.970                       | 1.244,6                          | 23.648,8                  |
|            | Building | 3.171,04  | 0.5 | 0.5 | 1.970                       | 3.123,6                          | 3.123,6                   |
| Green Area | Vegetated Land | 16.899,41 | 1.00| 0  | 1.970                       | 33.291,8                         | 0                         |
| Total      |          | 35.270,82 |     |     | 37.913                       | 31.571                           |                           |

Table 6 shows that the water infiltration discharge rate in the Kalijodo green open space is 37.913 m³/year, which is the current potential water infiltration value. The discharge of water infiltration is greater than the discharge of water runoff. The Kalijodo green open space's water absorption capacity from the current absorption potential (37.913 m³/year) compared with the maximum absorption potential that can be obtained (69,484 m³/year), the result is only 54.56 %. The water absorption capability in the Kalijodo green open space is not sufficient to meet the ideal criteria of a green open space or city park, which at least can absorb water by 75 to 95 % [7]. This is due to the lack of several vegetation areas that function to increase water absorption into the soil so that the potential for water in the Kalijodo green open space is reduced.

### 3.3. The value of thermal humidity index

Measurement of temperature and air humidity was carried out on 6, 7, 11, 17, and 18 July 2020. Temperature and humidity data obtained from the five measurement locations in the Kalijodo green open space are then calculated to obtain the thermal humidity index's value and find out the comfort category based on the classification in Frick and Suskiyanto (2007). The value of the thermal humidity index can be seen in table 7.
Table 7. The value of Thermal Humidity Index in Kalijodo Green Open Space.

| Location | Thermal Humidity Index | Average Value | Classification |
|----------|------------------------|---------------|----------------|
|          | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 |             |                |
| TP-1     | 29.18 | 29.38 | 29.44 | 29.41 | 28.99 | 29.28       | Uncomfortable  |
| TP-2     | 31.97 | 31.99 | 31.34 | 31.64 | 31.11 | 31.61       | Very Uncomfortable |
| TP-3     | 30.66 | 30.62 | 30.65 | 31.20 | 30.31 | 30.68       | Very Uncomfortable |
| TP-4     | 31.52 | 31.45 | 31.41 | 31.45 | 31.46 | 31.46       | Very Uncomfortable |
| TP-5     | 30.95 | 30.55 | 30.85 | 30.64 | 30.73 | 30.74       | Very Uncomfortable |
| Total    | 30.75 |        |        |        |        |             | Very Uncomfortable |

Several factors other than temperature and humidity can affect the difference in the thermal humidity index's value at the temperature and humidity measurement locations in the Kalijodo green open space. Solar radiation can influence the climate. Sunlight can affect temperature and humidity in a location. High-intensity sunlight can increase air temperature and decrease humidity, thus affecting thermal comfort. Conditions also influence changes in temperature and humidity in a place. The condition in question is the existing land cover and canopy. Land cover and cover (canopy) are objects that can reflect, absorb, and even transmit radiation from sun rays [13]. An object that can radiate absorbed energy has an emissivity value. Each object also has an albedo value, which is the ratio of the radiation received to that reflected.

According to Brown and Gillespie (1995), vegetation and pavement types (cement, asphalt, buildings, stones) significantly influence the inner climate. Pavement can absorb radiation or heat from sunlight, which is higher than the type of vegetated land cover, causing air temperatures to increase and making the climate uncomfortable [13]. This is evidenced by the research results at the TP-1 temperature and humidity measurement location, which has the lowest thermal humidity index value of all measurement location points. In contrast, the TP-2 temperature and humidity measurement location has the highest thermal humidity index. The TP-1 measurement location has land cover types, namely grass, and cover (canopy), namely large trees. In contrast, the TP-2 measurement location conditions have the type of land cover, namely cement/concrete. And there is no cover (canopy).

The value of the thermal humidity index at the TP-3 temperature and humidity measurement location, shown in Table 7, is lower than that of TP-5. The conditions at the measurement location at TP-3 have cement pavement, and there is a tree cover (canopy). In contrast, the conditions at the measurement location at TP-5 has grass pavement and no cover (canopy). This also proves that solar radiation is blocked by a cover (canopy) so that the air temperature around the TP-3 measurement location does not increase too much. Pavement conditions around the temperature and humidity measurement point of TP-3, which has grass pavement, also inhibit the rise in air temperature.

The TP-4 temperature and humidity measurement location have a thermal humidity index value that is lower than the TP-2. The condition of the TP-4 has pavement made of asphalt, and there is no cover (canopy), while the condition of the TP-2 has pavement made of cement/concrete and does not have a cover (canopy). According to Brown and Gillespie (1995), cement pavements have a higher albedo value than asphalt, thereby increasing the surrounding air temperature. The absence of a cover (canopy) at the measuring point can also increase the air temperature due to unobstructed solar radiation.

Table 7 shows the average value of the overall thermal humidity index in the Kalijodo green open space, which is 30.75. This thermal humidity index value is included in the very uncomfortable
category, according to the classification [8]. Although there are locations for measuring temperature and humidity in vegetated conditions, the thermal humidity index's value is proven to be better than the measurement point under pavement conditions. Still, it does not significantly impact the overall thermal humidity index value in the Kalijodo green open space.

4. Conclusion
This study indicates that the Kalijodo green open space has not yet performed its function as a water catchment area and a source of thermal comfort. The water absorption capacity is not optimal yet, causing a large amount of water runoff to be produced, and the climatic conditions are very uncomfortable. This happens because the availability of vegetated land is still less than the proper provisions. Therefore, the Kalijodo green open space must be repaired immediately, especially in providing a suitable vegetated area and making infiltration wells to assist in absorbing water into the ground and creating favorable thermal comfort conditions for the environment.

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