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The role of vegetation on thermal comfort the Ria Rio reservoir area in DKI Jakarta province

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ABSTRACT

Urban physical development in Indonesia can lead to an increase in urban air temperatures which generally have higher temperatures than in rural areas and can be outside the standard of human thermal comfort. Thermal comfort is a way for humans to respond to stimuli to the temperature of the surrounding environment. Vegetation has an important role in controlling the comfort of thermal microclimates, namely modifying air temperature, controlling humidity, reducing solar radiation and regulating wind speed. The Ria Rio Reservoir area in the DKI Jakarta province, is in an urban environment with a high population and dense building. The purpose of this study is to measure the amount of vegetation function towards thermal comfort in the Ria Rio Reservoir area. The research method used is descriptive qualitative and quantitative methods. Measurement of thermal comfort in the area is done by direct observation. Assessment of vegetation function as a modification of the microclimate will be assessed quantitatively using the Key Performance Index to see how large the function of vegetation is in thermal comfort. The results of the study are the magnitude of the value of vegetation comfort as a thermal comfort control in determining the criteria for selecting plants in the regional landscape design.

Key words: *Thermal Comfort, Micro Climate, Vegetation, Landscape,*

Introduction

The Ria Rio Reservoir area is located in an urban environment in DKI Jakarta province covering an area of 24 hectares with a fairly high population level and dense buildings. With the increasing population, the demand for land for housing is increasing. This raises environmental problems namely higher urban environmental temperatures and is outside the standard of human comfort. Thermal comfort greatly affects human needs in their activities. According to Rahtama (2014: 1) thermal comfort is the human response to the stimulation of hot or cold temperatures received from the environment. One of the environmental elements which is the main determinant of thermal comfort is the microclimate which includes air temperature, solar radiation, humidity and wind speed. In landscape architecture, the composition of vegetation has the function of climate amelioration, namely modification of air temperature, humidity control, solar radiation control and wind control. The Ria Rio Reservoir area is an area that will be developed into a mixed used environment consisting of residential, recreational and commercial areas. The development of the Ria Rio Reservoir area has led to outdoor activities that require comfortable environmental conditions, including thermal comfort. There fore it is necessary to assess the function of vegetation in increasing thermal comfort in the Ria Rio Reservoir area. According to Gray & Deneke (1986: 56) vegetation can change the air temperature in an

area to be more comfortable compared to areas that are not overgrown with vegetation. During the day the temperature under the canopy of vegetation is cooler, but at night the temperature gets warmer. It can be said that the arrangement of vegetation is closely related to creating a thermally comfortable landscape environment. Plants in a landscape according to Carpenter (1975: 154) have four main functions for the environment of the outer space namely aesthetic functions, climate control functions, architectural functions and engineering functions. Vegetation can modify air temperature through the evapotranspiration process. Kramer and Kozlowski (Deneke, 1978: 45) state that a tree can absorb about 400 liters of water in one day. At night the tree canopy slows the release of heat from the soil surface or pavement, so that the air temperature under the tree is higher than the air temperature in the environment without trees. This can be beneficial in environments with a subtropical climate, especially in winter. Vegetation can also modify the temperature of the air by controlling solar radiation. According to Robinette (Mahardi, 2013: 26) one of the significant uses of trees against climate control is radiation control. Brown and Gillespie (1995: 117) state that one leaf layer in general will absorb 80%, reflect 10% and transmit 10%. Therefore, the more layers of leaves in a tree, the more efficient it is in reducing solar radiation. Booth and Hiss (2012: 77) state that trees with wide canopies can provide greater shade than trees with upright canopies, while Shahidan and Salleh (2007: 6) state that trees that can provide maximum shade are trees with a spread canopy shape (spreading), round and dome. Vegetation can capture and filter radiation beams, block the wind, release water by transpiration and reduce evaporation from soil moisture.

Therefore, the more and more leaf area in a tree, the more moisture is released and affects the humidity level. Gray and Deneke (1978: 56) state that the criteria for plants that can affect the level of humidity are needle-leaf or rough-leafed plants (hair), horizontal branching patterns and rough stem texture. Vegetation can reduce wind speed and create an environment that is protected from the wind. Vegetation controls the wind by breaking, directing, bending and filtering. The degree of effect of vegetation on wind control varies greatly, depending on the type, size, shape of leaf density, and placement of the vegetation itself. Breaking the wind in vegetation is done by reducing wind speed and creating a barrier as resistance to wind flow. In an environment with a tropical climate that has a fairly high temperature level, vegetation control is carried out by flowing air through the site. The composition of trees with different heights is able to protect and reduce wind speeds of around 40-50%. Some criteria of plants as windbreaks according to Nurnovita (2011: 12), among others, have strong branches but are quite flexible, and the leaves are not easily knocked down by the rather strong wind. canopy on trees as wind protection is not too tight and also not too rare. A canopy that is too dense will result in turbulent wind formation, while a canopy that is too sparse cannot function as a windbreak. Thus vegetation has a fairly large function in determining thermal comfort controls which include functions of air temperature, solar radiation, wind speed and humidity. The determinant factor of thermal comfort becomes the research variable in the measurement of thermal comfort in the Ria Rio Reservoir area based on the bioclimatic chart thermal comfort standard. The purpose of this study is to measure and evaluate the role of vegetation in thermal comfort control. The results of this study will provide the value of vegetation criteria in thermal comfort that is beneficial in the development of regional landscape designs.

Research Methods

The study was carried out through three stages, namely, First, a literature review, regarding the criteria for vegetation that plays a role in thermal comfort, then from these criteria will be a parameter in the assessment of vegetation in the area. Second, is empirical measurement, which is a direct measurement of microclimate conditions at the research location used using certain equipment, and data collection of existing vegetation characteristics. Third, is calculating the value of vegetation criteria in its function as a thermal comfort control using the Key Performance Index (KPI) to assign values to each criterion. The highest value given is 4 (four) and the lowest is 1 (one). Furthermore, the assessment results are divided into very good, good, medium, and bad categories, and the percentage of total species and total individual plants is calculated.

Key Performance Index (KPI)

The assessment of vegetation criteria in its function

Table 1. Criteria for the Function of Vegetation Thermal Comfort

Variable	Assessment criteria
Temperature modification	1. Canopy width of more than 2 meters (Simonds, 1983) 2. Spreading canopy shape, round, dome. (Shahidan, Salleh, 2007) 3. Solid leaf mass (DPU Director General of Highways, 1996) 4. Thick leaves (Carpenter *et al.*, 1975)
Solar radiation	1. Solid leaf mass (DPU Director General of Highways, 1996) 2. Large and wide canopies (Booth and Hiss, 2005) 3. Thick leaves (Carpenter *et al.*, 1975)
Humidity Control	1. Low leaf density (Bianpoen *et al.*, 1989 in Asgitami, 2017) 2. Needle or rough leaf (Gray and Deneke. 1978) 3. Coarse stem texture (Gray and Deneke. 1978) 4. Large leaf counts (Carpenter *et al.*, 1975)
Wind Control	1. Leaves do not easily fall (Dahlan, 1992 in Asgitami, 2017) 2. Meeting leaf mass (DPU Director General of Highways, 1996) 3. Tall plants (Carpenter *et al.*, 1975) 4. Thick leaves (DPU Director General of Highways, 1996)

as a thermal comfort control in the Ria Rio Reservoir area is carried out to determine qualitatively and quantitatively the weight value of the vegetation criteria in its function as a thermal comfort control and the percentage of vegetation categories to the total number of species. The assessment for each criterion will be added up so that the total value is obtained. The total value is then compared with the ideal number (maximum total) that can be obtained and converted into percent (%).

$$\text{KPI} = \frac{\text{Sum of each criterion}}{\text{The ideal number (maximum total) of each}}$$

$$\text{Percentage of total type} = \frac{\text{Number of species of category X}}{\text{Total types of plants}} \times 100$$

Research Location

Ria Rio Reservoir area is one of the reservoirs in urban areas located in the Pedongkelan area, Pulogadung, East Jakarta, DKI Jakarta Province with an area of 24 hectares.

The Ria Rio area of 24 hectares consists of the Ria Rio Reservoir of 7.0 hectares and the rest is a park area in the south and a greening environment in the west. From observations, there are 310 numbers of trees and 18 tree species. The vegetation conditions in the park and environment of the Ria rio area are quite good. Existing trees such as *Samanea saman, Mangifera indica* and *Delonix regia* grow quite well in this environment. Vegetation in the area is dominated by *Mangifera Indica* and *Samanea saman* trees that function as shade. Measurement data is divided into 3 (three) environmental zoning namely:

Fig. 1. Location of the Ria Rio Reservoir research area in DKI Jakarta
Source: Google Maps

Environmental Zoning 1, located on the west side of the reservoir area in the form of a green area and vegetation that is quite dense.

Source: Personal Documentation

Fig. 2. Environmental Zoning - 1 dense vegetation.

Environmental Zoning 2, located on the south side of the area in the form of a park with public facilities with the use of pavement.

Environment Zoning 3, is a greening environment whose landscape surface is a combination of grass

Fig. 3. Environmental Zoning - 2 fairly dense vegetation.
Source: Personal Documentation

Fig. 4. Zoning Environment - 3 a combination of grass and pavement
Source: Personal Documentation

and pavement for a jogging track facility.

Results and Discussion

Thermal Comfort in 3 (three) Research Zoning

Air Temperature

The measurement of temperature in 3 (three) zoning environments for 3 days, showing the temperature at a certain time is beyond a sense of comfort, causing discomfort for visitors. On the morning of the third day the environmental zoning indicated that the temperature was still in the comfort zone. The results of the measurement data can be seen differences in the temperature of each environment in the same time period, this is caused by differences in the use of types and amounts, vegetation and characteristics of each environment. In the morning and afternoon, environmental zoning is 2 (two) temperatures higher than environmental zoning 1 (one) and 3 (three). Environmental zoning 2 (two) has more pavement facilities than environment 1 (one) and 3 (three), this causes higher temperatures in the pavement. In the afternoon 2 (two) environmental zoning shows lower temperature compared to environment 1 (one) and 3 (three). This is due to the large number of open areas in the 2 (two) environment which are not covered by tree canopies, so heat release is faster.

Humidity

The measurement results show that the highest average humidity is in environmental zoning 1 (one). The high humidity is caused by the factor of land use utilization which is the area of greening the area by planting trees with wide, dense canopy and dense planting patterns. Trees with wide and dense canopies can block water vapor from the soil surface upward so that the water vapor under the canopy is larger than the water vapor above the tree canopy. The results of measurements of humidity to 3 (three) environments indicate that environmental zoning 1 (one) becomes uncomfortable for activities

Table 2. Results of Air Temperature Measurement

Time	Environmental Zoning 1	Environmental Zoning 2	Environmental Zoning 3
08:00 - 11:00	27.50° C	27.30° C	26.80° C
11:00 - 15:00	31.00° C	32.50° C	31.50° C
15:00 - 17:00	32.50° C	30.20° C	30.90° C
Average	30.220 C	30.30° C	29.70° C

Source: Personal Documentation

Table 3. Moisture Measurement Results

Time	Environmental Zoning 1	Environmental Zoning 2	Environmental Zoning 3
08:00 - 11:00	80.00%	79.30%	73.50%
11:00 - 15:00	73.00%	61.50%	64.00%
15:00 - 17:00	76.50%	67.90%	75.50%
Average	76.50%	69.50%	71.00%

Source: Personal Documentation

because of its humidity outside the human comfort zone. 2 (two) and 3 (three) environmental zoning in the human comfort zone.

Wind

Based on data BMKG (Indonesia Meteorology Climatology and Geophysics Agency), the average wind speed in the last 5 years is 10.707 kilometers / hour on the Beaufort scale. The average wind speed in the Ria Rio Reservoir area falls into category 3, which is a gentle breeze. The results of measurements of wind speed in the 3 (three) environmental zoning indicate 1 (one) environmental zoning in the weak breeze category. Environment 2 (two) and 3 (three) in the gentle breeze category and therefore it can be concluded that the wind speed in the area is not too fast and does not interfere with existing user activity.

Sunlight Radiation

The highest measurement of solar radiation is environmental zoning 2 (two) because it has a lot of activities and open space without shade trees, so that it gets the most sunlight. Environmental zoning 1 (one) is the environment with the lowest radiation level among the three environments. Environmental zoning 3 (three) is a passive environment containing large trees with tight spacing, so that sunlight is blocked by tree canopies. The results of the measurement time, the highest level of sunlight radiation is in the morning and afternoon.

Assessment of Vegetation Criteria in Thermal Comfort Control

Environment Zoning - 1

The results of the assessment of the physical characteristics of vegetation types in environmental zoning 1 (one), vegetation has a good category more dominant than the other categories. Tree species with a good category *Mangifera indica* with a Key Performance Index (KPI) value of 68.18 percent, *Delonix regia* with a value of 72.00 percent and *Switenia macrophylla* with a value of 75.00 percent. A very good category is obtained by the *Samanea saman* tree which has a high value in the criteria of the width of the canopy with a large, dense leaf density, so that it can provide shade underneath and sunlight filtered by the tree canopy. In environmental zoning 1 (one), there is also a type of tree with an unfavorable category, namely *Musa paradisiaca (Banana)* with a value of 43.10 percent. In the criteria of leaf thickness, banana trees get the highest value of 4.00 percent, but in other criteria banana trees get a low value, so the banana tree has not met the criteria. Planting patterns in environmental zoning 1 (one) group and spread. Trees with good and very good categories are planted in a clustered pattern with fairly tight spacing.

The graph above shows the percentage of tree categories in environmental zoning 1 (one) to the total amount of vegetation available. Vegetation with good category is the most dominant in envi-

Table 4. Wind Speed Measurement Results

Time	Environmental Zoning 1	Environmental Zoning 2	Environmental Zoning 3
08:00 - 11:00	5.40 km/jam	8.28 km/jam	7.10 km/jam
11:00 - 15:00	7.00 km/jam	10.44 km/jam	11.52 km/jam
15:00 - 17:00	10.08 km/jam	19.44 km/jam	11.52 km/jam
Average	7.70 km/jam	12.72 km/jam	10.04 km/jam

Source: Personal Documentation

Table 5. Solar Radiation Measurement Results (Lux)

Time	Environmental Zoning 1	Environmental Zoning 2	Environmental Zoning 3
08:00 - 11:00	1543	1565	1536
11:00 - 15:00	834	1530	1105
15:00 – 17:00	975	1440	489
Average	839	1511	1043

Source: Personal Documentation

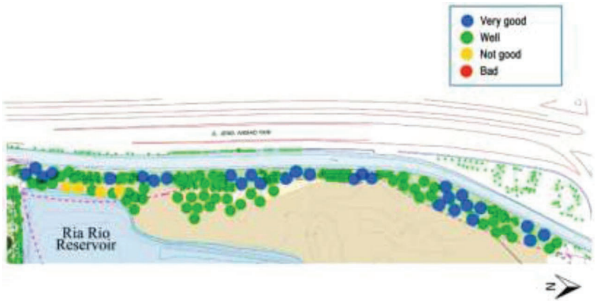

Fig. 5. Distribution of Area 1 Vegetation by Category.
Source: Personal documentation, 2019

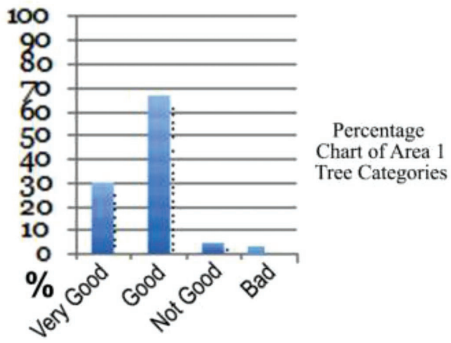

Fig. 6. Percentage of Area 1 Trees
Source: Personal documentation, 2019

ronment 1 (one) and the second most is tree with very good category. Although trees with bad categories do not exist in this environment, there are still trees with poor categories. From the results of measurements of humidity, temperature, radiation obtained and compared with the standard bioclimatic comfort chart, it shows that the environment of 1 (one) has not yet reached the ideal thermal comfort condition, even though the use of vegetation is mostly in the good category. When viewed from the results of the humidity data, environment 1 (one) has the greatest average humidity compared to other environments. This is due to the dense and dense condition of the 1 (one) environmental planting pattern. The results of the vegetation assessment for humidity control have not been fulfilled because it does not fit the criteria of rough leaf trees and rough stem texture which is a criterion of vegetation. Planting patterns can affect thermal comfort in the area. Trees with very good and good category are planted in a clustered pattern and with fairly spaced spacing. Trees with a very good category are trees with a canopy criterion of more than 2.0 meters so that in environment 1 (one) there is sufficient shade to be obtained from a tree canopy that is planted with tight spacing.

Environment Zoning – 2

In environmental zoning 2 (two) more than half the tree species are in the unfavorable category. The type of tree with the lowest weight rating is banana tree with a score of 43.10 percent. In the good criteria category there are 6 species of trees with the number of trees dominated by mango and flamboyant trees. The type of tree that gets a very good category is the trembesi tree with a score of 81.80 percent. Planting patterns in 2 (two) environments vary, namely, linear, solitary, spreading and grouping. Figure 8 about the percentage of tree categories by comparing the number of existing trees, shows that the number of trees with an unfavorable category gets a value of 50.30 percent, consisting of 8 tree species. then the percentage of trees with a good category is 38.20 percent which also consists of 8 tree species. The tree species with a very good category are at 11.40 percent consisting of only 1 tree species, namely *Samanea saman*.

The results of thermal comfort calculations using bioclimatic chart comfort standards can be concluded that the environment 2 (two) is outside the ideal comfort conditions. The results of the calculation of vegetation criteria in the unfavorable category are factors that have not yet reached the ideal comfort conditions in environment 2 (two). Vegetation in environment 2 (two) mostly does not meet the criteria as a thermal comfort control.

Environment 2 (two) is the environment with the highest level of activity when compared to other environments. There fore ideal thermal comfort conditions are an important element for users, especially in the morning and evening. The tree planting pattern with a very good category is arranged in a linear pattern and its location does not spread to the entire environment which influences the amount of sun radiation, especially at noon. Uncoated pavement causes the surface to be exposed to direct sunlight so that the sun's heat evaporates and can raise uncomfortable air temperatures. Placement of trees in groups on the edge of the reservoir tends to have higher humidity so it requires vegetation that has a function in humidity control.

Environment Zoning – 3

In zoning environment 3 (three) types of vegetation are not much different from environment 1 (one), there is only one tree species that gets the highest

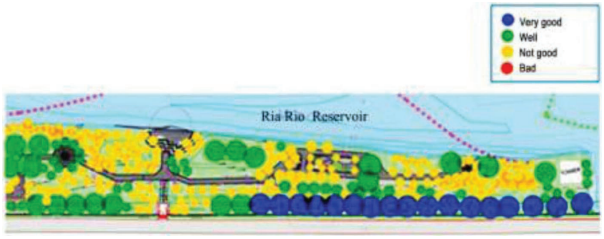

Fig. 7. Distribution of Area 2 Vegetation by Category
Source: Personal documentation, 2019

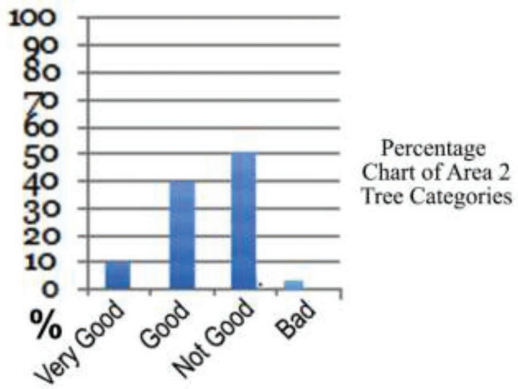

Fig. 8. Percentage of Area 2 tree categories
Source: Personal documentation, 2019

score, Samanea saman. The categories of tree species that dominate in this environment are good categories, namely *Mangifera indica, Switenia macrophylla,* and *Delonix regia.* There are no tree species with bad categories. The percentage value of the tree category indicates that the tree species with a good category is 75.00 percent of the total number of trees. Planting patterns are mostly grouped, linear, random and solitary. Trees with good categories consisting of Mangifera indica tree species are placed in groups and with a short planting distance, so that under the *Mangifera Indica* trees provide enough shade. Trees with Switenia macrophylla species are placed scattered randomly, while Delonix regia trees are placed linearly along garden boundaries. Trees in the excellent category are worth 20.80 percent of the total number of tree species. Trees with this category only have one type of tree, Samanea saman, which is placed randomly with a distance of planting apart. Trees with bad category are worth 4.16 percent with 1 (one) type of tree, namely banana tree *(Musa paradisiaca)* and placed randomly in the reservoir edge environment. The results of thermal comfort measurements using bioclimatic charts show that humidity, air temperature and solar radiation levels have not yet reached the ideal thermal comfort. Figure 10 shows the results of research on the criteria for vegetation of very good tree species, which is still less than the good category of 20.80 percent compared to 75.00 percent. To get the vegetation function as an ideal thermal comfort control, it is necessary to add a very good category of tree species. The layout of the large canopy tree is dense enough so that water vapor is trapped under the tree canopy which will result in higher humidity than the canopy in the tree. This has an impact on the level of humidity in the area that becomes uncomfortable.

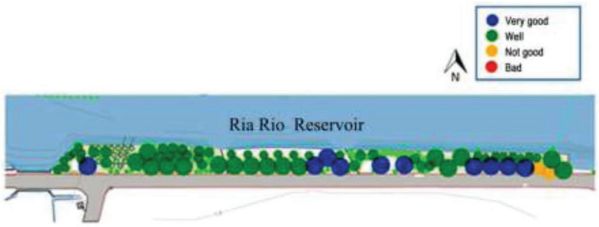

Fig. 9. Distribution of Area 3 Vegetation by Category.
Source: Personal documentation 2019

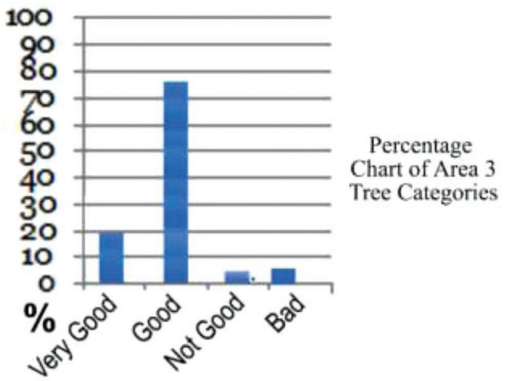

Fig. 10. Percentage in area 3 of Category Trees
Source: Personal documentation, 2019

The results of thermal comfort measurements show that all environmental zoning has not yet reached the ideal thermal comfort conditions. The results of the assessment of vegetation criteria in environment 1 (one) and environment 3 (three) show good criteria fulfillment. The results of the measurement of environmental thermal comfort 2 (two) show the air temperature and humidity exceed the thermal comfort standard. This shows that the determination of vegetation function criteria influences the level of environmental thermal comfort. In the zoning environment 1 (one) and 3 (three) the results of the measurement of thermal comfort at air temperature and humidity are outside the thermal

comfort standard, but the air temperature in environment 2 (two) is still lower. Measurement of the determinants of thermal comfort, namely temperature, wind, humidity and solar radiation, shows that environmental zoning 1 (one) and 3 (three) shows a high level of humidity compared to environment 2 (two). From the comparison between the results of the measurement of humidity measurement and assessment of vegetation criteria in the environment 1 (one) 2 (two) and 3 (three) it can be concluded that vegetation has different functions in increasing thermal comfort as a control of humidity, temperature modification, solar radiation and wind control. Therefore, to maximize the function of vegetation in thermal comfort, the selection of vegetation is adjusted to the criteria for each function.

Conclusion

- Vegetation in the form of trees in the study location in the western and southern regions of the species is diverse and has different characteristics. Trees in environmental zones 1 (one), 2 (two), and 3 (three) are planted in groups, spread, solitary in each environment.
- From the results of the calculation of thermal comfort in all three zoning environments, it shows that it is outside the ideal standard of thermal comfort. Trees in the three environmental zones have not met the criteria of vegetation function as a thermal comfort control, because the humidity conditions are still quite high.
- The existence of trees as a function of temperature modification is sufficiently fulfilled, it can be seen from the results of the air temperature assessment in the three environmental zoning
- The existence of trees as a function of solar radiation control has been fulfilled in environments 1 (one) and 3 (three), compared to the level of sunlight radiation in 2 (two) zoning environments.
- The function of vegetation as wind control is sufficiently fulfilled in all three environmental zoning. The wind speed is at a gentle level that does not interfere with activity. Measurement of the level of thermal comfort and assessment of vegetation criteria produce a recommendation in improving the quality of thermal comfort and maximizing the function of vegetation in its function as a thermal comfort control in the Ria Rio Reservoir area.

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