



Thermal Comfort Simulation for the Arrangement of the Krueng Aceh Riverbank Park

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Abstract

Taman Tepian Krueng Aceh is the main river in Aceh Province, with a geographically advantageous position, making the area along its banks a central hub for urban activities. The development of the area around the Krueng Aceh River in Banda Aceh City aims to utilize the river's surroundings as public space for the community without disrupting the river's function itself. Green Open Space (RTH) in the Tepian Krueng Aceh Park refers to an area where RTH is spread out or a group uses a broader area where both natural flora and intentionally planted flora can grow. This research focuses on the Thermal Comfort Simulation for the Arrangement of the Krueng Aceh Riverbank Park using the Temperature Humidity Index (THI) method, and is simulated with the ENVI-met software to measure thermal conditions in the Krueng Aceh Riverbank Park. The research results indicate that the Krueng Aceh Riverbank Park has an uncomfortable thermal qualification level with THI values above 26°C, supported by simulations into several scenarios using the ENVI-met software. The measurement results show that the recommendation for design in the Krueng Aceh Riverbank Park is based on the ENVI-met simulation results, suggesting the addition of vegetation. Therefore, several new vegetation types were added to meet the thermal comfort in the Krueng Aceh Riverbank Park. The addition of supporting facilities such as playground areas and seating is also recommended to meet the thermal comfort level in the Krueng Aceh Riverbank Park. The results of this study are expected to serve as a reference in landscape planning that can lower temperatures and improve thermal comfort in outdoor spaces in Banda Aceh City.

Keywords: *Simulation; Thermal Comfort; Park Arrangement; Krueng Aceh Riverside Park*

Introduction

The Krueng Aceh River Basin (DAS) stretches approximately 10 km, dividing the city of Banda Aceh and the district of Aceh Besar into two parts: the northern and southern sections. The existence of the Krueng Aceh Watershed serves as a source of clean water for the community (Djumali et al., 2022; Polie et al., 2014), although its water availability has started to decrease. Additionally, the function of the watershed as a flood channel (Putranto & Susanto, 2019; Ujianti et al., 2021) is currently not as optimal

because the riverbanks and flood channel embankments of the Krueng Aceh watershed are not being used for their intended purposes, such as community service facilities in the trade and service sectors. This has attracted the attention of city residents seeking opportunities in the informal sector, leading to increased residential density and intensified activities in the coastal areas of Krueng Aceh (Septiyana, 2022).

Taman Tepian Krueng Aceh is a way of using the riverbank as a public area for the community without diminishing the river's role itself, thereby creating a better environment and becoming a proud tourist destination for the residents of Banda Aceh. This is evident from the presence of Taman Tepian Krueng Aceh, which is built and divided into four segments: segment one and segment two in the Kodam Iskandar Muda area, while segment three and segment four are in the residential area and behind the Medan Hotel. Taman Tepian Krueng Aceh is the area closest to the city center. The area of segment one is 1,131 m², segment two is 3,359 m², segment three is 2,719 m², and segment four is 4,524 m², with a total area of 11,733 m². Where among the four segments, Taman Tepian Krueng Aceh has quite a few facilities, where the basic idea is to transform the green open space into a place for exercise (jogging track) in the beautiful, cool, and pleasant city center, attended by residents in the morning and evening (Chairina, 2023).

Based on the observational results of the study, the issues found in the four segments of Taman Tepian Krueng Aceh are located in segments one and two. These segments are located within the area of the Iskandar Muda Military Command, which is currently undergoing the construction of a pier for soldiers, enhancement of the Iskandar Muda Military Command signage and landscape area, as well as the development of pedestrian paths, sports facilities, and a pier intended for high-ranking officers. As a result, the general public who wish to visit the Taman Tepian Krueng Aceh in segments one and two must report and request permission from the Iskandar Muda Military Command Provost first, leading many people to be reluctant to visit the park located in the Iskandar Muda Military Command land zone. In addition to those issues, another problem that arises in the Taman Tepian Krueng Aceh is the climate conditions in the city of Banda Aceh, where according to the BMKG of Aceh Province, the average air temperature ranges from 26.9°C to 27.2°C. The maximum temperature reaches 32.5°C and the minimum temperature is 22.9°C.

One of the green open spaces located along the riverbank in Banda Aceh is the Krueng Aceh area. This park serves as a regulator and protector of the surrounding microclimate. In addition, the people of Banda Aceh use this park for various activities, such as areas for resting and waiting, places for playing and exercising, social interactions, relaxation spots, and connections between different locations. Various activities carried out in the Krueng Aceh park or open area can impact thermal comfort.

Thermal comfort is the response of skin receptors to the influence of environmental temperature. The warm atmosphere indoors is influenced by various elements, such as air temperature, humidity levels, and wind speed. This thermal comfort is an absolute necessity for the human body. The ability of humans to manipulate the environment to achieve a level of comfort that can be perceived by the human body in urban park design. In addition to serving the functions of beauty and social interaction, a good urban park must meet various needs and requirements for the comfort of every user (Wisambudi, 2018).

Research Method

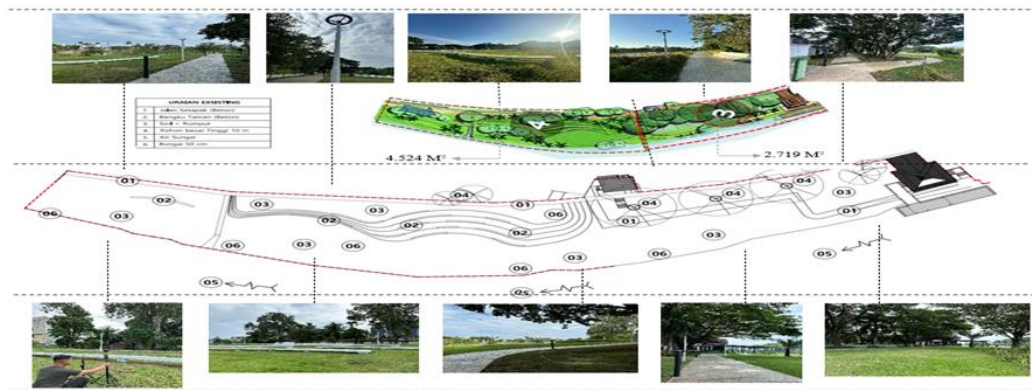
This research was conducted in the city park area of Banda Aceh, focusing on the Taman Tepian Krueng Aceh. Its location is on the banks of Krueng Aceh, Peunayong, Kec. Kuta Alam, Banda Aceh City, Aceh Province, Indonesia. The area of the Taman Tepian Krueng Aceh reaches 7,243 m². In this study, a qualitative method with a descriptive approach is used. This method relies on the collection of data and information in the form of numerical symbols or figures. In the conclusion phase, the results of this research will be complemented with visual representations such as tables, graphs, images, or other forms of display (Hermawan, 2019). This conclusion also includes the creation of recommendations or

design suggestions based on the analysis results. The analysis techniques used in the research include descriptive analysis, inferential analysis, simulation, and evaluation.

Discussions

1. Characteristics of the Krueng Aceh Riverbank Park

Taman Tepian Krueng Aceh shows a diverse variation in its landscape. From the observations conducted at the research site, the elements in the landscape are classified into a composition of artificial land use. In the area of the stands, pathways, and park benches, there is a lack of plants and trees.



Picture 1. Existing Layout of the Krueng Aceh Riverbank Park

2. Point of Thermal Measurement

Table 1. Thermal Landscape Characteristics at Thermal Measurement Points

Existing	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Concrete	■	■						■		
Grass			■							
Shade Tree				■			■			
Shelterbelt Tree					■					
Natural Stone						■				
Near the Body of Water									■	
Near Pavement										■

Table 1. showing environmental features at temperature measurement locations that include hard and soft components. Hard components include concrete and natural stone. Soft components include grass and trees.

3. Results of Thermal Measurements

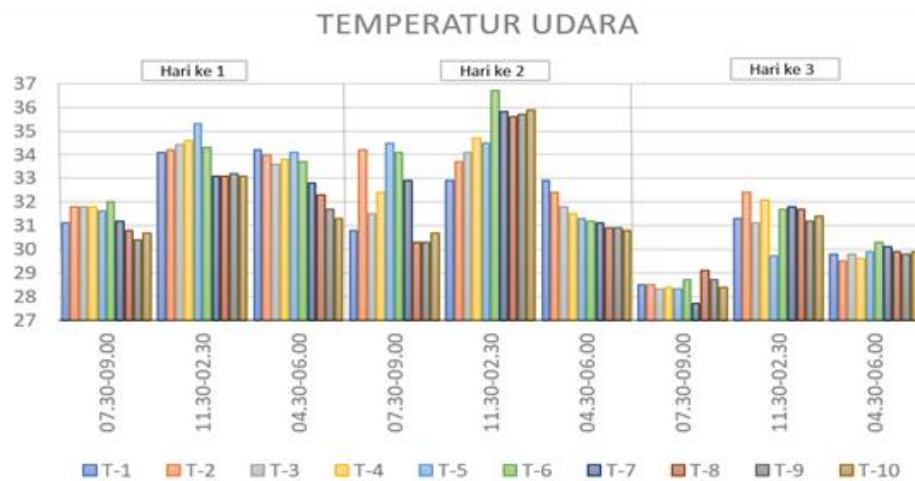
Thermal measurements were conducted in the outdoor environment using two instruments, namely the WetBulb Globe Temperature (WBGT) and an Anemometer, which had been prepared in advance with predetermined measurement times. Measurements were taken every 10 minutes, from 07:30 to 06:00, over a three-day observation period. This device is capable of recording various relevant thermal parameters, including air temperature, air humidity, and wind speed.

a. Air Temperature

The measurement of air temperature at the Krueng Aceh Riverbank Park was conducted at a single measurement point using the WetBulb Globe Temperature (WBGT) device. The measurement results show significant temperature variations during the observation period. The lowest temperature was recorded on the third day from 07:30 to 09:00 WIB, reaching 28.3°C, while the highest temperature was recorded on the second day from 11:30 to 02:30 WIB, reaching 36.7°C. The average air temperature during the observation period was 31.9°C. However, these results indicate that the air temperature in Taman Tepian Krueng Aceh does not yet meet the standards set in SNI 033572-2001. A more in-depth evaluation is needed to determine the elements that contribute to temperature variation and the steps that can be taken to improve thermal comfort and ensure compliance with the established standards.

One of the factors contributing to the high air temperature in this Park is the lack of vegetation planting in several areas. Vegetation plays an important role in reducing air temperature by providing effective thermal insulation and reducing the rate of heat transfer. When plants grow, they absorb sunlight through the process of photosynthesis, which in turn reduces the amount of heat emitted into the surrounding air. Additionally, dense foliage can provide shade that helps reduce direct exposure to sunlight, which ultimately lowers the surface and surrounding air temperature.

Therefore, the presence of adequate vegetation in the park will not only enhance thermal comfort for visitors but also help create a cooler and healthier environment overall. By planting more trees and plants, the park can become a greener public space, stimulate social interactions, and reduce the heat impact generated by the abundant concrete and asphalt surfaces in the urban environment.



Picture 2. Graph of Air Temperature Measurements Over 3 Days

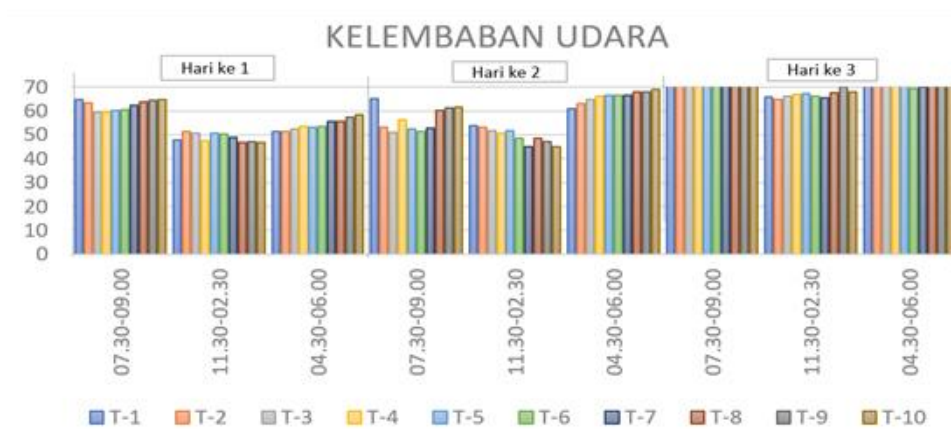
b. Air Humidity

The measurement of air humidity at Taman Tepian Krueng Aceh was conducted using the WetBulb Globe Temperature (WBGT) device. The collected data provides an interesting picture of the variation in air humidity during the observation period. The lowest value was recorded on the second day, specifically from 11:30 PM to 2:30 AM WIB, where the humidity reached 45%. Conversely, the highest value was recorded on the third day, from 7:30 AM to 9:00 AM WIB, with humidity reaching 82%. The average humidity during the observation period was 61.7%. A more in-depth analysis of this information provides important insights into the air humidity patterns at Taman Tepian Krueng Aceh during the observation period. Such variations in humidity can affect visitor comfort as well as the growth and health of the plants in the park. Therefore, a better understanding of air humidity fluctuations is important in

planning and managing the park to ensure optimal conditions for public use and the success of the vegetation planted there.

The results of the air humidity measurements show an average value of 61.7%. This reflects conditions that are generally considered warm and comfortable, under the standards set in SNI 033572-2001, where the threshold for thermal comfort is in the range of 60% to 70%.

The measurement of air humidity within this range is a positive indication that Taman Tepian Krueng Aceh has maintained a pleasant environment for its visitors. Adhering to these standards is important to ensure optimal comfort for park users. By achieving the right balance in air humidity, the park can become a desirable place for outdoor activities, whether for recreation, sports, or relaxation. Additionally, maintaining the proper air humidity can also support the growth and health of plants and the sustainability of the park's ecosystem as a whole. Therefore, the measurement results that show thermal comfort in accordance with the standards are an achievement that important in the sustainable management of the Krueng Aceh Riverside Park.



Picture 3. Graph of Air Humidity Measurements Over 3 Days

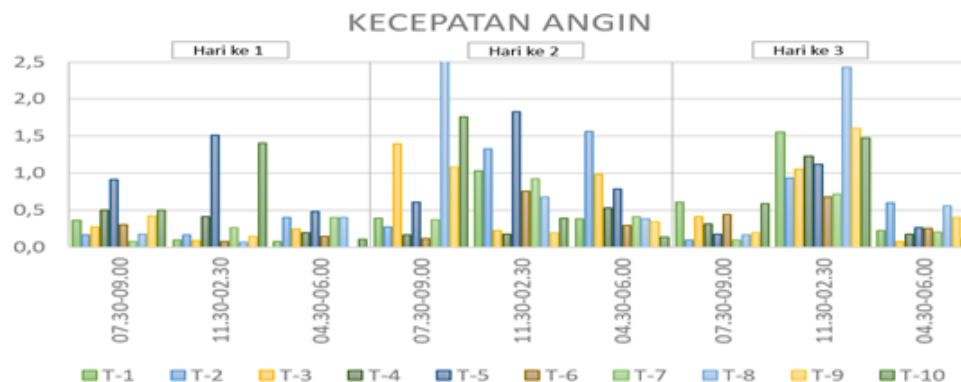
c. Wind Speed

Measurement of air speed or wind speed at Taman Tepian Krueng Aceh was conducted using an Anemometer. The data collected provides an interesting picture of the wind dynamics in the area during the observation period. It can be seen that the lowest value was recorded on the first day, between 04:30-06:00 WIB, where the wind speed only reached 0.1 m/s. Conversely, the highest value was recorded on the second day, between 07:30-09:00, with a wind speed reaching 2.6 m/s. The average wind speed during the observation period reached 0.57 m/s.

This data provides valuable insights into the variations in wind speed at the Krueng Aceh Riverside Park, which can affect visitor comfort as well as the growth patterns of plants in the park. Further understanding of such wind patterns is important for the planning and management of the park, especially in terms of infrastructure design and vegetation placement. By paying attention to wind dynamics, park managers can take appropriate steps to create a comfortable and safe environment for visitors and maximize the growth and health of the plants. Therefore, regular wind speed measurements are an important part of the monitoring and maintenance efforts at Taman Tepian Krueng Aceh. The wind speed measurements show that the average value reaches 0.57 m/s. This figure indicates that the wind speed at Taman Tepian Krueng Aceh is within the range considered optimal and comfortable. These results are in accordance with the standards set in SNI 033572-2001, where the optimal wind speed range for comfort is between 0.15 m/s and 0.25 m/s.

Wind speed that is neither too slow nor too strong is an important factor in creating a comfortable environment for park visitors. Wind speed that is too low can cause stuffiness and a lack of good air circulation, while wind speed that is too high can cause discomfort and even danger for visitors.

Therefore, the presence of wind speed within a comfortable and optimal range like this is a positive indicator for user comfort and safety at Trembesi Park. By maintaining wind speeds within the appropriate range according to standards, park management can ensure that visitors can enjoy A pleasant and safe experience in this open environment.



Picture 4. Graph of Wind Speed Measurements Over 3 Days

d. Temperature Humidity Index (THI)

The analysis of comfort levels is expressed in the comfort index or temperature-humidity index (THI). This is an index measured in degrees Celsius and can be related to how comfortable the community feels in urban areas. The comfort index is obtained by calculating using a formula. Thermal measurements were conducted at the Krueng Aceh Riverside Park using two instruments, namely the WetBulb Globe Temperature (WBGT) and Anemometer. Measurements were taken every 10 minutes, from 07:30 to 06:00, over a period of three consecutive days.

To calculate the comfort index, a formula is used that combines both factors. This formula is designed to produce a value that can be easily interpreted to assess thermal conditions. By knowing the THI value, we can classify the thermal comfort level of an area and take the necessary actions to improve the surrounding comfort.

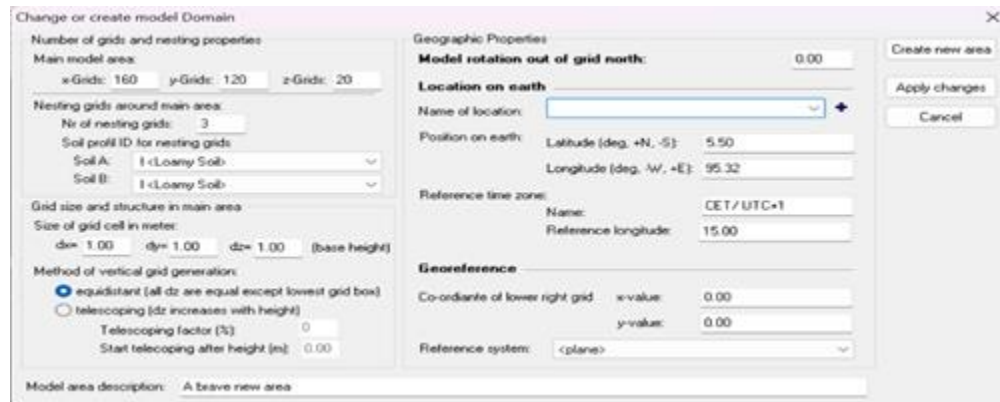
The calculation of the Temperature Humidity Index (THI) at Taman Tepian Krueng Aceh, with an average temperature of 31.9 °C and an average relative humidity of 61.7%, results in a Temperature Humidity Index (THI) value of 29.5 °C. This means that the thermal conditions at Taman Tepian Krueng Aceh are quite hot and uncomfortable for most people. On the first day's measurement, from 07:30-09:00 until the third day from 07:30-09:00, most showed uncomfortable conditions. This is caused by the rainfall that resulted in changes in temperature and humidity, thereby affecting the THI value at Taman Tepian Krueng Aceh. At other measurement times, the THI value continued to show uncomfortable conditions because it exceeded 26, which is the discomfort threshold. Weather, especially rain, greatly affects the THI value by altering air temperature and humidity levels. The surrounding environment and garden layout may also affect how temperature and humidity accumulate, so it needs to be considered in further planning. It can be concluded that the thermal conditions in the Krueng Aceh riverside park at certain times are not ideal for comfort. Further measures are needed to optimize comfort conditions in the

park area, such as adding vegetation, providing shaded areas, incorporating water features, or implementing other passive cooling systems.

4. Simulation

a. Setting of Domain Model

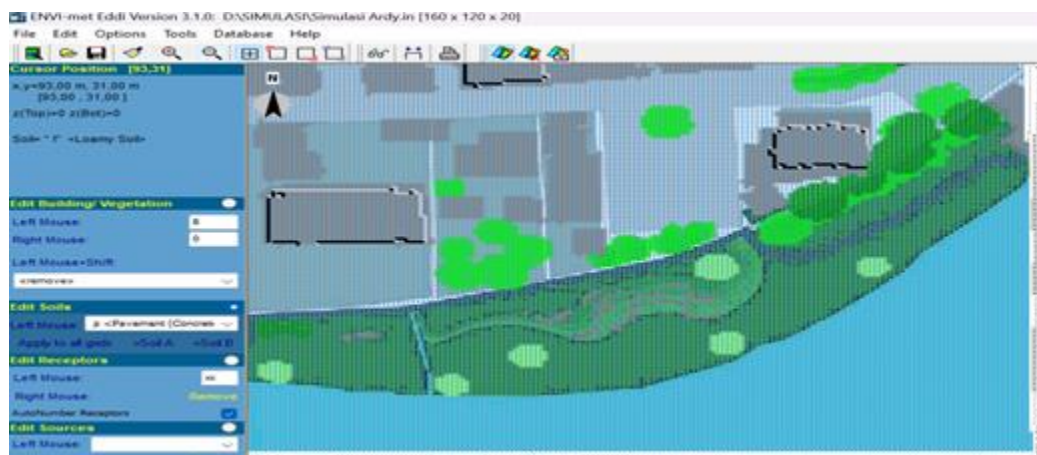
Setting the Envi-Met model domain to define grid size (horizontal and vertical resolution), setting the domain boundaries (simulation area dimensions in meters or grid cells), and Position on Earth Latitude 5.50 and Longitude 95.32 in the city of Banda Aceh.



Picture 5. Setting Model of Taman Tepian Krueng Aceh

b. Modeling

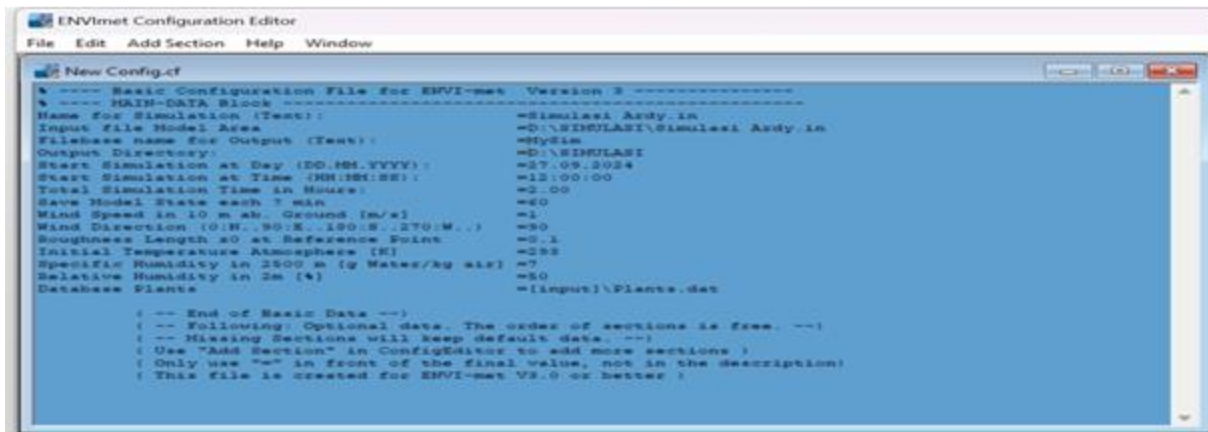
In this simulation, the first stage of modeling is conducted to identify the materials present in the Krueng Aceh Riverside Park, such as the Pathway (Concrete), Park Benches (Concrete), Soil (Grass), Large Trees (10 m tall), River Water, and Flowers (50 cm).



Picture 6. Modeling Envi – Met Riverside Park of Krueng Aceh

c. Configuration Modelling

Modeling Configuration is an important stage before running the simulation. This step ensures that all parameters align with the simulation objectives and the environmental conditions to be modeled to determine the time and date of the simulation.



Picture 7. Riverside Park Configuration of Krueng Aceh

d. Load Configuration

To load the previously created configuration file. This file can be a configuration file, simulation settings, and create existing configuration data to subsequently input simulation run data.



Picture 8. Load of Krueng Aceh Riverside

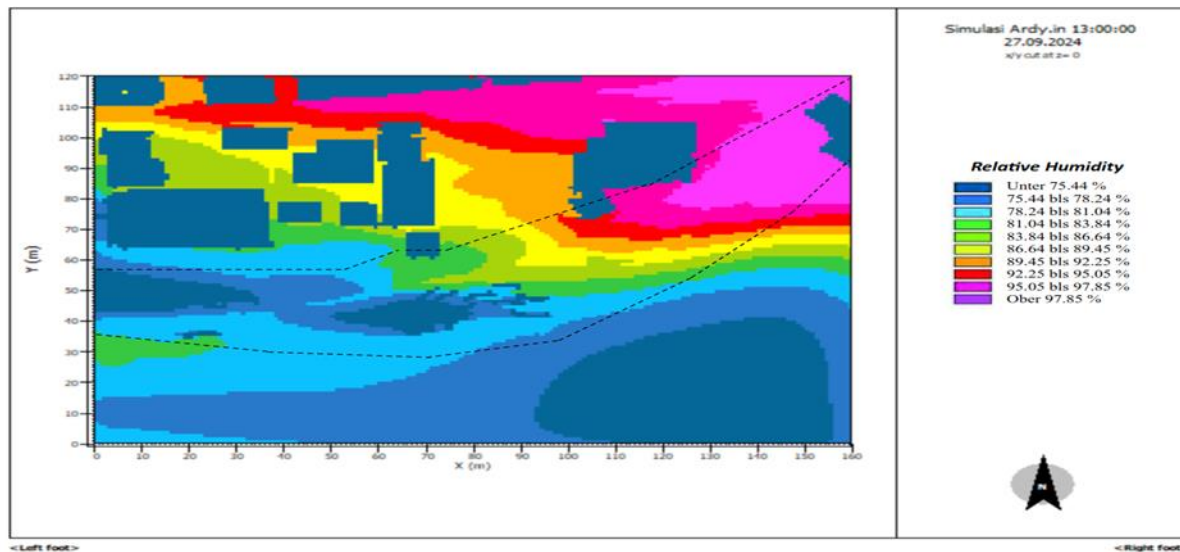
e. Run Model

Seeting to create model for 4 hours by software at micro climate simulation that is strong making it possible to modelize and analize such as temperature , humidity and wind speed.



Picture 9. Run Model Krueng Aceh's Riverside Park

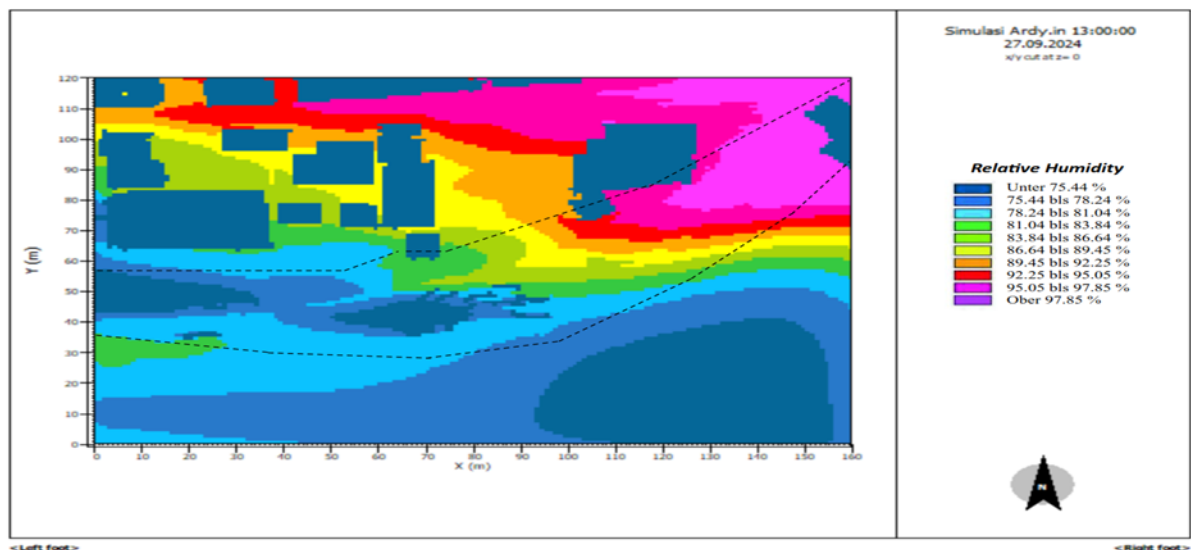
f. Air Temperature



Picture 10. Air Temperature of the Krueng Aceh Riverside Park a). Pathway, b). Park Bench, c). Soil + Grass, d). Trees 10 m tall, f). River Water, and g). Flowers 50 cm

After conducting measurements and evaluations, simulations were carried out to observe the impact of modifying a landscape design element. The results of the air temperature simulation at Taman Tepian Krueng Aceh in Figure 4.11 show that on the footpath and park benches, the maximum temperature is 31.65 - 32.31, and the minimum temperature in the vegetation area is 29.65 - 30.32.

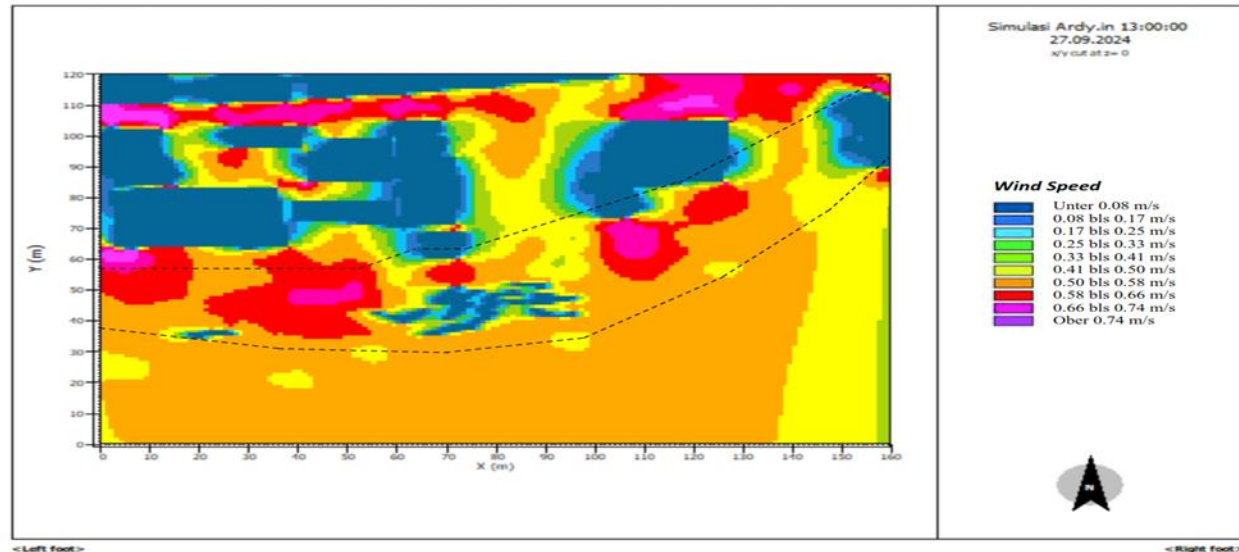
g. Humidity



Picture 11. Humidity of the Krueng Aceh Riverside Park a). Pathway, b). Park Bench, c). Soil + Grass, d). Trees 10 m tall, f). River Water, and g). Flowers 50 cm

After conducting a humidity temperature simulation at the Krueng Aceh Riverside Park, Figure 4.12 shows that the maximum humidity is found in the riverbank area at 95.05% – 97.85%, and the minimum humidity is found in the tree vegetation area at 75.44% – 83.84%.

h. Wind Speed



Picture 12. Wind Speed at the Krueng Aceh Riverside Park
a). Pathway, b). Park Bench, c). Soil + Grass, d). Trees 10 m tall,
f). River water and g). Flowers 50 cm

After conducting wind speed simulations at the Krueng Aceh Riverside Park, as shown in Figure 4.13, the maximum wind speed is found in the tree vegetation area at 0.66 – 0.74 m/s, and the minimum wind speed is found in the footpath and park bench area at 0.8 – 0.33 m/s.

5. Model Design of Krueng Aceh Riverside Park

a. Landscape Elements

The selection of material components in the design of the City Park landscape needs to be considered. Material and green infrastructure are design applications that play an important role in landscape planning (Hakim, 2012). In general, landscape materials are divided into two parts, namely soft elements and hard elements.

1) Structure of Landscape

The landscape structure in an urban park is also a design component that influences the modification of the city's thermal environment. Landscape structure is defined as the spatial pattern of various landscape components concerning size, diversity, density, and configuration (Tarumingkeng, 2000). Landscape structure is classified into two parts (Gökyer, 2013), namely landscape composition and landscape configuration.

2) Albedo of Landscape Material

The thermal environment in urban areas is also influenced by the albedo of a land cover material. Albedo is the amount of shortwave radiation energy reflected after it hits the land surface (Trlica et al., 2017). The albedo value affects the ability to reflect sunlight on a land cover material. The higher the albedo value, the greater the material's ability to reflect sunlight. Materials with high reflection capabilities towards solar radiation are more capable of reducing surface temperature on the ground. This happens because the heat from the radiation is not absorbed and stored in the material. In addition to being influenced by the type of material, the albedo value is also affected by the color of the material

(Pratiwi & Safitri, 2019). Light-colored materials have a higher albedo compared to dark-colored materials. The range of albedo values starts from 0 to 1.

3) Circulation Pattern

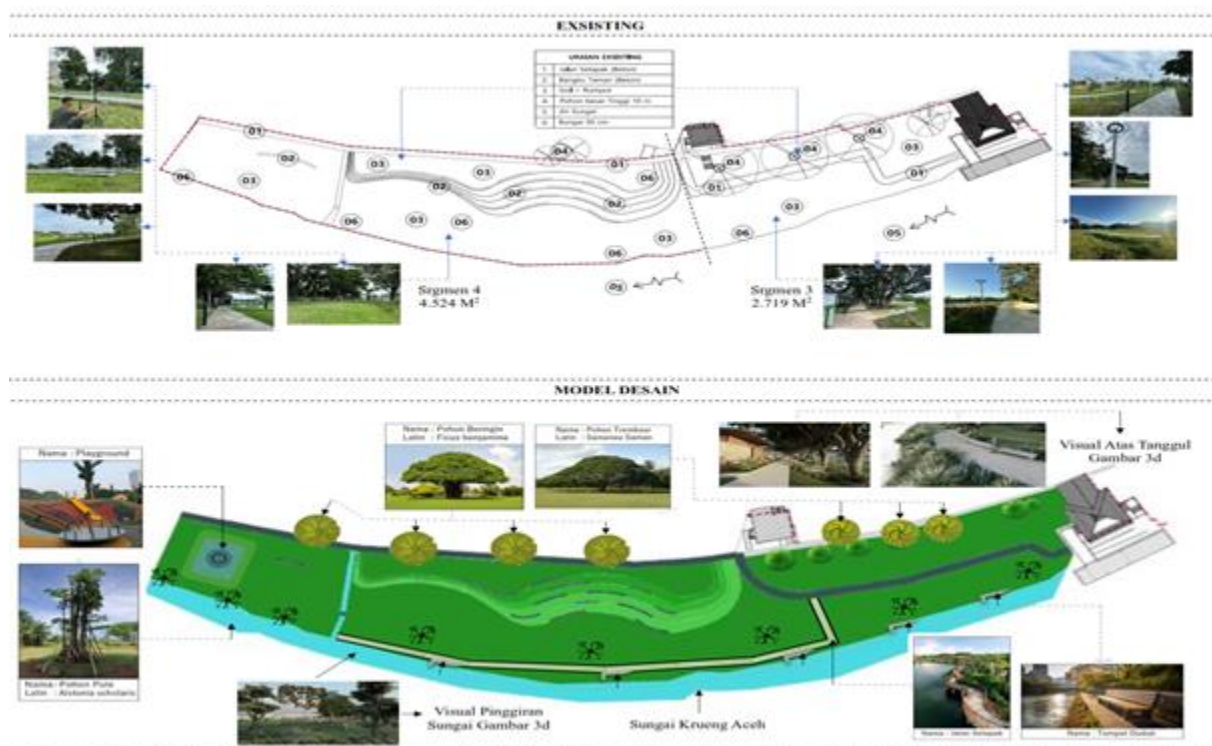
The shape of pathways or circulation patterns in the landscape also plays an important role in modifying the microclimate, as it can influence the arrangement of vegetation, building mass, and the structure of a garden. Circulation patterns have several forms, including winding, diverging, circular, meandering, hyperbolic, centrifugal, centripetal, turning left or right, floating upwards, ascending, descending, arching, and straight (Hakim & Utomo, 2003).

4) Vegetation Selection

Reducing the heat generated by direct sunlight can be achieved by planting more vegetation in the garden area. Vegetation can function as a passive cooler in the landscape. Based on its functions, vegetation in landscape design is categorized into four types (Mutfianti, 2011), namely: cover vegetation, wall-forming vegetation, canopy or shade vegetation, and vegetation as ornaments and fillers.

b. Recommended Design

The design model for the Taman Tepian Krueng Aceh includes the addition of vegetation and supporting facilities. The addition of vegetation is based on the results of the Envi-met simulation, which showed that the vegetation is still sparse according to the simulation results. Therefore, in areas with insufficient vegetation, several new plants will be added to enhance the barren areas of Taman Tepian Krueng Aceh. The addition of supporting facilities such as a playground, several footpath areas, and seating will also be implemented to improve the thermal comfort levels in Taman Tepian Krueng Aceh.



Picture 13. Recommended Design Model Pic

Conclusion

The results of the thermal comfort simulation study for the Krueng Aceh Riverbank Park are as follows: The findings indicate that the air temperature at the Krueng Aceh Riverbank Park ranges from 28.3°C to 35.9°C, with an average air temperature of 31.9°C. These measurements show thermal discomfort according to SNI standards, which recommend an optimal comfortable temperature of 21.0°C - 24.0°C. The humidity levels at the Krueng Aceh Riverbank Park range from 45% to 82%, with an average humidity of 61.7%. These measurements indicate thermal discomfort according to SNI standards, which recommend an optimal comfortable humidity of 70% - 80%. The wind speed measurements at the Krueng Aceh Riverbank Park range from 0.1 m/s to 2.6 m/s, with an average wind speed of 0.57 m/s. These results indicate thermal discomfort according to SNI standards, which recommend an optimal comfortable wind speed of 0.15 m/s – 0.25 m/s.

The results of the Temperature Humidity Index (THI) evaluation at Taman Tepian Krueng Aceh range from 27°C to 32°C, with an average THI value of 29.4°C. The THI value still indicates uncomfortable conditions as it exceeds 26°C, which is the threshold for discomfort. Design suggestions for the Taman Tepian Krueng Aceh include the addition of vegetation and supporting facilities. The addition of vegetation is based on the results of the Envi-Met simulation, which indicates that the vegetation density in the Krueng Aceh Riverside Park is still quite sparse. Therefore, in areas lacking vegetation, new plants will be added to enhance the barren areas of the Krueng Aceh Riverside Park. The addition of supporting facilities such as a playground and more seating areas will also be implemented to improve the thermal comfort level in the Krueng Aceh Riverside Park.

Suggestion

The results of this study regarding Taman Tepian Krueng Aceh in providing thermal comfort in the park. It is hoped that in future research, thermal measurements can be conducted for more than 3 days, and it would be even better to compare the thermal measurements of Taman Tepian Krueng Aceh annually to produce better measurements. Including an Envi-Met simulation study to predict the impact of design changes to the Taman Tepian Krueng Aceh on thermal comfort. Regarding the type of vegetation that has high effectiveness in heat absorption, it needs to be addressed. With this further research, it is hoped that more innovative and adaptive solutions will emerge to improve the quality of the Riverbank Park in Aceh.

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