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IMPACT OF URBAN RIVER DYNAMICS ON MICROCLIMATE: CLIMATIC FACTORS ALONG THE MARTAPURA RIVER

Yuswinda Febrita[1], *Sri Nastiti Nugrahani Ekasiwi[1] and I Gusti Ngurah Antaryama[1]

[1]Department of Architecture, Faculty of Civil, Planning, and Geo Engineering, Sepuluh Nopember Institute of Technology (ITS), Surabaya, Indonesia

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ABSTRACT: This study investigates the impact of the Martapura River on the microclimate of Banjarmasin City, Indonesia. Data were collected using twenty strategically placed sampling points along two routes adjacent to the river, with air temperature and relative humidity readings recorded at 10-minute intervals. Additionally, a portable weather station monitored these parameters over the river from 6:00 to 18:00. Using ENVI-met software, the study analyzed the effects on air temperature, relative humidity, and Predicted Mean Vote (PMV). The results indicated that the Martapura River significantly influences the local microclimate by reducing air temperatures by up to 1.5°C and increasing humidity levels by up to 5% near its banks. The cooling effect was more pronounced downwind of the river compared to upwind areas, and roads contributed to air temperatures that were up to 0.5°C higher. The study highlights the river's role in enhancing thermal comfort and mitigating urban heat islands, emphasizing the importance of integrating natural water bodies into urban planning for sustainable development and climate resilience.

Keywords: Solar Radiation, Urban River, Microclimate Dynamics, Climate Resilience

1. INTRODUCTION

Urban heat islands (UHIs) are areas where urban temperatures are significantly higher than in surrounding rural areas due to human activities and environmental modifications [1]. Rivers within urban areas play a crucial role in mitigating the UHIs effect by influencing the local microclimate. Studies have shown that flowing water in rivers absorbs heat from the surrounding environment and provides additional cooling effects through evaporation, thereby lowering air temperature and affecting factors such as relative humidity [2,3].

Research has highlighted the importance of green and blue spaces, such as rivers, in reducing the intensity of UHIs by modifying surface properties to enhance cooling through increased evapotranspiration and reduced solar radiation absorption [4]. Furthermore, the dynamics and evolution of blue-green spaces driven by urban development have been linked to temperature variations between built-up areas and suburbs, contributing to the UHIs effect [5]. Moreover, the thermal characteristics of urban areas, including the influence of rivers, have been studied to understand their impact on the local urban thermal environment. Rivers, along with other factors like urbanization, affect the local thermal environment, highlighting the complex interactions between natural and built environments in shaping urban microclimates [6].

Wind significantly influences various aspects of urban rivers. Research has shown that wind speed can impact the hydrological response in urban areas [7]. Strong winds can lower water temperature and affect thermal comfort and climate conditions [8,9]. Urban obstacles and their orientation can alter wind speed patterns, impacting factors like thermal comfort [10]. Understanding the complex relationship between wind dynamics and urban river environments is essential for sustainable urban development and effective river system management [11].

Urban development along rivers can significantly impact the local climate. Factors such as building height, urban density, and the design of streets and open spaces play crucial roles in shaping the UHIs effect [12]. The influence of buildings on heat fluxes and temperatures downstream highlights the interconnectedness of urban structures and microclimates [13]. The combination of urbanization, microclimate, and UHIs effect, exacerbated by climate change, affects buildings' energy demand and the outdoor thermal environment [14]. The design of urban areas, including land use distribution, street layouts, and material choices, can lead to variations in wind patterns, humidity levels, temperature, and air quality, emphasizing the impact of urban planning on local climate conditions [15]. Moreover, the orientation of buildings plays a significant role in indoor thermal comfort, with considerations for solar radiation exposure and ventilation influenced by prevailing winds [16]. Understanding buildings' outdoor thermal comfort is essential for enhancing environmental quality and human well-being in urban neighborhoods [17].

Natural elements like rivers can significantly influence the urban thermal environment by providing cooling effects that mitigate urban heat, especially during nighttime [18]. Additionally, urban rivers are impacted by vegetation cover, which can be degraded by urbanization. Riparian vegetation serves as a passive cooling strategy, emphasizing the importance of integrating vegetation management into urban river practices [19,20]. Additionally, the spatial structure of riparian vegetation along rivers is influenced by river hydrology, among other factors [21]. The riverside area holds significant importance as a recreational hub for city dwellers, with the local microclimate playing a crucial role in determining the thermal comfort of individuals participating in outdoor pursuits [22].

The present study distinguishes itself from previous research on microclimate regulation by conducting a comprehensive analysis of multiple river dynamic parameters and their specific impacts on urban microclimates. Unlike earlier studies that primarily focused on individual aspects such as vegetation or roughness scale, this research integrates the examination of wind speed and direction, solar radiation, evaporation processes, and temperature distribution. Utilizing advanced ENVI-met simulation software, the study provides a detailed and nuanced understanding of how these dynamic interactions collectively influence the urban microclimate. By focusing on the Martapura River in Banjarmasin, the study offers localized insights that are essential for developing effective urban planning strategies tailored to similar environments. This multifaceted approach and the integration of advanced simulation techniques represent a significant advancement over previous works, highlighting the critical role of comprehensive river dynamics in urban microclimate regulation.

In this paper, a comprehensive analysis of the Martapura River's impact on Banjarmasin City's microclimate is presented. The study investigates the complex relationship between solar radiation, wind speed, air temperature, and relative humidity along the urban river, using data collection and advanced ENVI-met simulations. The results highlight variations in air temperature and relative humidity, comparing these findings with similar studies. Practical recommendations for mitigating urban heat island effects are provided. Finally, the study concludes with key insights and practical applications, offering localized insights essential for effective urban planning and microclimate regulation.

2. RESEARCH SIGNIFICANCE

Urban rivers play a vital role in alleviating urban thermal conditions, complementing greening efforts. They impact the urban climate by fostering the generation of cool air at the water surface and augmenting ventilation through the wind path effect in open river areas. For instance, the Martapura River in Banjarmasin, Indonesia, exemplifies this phenomenon. Current research is centered on quantifying the influence of landscape and building layouts in urban river areas on surrounding microclimates attributed to factors such as solar radiation, evaporation, and urban wind movements. A comprehensive understanding of these impacts holds paramount importance for urban planning endeavors, facilitating the optimization of urban river benefits in enhancing microclimates and thermal comfort within cities.

3. METHODS AND PROCEDURES

3.1 Measurement Object

The city of Banjarmasin is located between 3°15' and 3°22' South Latitude and 114°32' East Longitude, with the original ground elevation situated at 0.16 meters below sea level. The city is divided by the Martapura River, which originates from the Meratus Mountains.

To investigate the water cooling effect in urban areas, a relatively typical urban area near the Martapura River was selected for conducting the measurements. The density and height of buildings in the surrounding area are relatively low. The sampling points were selected to meet the criteria and were considered to represent the typical characteristics of the urban river landscape in Banjarmasin City. In order to observe the outdoor temperature distribution, a stratified random sampling technique was applied to determine the sampling points. Samples were drawn disproportionately across all types of land use and land cover (i.e., water bodies, built-up areas, and green areas). The survey points are spread over two routes: Jalan Kapten Pierre Tendean (PT) and Jalan Jendral Sudirman (JS), both of which are along the river. Twenty sampling points were selected for temperature measurements in the landscape area of the Martapura River in Banjarmasin city. The locations are shown in Fig. 1 and the detailed surrounding environment is depicted in Fig. 2.

As shown in Fig. 2, segment I depicts significant urban development with built structures on both sides of the riverbank and minimal vegetation. Segment II features a more balanced landscape with dense vegetation on one side and a road on the other, representing a transitional area between urban and natural environments. Segment III presents a mix of residential buildings and green spaces, including taller buildings and some trees, indicating moderate urbanization. Segment IV highlights a contrasting environment with one side having vegetation and a clear area, while the other side has a heavily urbanized section with high-density buildings, showing a stark difference in land use. Segment V shows a densely built environment with closely packed structures and multiple bridges, emphasizing minimal natural elements. These diagrams visually represent the diverse landscape features within the study area, illustrating the varying degrees of urbanization and their impact on the river's microclimate.

Fig. 1 Location of research objects

Table 1 lists specific sampling points distributed across five segments along the river. Each segment includes multiple sampling points, identified by segment number and a unique coordinate pair. This structured segmentation facilitates a comprehensive analysis of the river's microclimate by providing precise locations for data collection within each segment, ensuring a thorough investigation of environmental variations along the Martapura River.

Table 1. Sampling segments and coordinates along the Martapura River

Seg.	No	Coordinate	No	Coordinate
I	1	-3.32205, 114.59357	3	-3.32134, 114.59437
	2	-3.32238, 114.59265	4	-3.32067, 114.59449
II	5	-3.31981, 114.59277	7	-3.31981, 114.59351
	6	-3.31982, 114.59188	8	-3.31969, 114.59443
III	9	-3.31678, 114.59234	11	-3.31698, 114.59328
	10	-3.31695, 114.59134	12	-3.31704, 114.59387
IV	13	-3.31420, 114.59274	15	-3.31438, 114.59360
	14	-3.31372, 114.59185	16	-3.31395, 114.59439
V	17	-3.31179, 114.59317	19	-3.31209, 114.59398
	18	-3.31209, 114.59398	20	-3.31243, 114.59486

3.2 Methods and Schedules

In the region, various climate variables are monitored, including air temperature, humidity, wind speed, wind direction, solar radiation, and surface covering temperature. These parameters are measured using specialized instruments. For example, a Portable Weather Station measured air temperature, humidity, wind speed, and direction with an accuracy of ±1°C for temperatures ranging from -40°C to 65°C, ±5% for humidity within the 10% to 99% range, and 1m/s for wind speeds below 10 m/s, with wind direction measured in a 0−360° range.

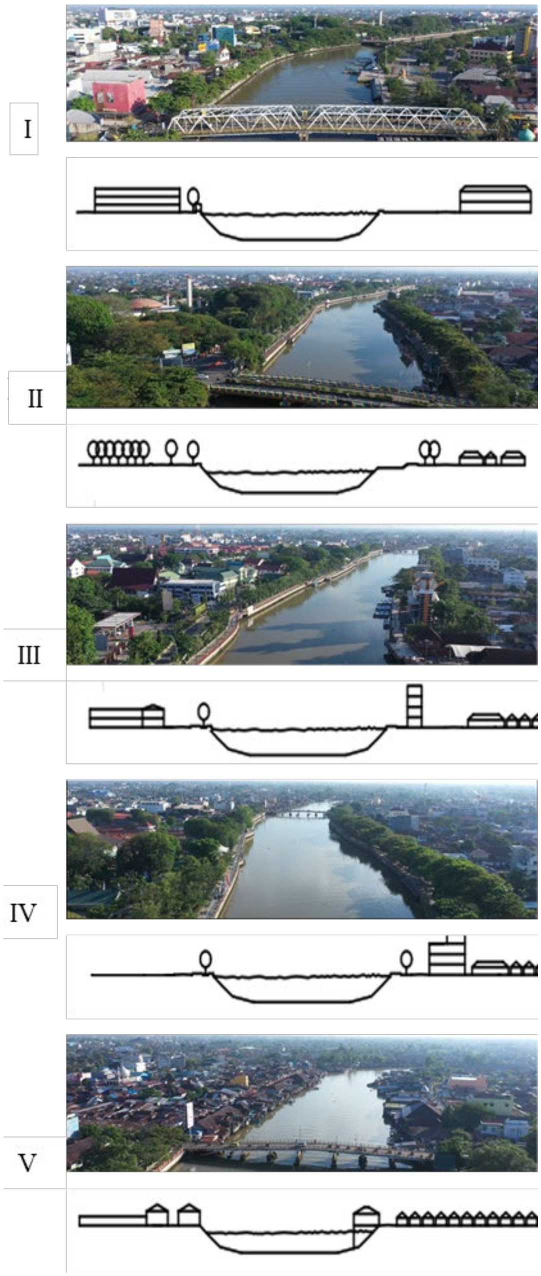
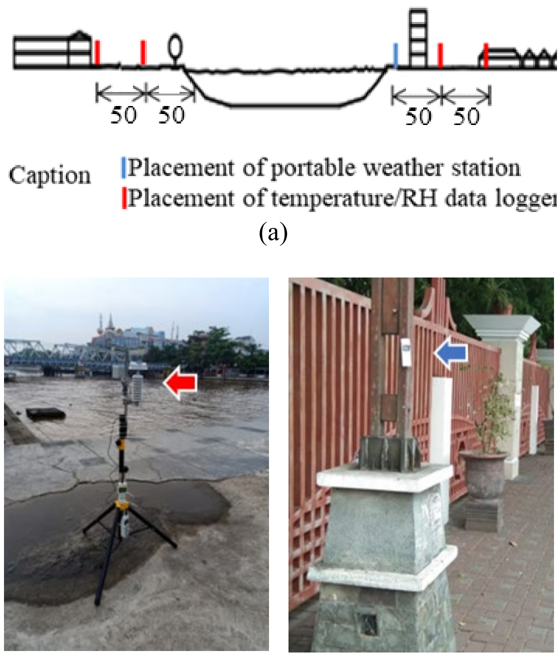


Fig. 2 Sampling segmentation on research objects

Temperature and humidity were also tracked separately using Temperature/RH Data Loggers, ensuring precision of ±1°C for temperatures spanning from -40°C to 60°C, and ±5% for humidity between 10% and 99%. Solar radiation was gauged using a Solar Power Meter with an accuracy of 0.1 W/m^2 for radiation levels under 1000 W/m^2. Surface covering temperature was monitored using a Fluke VT02 Visual Infrared Thermometer, providing a temperature accuracy of ±2^{o}C across a range from -10^{o}C to +250^{o}C.

The sensors were positioned at a height of 1.5 meters. Temperature/RH Data Loggers were positioned at 50 meters and 100 meters from the water body/river's edge in the west and east sections of the study area, recording data at 10-minute intervals over a 12-hour period. The measurements were conducted for 3 days. Microclimate data included air temperature, air humidity, wind speed, and solar radiation intensity. Measurements were carried out during the day as the water body served as a cooling source for the microclimate of the surrounding area. A portable weather station was placed on the bank of the Martapura River to monitor air temperature, humidity, wind speed, and direction over the water. Data were collected from 6:00 to 18:00.

The designated placement points for both the portable weather station and the Temperature/RH Data Logger are illustrated in Fig. 3. A sketch showing the strategic placement of portable weather stations (blue markers) and temperature/RH data loggers (red markers) at 50-meter and 100-meter intervals from the riverbank on both sides to capture microclimate variations is shown in Fig. 3(a).



(a)

(b) (c)

Fig. 3 Placement points of measurement: (a) sketch of location, (b) portable weather station, and (c) Temperature/RH Data Logger

The typical placement of a portable weather station in an open area with a concrete surface, indicated by a red arrow, used to measure parameters such as air temperature, humidity, wind speed, and direction is displayed in Fig. 3(b). Meanwhile, the typical placement of temperature/RH data loggers near a fence, possibly adjacent to vegetation, indicated by a blue arrow, for continuous monitoring of temperature and relative humidity is shown in Fig. 3(c). This setup facilitates a comprehensive analysis of how proximity to the river influences air temperature and humidity, providing crucial data for urban planning and environmental management.

3.3 ENVI - Met Modeling and Parameter Settings

ENVI-met is a sophisticated three-dimensional software application designed for the purpose of simulating intricate interactions at a small scale between various urban components and the surrounding atmosphere. Numerous scholars and experts in the field employ ENVI-met as a tool to investigate and analyze the microclimate conditions within urban environments [23-26]. In this work, ENVI-met V.3.1 was used to study the influence of the rivers on the urban microclimate. The parameters of the ENVI-met model are presented in Table 2.

Table 2. The parameters of the ENVI-met model

3D Model		Initial meteorological conditions	
Size of the area in meter	300×1500×30 100×500×30 50×250×30	Initial temperature in atmosphere	Min: 27°C Max:33.7°C
Size of grid cell in meter	3.00×3.00×3.00	Wind speed measurement in 10 m height (m/s)	0.3 m/s and 0.7 m/s
Reference Time Zone	GMT+7	Wind direction	270°
Location	Banjarmasin	Roughness length at site	0.01
Longitude	106.48°	Specific humidity at model top	90% and 58%
Latitude	-6.16 °	Relative humidity at 1.5 m height (%)	7 g/kg

The ENVI-met model of the study area is depicted in Fig. 4. Five segments (I, II, III, IV, and V) were chosen to assess the variation of air temperature and relative humidity in the region. The initial boundary parameters settings of the ENVI-met software are presented in Table 2. The prevailing wind direction in the study area is from the left bank to the right bank.

4. RESULTS AND DISCUSSIONS

This section elucidates the relationship among climate elements, including air temperature, humidity, wind speed, and solar radiation intensity, as derived from field measurement. By analyzing these relationships, conclusions can be drawn regarding the microclimate patterns observed over 12 hours within each sampling segment of the research area. This analysis aims to ascertain the impact of landscape composition and building configuration in urban river areas on the urban thermal environmental system in humid tropical regions, within each specified landscape type.

Fig. 4 The ENVI-met model of the study area

4.1 Solar Radiation

Solar radiation measurements commenced at 06:00 and continued until 18:00, encompassing the full diurnal cycle. The peak solar radiation intensity occurred at 11:00, reaching a maximum value of approximately 661.7 W/m². At the beginning of the measurement period, solar radiation was modest, registering at 8.7 W/m² at 06:00, and gradually increasing as the day progressed. However, as evening approached, solar radiation began to decline, reaching 3.7 W/m² by 18:00 (refer to Fig. 5 for visualization). This temporal variation in solar radiation intensity reflects the dynamic nature of solar energy absorption and dispersion throughout the day, influencing local microclimatic conditions and thermal dynamics.

4.2. Wind Speed

The average wind speed near the river ranges from 0.3 m/s to 3.4 m/s, as depicted in Fig. 6. Notably, the peak average wind speed occurs at 12:00, coinciding with the culmination of daytime temperatures and atmospheric dynamics, while the lowest speed is observed at 06:00 during the early morning hours.

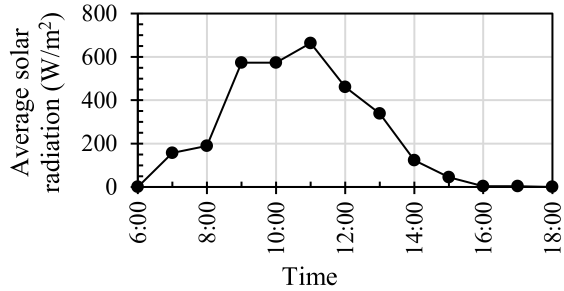


Fig. 5 Average solar radiation as a function of time

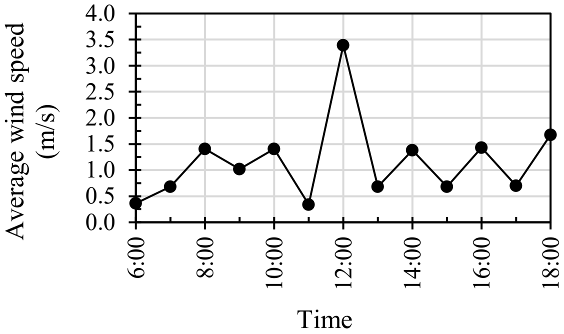


Fig. 6 Average wind speed (m/s) over time

Prevailing wind directions primarily align with the North (N) and South (S) directions, running parallel to the river's course, as illustrated in Fig. 7. This prevailing wind pattern underscores the influence of the wind path parallel to the river, facilitating increased ventilation within the open areas adjacent to the river and its banks. The distribution of wind speed follows a diurnal pattern, characterized by higher speeds during daylight hours followed by a gradual decline as afternoon transitions into evening.

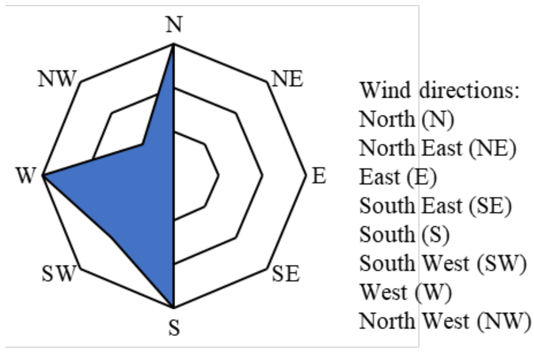


Fig. 7 Wind direction in the river landscape area

4.3 Air Temperature and Humidity

This section provides a comparison of air temperature and relative humidity above the river. The average air temperature measurements above the river surface indicate a reading of 27°C at 06:00, with a subsequent increase of approximately 1°C per hour. The highest average temperature is recorded at 13:00, peaking at 33.7°C. Subsequently, temperatures gradually decrease, reaching around 27.3°C by 18:00. In contrast, the average relative humidity above the river surface is at its highest at 06:00, registering at 90%. The average humidity then decreases until 13:00, reaching its lowest value of 58% at an average temperature of 33.7°C. Following this, the average humidity begins to rise again, reaching approximately 89% by 18:00, with an air temperature of 27.3°C (refer to Fig. 8).

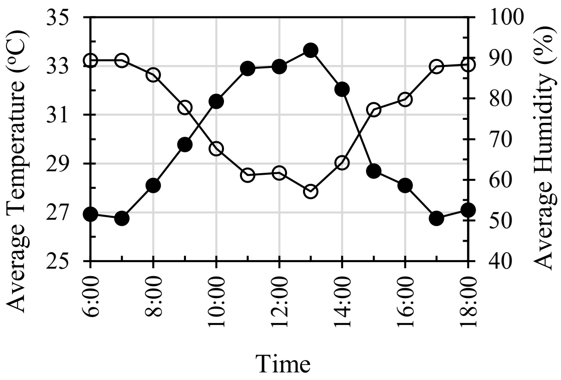


Fig. 8 Average temperature and humidity over the river

4.4 Validation of ENVI-Met Simulation

The hourly temperature, humidity, and solar radiation of the air inlet were selected as the initial simulation conditions. A comparison of air temperature and relative humidity between the measured values and the simulation results is presented in Tables 3 and 4, respectively. The relative error (RE) between the simulation values and measured values is calculated using Eq. (1).

$$RE = \left| \frac{Xmea - Xsim}{Xmea} \right| x\ 100\% \quad (1)$$

where Xmea represents the measured value and Xsim represents the simulation value.

The results indicate that the maximum relative error of air temperature and relative humidity is less than 5% as shown in Table 3. This suggests strong agreement between the simulation results of the ENVI-met software and the measured data, affirming the credibility of the ENVI-met model for use in the present study [2].

Table 4 presents a comparative analysis of relative humidity between observed and simulated values at 06:00 and 13:00 across various measuring points, including several along the river. In the morning (06:00), measured relative humidity ranges from 82% to 92%, with simulated values closely matching and relative errors mostly below 5%.

Table 3. Comparative analysis of air temperature between observed and simulated values

	06.00			13.00		
Measuring Point	Measured Value (°C)	Simulation Value (°C)	RE (%)	Measured Value (°C)	Simulation Value (°C)	RE (%)
1	25	25,49	1,96	32,2	33,35	3,57
2	24.7	25.49	3.20	33.2	32.77	1.30
river	25	25.08	0.32	33.7	32.19	4.48
3	25	25.49	1.96	33.4	32.19	3.62
4	25.3	25.49	0.75	33.8	32.19	4.76
5	25.5	25.08	1.65	34	32.77	3.62
6	25.2	25.08	0.48	33.2	31.62	4.76
river	25	24.68	1.28	33.2	31.62	4.76
7	25.2	25.08	0.48	31	32.19	3.84
8	24.7	25.08	1.54	31.6	32.19	1.87
9	25	25.49	1.96	33.8	33.35	1.33
10	24.8	25.08	1.13	33.8	32.79	2.99
river	25	25.08	0.32	33.7	32.19	4.48
11	25.1	25.08	0.08	31	32.19	3.84
12	25.2	25.49	1.15	31.4	32.19	2.52
13	25.6	25.08	2.03	31.6	31.62	0.06
14	25	25.49	1.96	31.4	31.62	0.70
river	25	24.27	2.92	33.2	31.62	4.76
15	24.7	25.49	3.20	33.1	32.77	1.00
16	25.5	25.08	1.65	33.8	32.19	4.76
17	25.5	24.27	4.82	35.7	33.93	4.96
18	25.2	24.68	2.06	34.4	32.77	4.74
river	25	23.87	4.52	33.7	32.19	4.48
19	24.9	24.68	0.88	31.2	32.19	3.17
20	25.4	24.27	4.45	32.2	32.77	1.77

Table 4. Comparative analysis of relative humidity between observed and simulated values

	06.00			13.00		
Measuring Point	Measured Value (%)	Simulation Value (%)	RE (%)	Measured Value (%)	Simulation Value (%)	RE (%)
1	87	86.08	1.06	33	33.35	1.06
2	90.5	86.08	4.88	34.4	32.77	4.74
river	90	87.63	2.63	30.8	32.19	4.51
3	90	86.08	4.36	33.8	32.19	4.76
4	86	86.08	0.09	30.7	32.19	4.85
5	82	86.06	4.95	35.8	37.4	4.47
6	88	86.08	2.18	34.3	32.7	4.66
river	90	87.63	2.63	34	33.7	0.88
7	88	89.19	1.35	31.9	30.4	4.70
8	91	90.74	0.29	31.1	29.6	4.82
9	89	86.08	3.28	33	33.35	1.06
10	89	86.08	3.28	34	32.79	3.56
river	90	86.08	4.36	33.7	32.19	4.48
11	87	86.08	1.06	32	32.19	0.59
12	89	86.08	3.28	32	32.19	0.59
13	88	92.29	4.88	33	31.62	4.18
14	91	93.84	3.12	32	31.62	1.19
river	90	92.29	2.54	33	31.62	4.18
15	90	90.74	0.82	33.1	32.19	2.75
16	90	93.84	4.27	34	32.77	3.62
17	92	95.39	3.68	33	33.93	2.82
18	91.6	95.84	4.63	34.3	32.77	4.46
river	90	92.29	2.54	33	32.19	2.45
19	90	92.29	2.54	32	32.19	0.59
20	89.7	93.84	4.62	31.5	32.77	4.03

In the afternoon (13:00), measured values range from 30.7% to 35.8%, again with simulated values showing close approximation and relative errors primarily under 5%. The river points exhibit low relative errors, indicating the model's reliability. Compared to the temperature results in Table 3, both tables demonstrate the simulation model's accuracy in predicting microclimatic conditions in Banjarmasin, validating its use for urban planning and climate regulation.

4.5 Simulation Results of Air Temperature

The distribution of air temperature in the research area is illustrated in Fig. 9. It can be observed that at a distance of 100 meters from the riverbank, the average air temperature on the left bank ranges from 27.52 to 28.09°C, while on the right bank, it ranges from 26.94 to 29.23°C. Similarly, at a distance of 50 meters from the riverbank, the average air temperature ranges from 27.23 to 27.83°C on the left bank and from 27.23 to 27.8°C on the right bank.

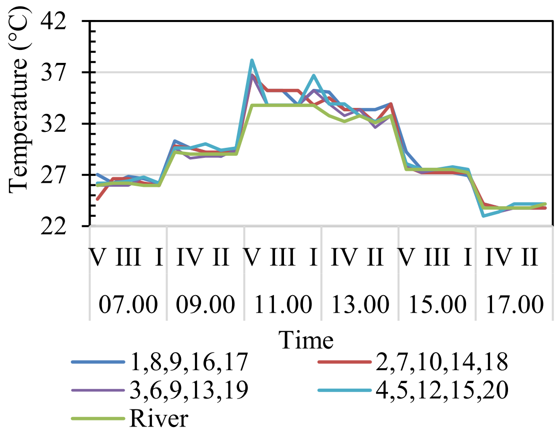


Fig. 9 The variation of air temperature with time

At a distance of 50 meters from the riverbank, the average air temperature is 27.47°C on the left bank and 27.34°C on the right bank. Additionally, the air temperature above the road is 0.22°C higher than the air temperature around the left bank and 0.07°C higher than the air temperature around the right bank. Moreover, the air temperature above the road is 0.23°C higher than the air temperature around the left bank, attributed to the absence of trees on both sides of the asphalt road. The presence of trees along the road provides shading effects, preventing direct sunlight from illuminating the road surface and thereby limiting the increase in air temperature above the road, as depicted in Fig. 10. These findings underscore the importance of green plants in efficiently reducing air temperatures in nearby areas, aligning with previous research indicating that green urban infrastructure can mitigate high temperatures within urban settings [24-27].

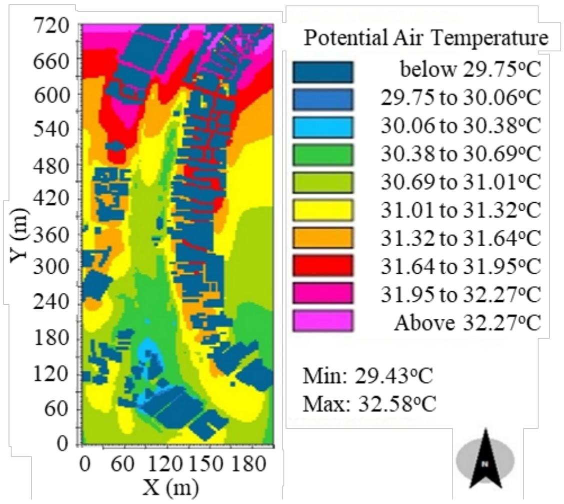


Fig. 10 Air temperature distribution of the study area at 15.00

According to Wang et al. [27], the distribution of cold temperatures above the river and its impact on the surrounding urban river landscape are influenced by various factors related to river ecology and interactions with the urban environment. Urban rivers serve as vital surface water sources that can significantly affect the temperature of their surrounding environment [28].

4.6 The Simulation Results of Relative Air Humidity

Relative humidity significantly influences the microclimate of specific areas, with previous research highlighting a strong correlation between changes in relative humidity and thermal comfort [29,30]. In this study, the variation of relative air humidity was also investigated, as shown in Fig. 11.

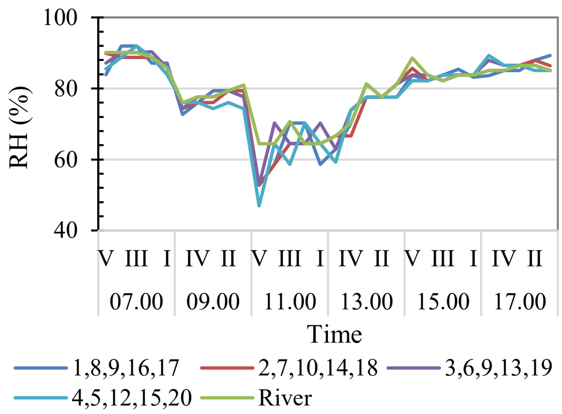


Fig. 11 The variation of relative air humidity over time

The curves representing relative air humidity exhibit similar trends over time. Notably, the average relative air humidity of the inlet channel displays the highest fluctuations, primarily influenced by hourly input relative air humidity parameters, while the variations of the other three curves are minimal. The highest relative air humidity at the inlet is recorded at 91.94% at 07:00, with the lowest relative humidity observed at 46.95% at 11:00.

The distribution of relative air humidity at 3:00 PM is depicted in Fig. 12. At a distance of 50 meters from the riverbank, the relative air humidity on the left bank is 83.76%, and on the right bank, it is 82.15%. Conversely, at a distance of 100 meters from the riverbank, the relative air humidity on the left bank is 83.25%, while on the right bank, it is 83.76%. Notably, at a distance of 50 meters from the riverbank, the relative air humidity on both the left and right banks is 83.76%, indicating lower humidity levels farther from the riverbank.

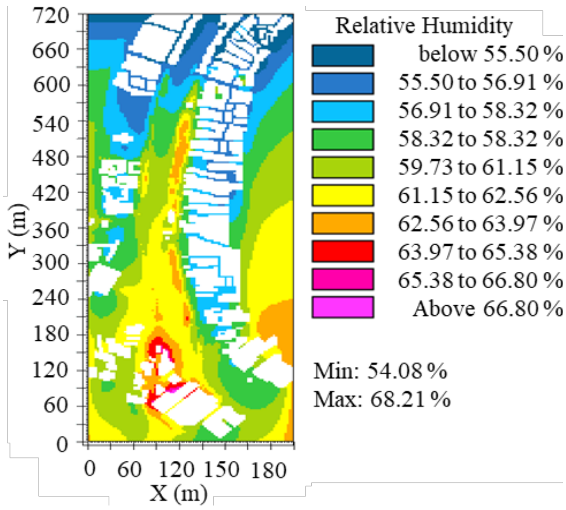


Fig. 12 Relative air humidity distribution of the study area at 15.00

Additionally, the relative air humidity is higher on the left bank compared to the right bank. This disparity is primarily due to air on the left bank absorbing water vapor from the river surface as it crosses the river. The continuous movement of water against the wind direction leads to an increase in relative air humidity. The data in Fig. 11 reveal that relative air humidity increases by 1.61% after passing through trees along the river, decreases by 0.61% after crossing the road, and increases by 2.89% after crossing the river. Thus, the sequence of different ground surface influences on relative air humidity is as follows: river > trees > road.

4.7 The Simulation Results of Wind Speed in the Study Area

The distribution of wind speed, as depicted in Fig. 13, exhibits variations ranging from 0.08 m/s to 0.66 m/s, indicating spatial differences in airflow patterns. Higher wind speeds above the river compared to points farther away suggest the influence of the water body on wind dynamics.

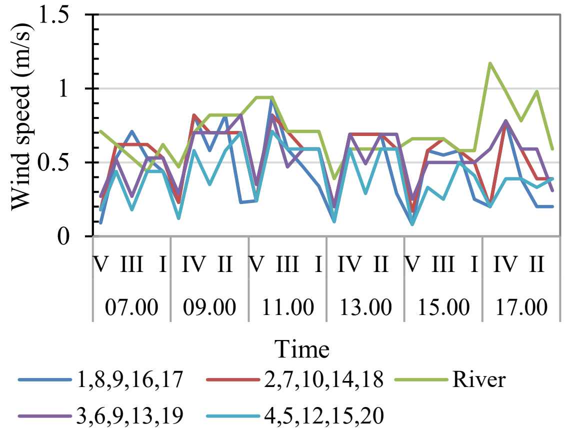


Fig. 13 Relative wind speed distribution of the study area at 15.00

Conversely, lower wind speeds observed at certain points near the river may be attributed to the sheltering effect of buildings or vegetation, impacting local airflow. The relationship between temperature, humidity, wind speed, and landscape composition in Segment I provides valuable insights into the environmental dynamics of the studied area. The observed temperature difference near the river compared to locations farther away, coupled with corresponding humidity variations, suggests a negative correlation between temperature and humidity. This negative correlation implies that high temperatures are associated with low humidity levels, while lower temperatures correspond to higher humidity levels. The landscape composition, comprising a mix of built-up and natural land cover components, significantly influences the microclimate dynamics, as illustrated in Fig. 14.

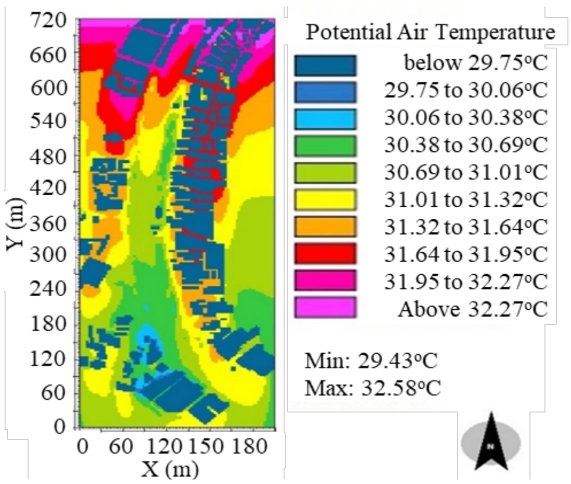


Fig. 14 Wind speed distribution of the study area at 15.00

The discussion presents valuable insights into the intricate relationship among solar radiation, wind speed, air temperature, and relative humidity along an urban river. The comprehensive observations conducted throughout the day provide a nuanced understanding of the dynamic interplay of these climatic factors and their impact on the microclimate near the river. Solar radiation measurements revealed a diurnal variation, with a peak value of 661.7 W/m² at 11:00, gradually declining from 8.7 W/m² at 06:00 to 3.7 W/m² at 18:00, reflecting sunlight's influence on the surrounding environment.

Comparing air temperature and relative humidity above the river surface revealed distinct trends. Air temperature rose from 27°C at 06:00 to a peak of 33.7°C at 13:00 before declining to 27.3°C by 18:00. Meanwhile, relative humidity peaked at 90% at 06:00, decreasing to 58% at 13:00, before rising again to around 89% by 18:00.

Segmented analysis elucidated spatial variations in temperature and humidity along the river. Segments I to V consistently showed lower temperatures and higher humidity levels near the river, underscoring the moderating effect of the river on microclimate conditions.

Overall, the findings highlight the significant role of natural features like rivers in shaping urban microclimates. Understanding the complex interactions among solar radiation, wind dynamics, temperature, and humidity is essential for effective urban planning and environmental management strategies. Further research focusing on the specific mechanisms through which rivers influence microclimate dynamics can provide valuable insights for sustainable urban development and climate resilience initiatives

The analysis of wind speed indicated fluctuations throughout the day, with predominant wind directions parallel to the river, influencing ventilation along the riverbanks and open spaces. Comparisons of air temperature and relative humidity above the river surface showed distinct trends. Air temperature gradually increased from 27°C at 06:00 to a peak of 33.7°C at 13:00 before decreasing, while relative humidity peaked at 90% at 06:00, decreased to 58% at 13:00, and then rose again to around 89% by 18:00.

Segmented analysis highlighted spatial variations in temperature and humidity along the river, emphasizing the moderating effect of the river on microclimate conditions. The data underscore the significant role of natural features like rivers in shaping urban microclimates and highlight the importance of understanding the interactions between solar radiation, wind dynamics, temperature, and humidity for urban planning and environmental management strategies. Further research focusing on how rivers influence microclimate dynamics can provide valuable insights for sustainable urban development and climate resilience initiatives. These findings are consistent with studies by Pelletier et al. [30], Bolick et al. [31], and Maclean et al. [32], which explore environmental science, vegetation, and microclimate dynamics. Additionally, the research contributes to understanding how natural features like rivers impact microclimates, aligning with studies by Hébert et al. [33] and Daniels and Danner [34] that investigate stream temperature dynamics and river temperature variations.

The findings also resonate with studies such as those by Sanusi et al. [35] and Lin et al. [36] and, which investigate the microclimatic effects of urban features and wind dynamics. The research underscores the importance of considering solar radiation, wind patterns, and temperature variations in urban planning, aligning with studies by Xie and Li [22], which explore the influences of microclimates on building energy demand and urban heat island effects.

A pertinent reference that aligns with the findings of Manteghi et al. [37] emphasizes the horizontal impact of water bodies on microclimates, which is influenced by factors such as building density, rivers, and street width. Furthermore, the study by Chen et al. [38] investigates the cooling effect of rivers on metropolitan Taipei using remote sensing. It identifies factors such as levees, stream temperature, solar incidence, wind speed, and relative humidity that influence temperature variation, providing valuable insights into how water bodies influence local microclimates in urban settings [38].

The presence of urban rivers, particularly rivers, plays a crucial role in shaping urban microclimates by mitigating temperature and humidity levels through the absorption and reflection of solar radiation. This research contributes to the broader understanding of microclimate dynamics influenced by natural and urban features, emphasizing the need for comprehensive studies to inform sustainable development and climate resilience strategies.

4.8 The Simulation Results of Thermal Comfort in the Study Area

Thermal comfort is subjectively assessed by individuals and influenced by both regional meteorological conditions and physiological factors. Outdoor thermal comfort is typically evaluated using the Predicted Mean Vote (PMV) index, which takes into account factors such as air temperature, humidity levels, radiant temperature, air movement, metabolic rate during physical activity, and the insulating properties of clothing. In a simulated scenario, the thermal comfort of a 35-year-old male, standing at 175 cm tall and weighing 75 kg, was considered. The clothing's thermal resistance was set at 0.9 CLO while engaging in light walking exercise.

The illustration in Fig. 15 displays the spatial distribution of outdoor Predicted Mean Vote (PMV) within the research area. Notably, the PMV reading along the right side of the road is lower compared to the PMV reading on the left side. This difference can be attributed to the effective thermal regulation facilitated by rivers through evaporative cooling mechanisms. Consequently, individuals experience enhanced comfort levels due to the cooling effect generated by the river on the right bank. It is important to note the presence of magenta lines delineating one side of the road, marking the right edges.

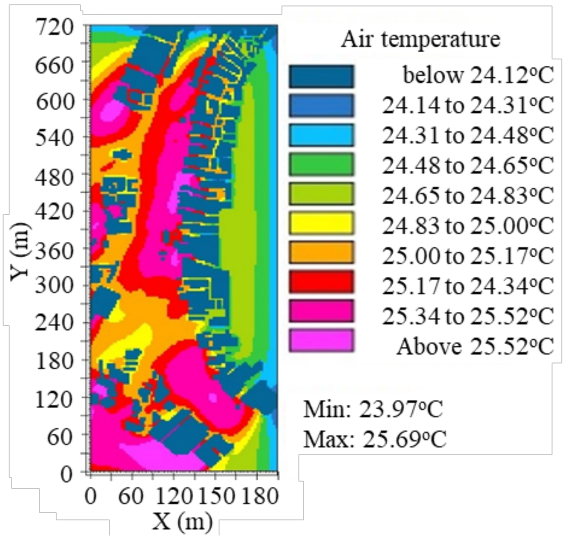


Fig. 15 The outdoor PMV of the study area at 15.00

In accordance with Zhou et al. [1], which explores the impact of spatial configuration on land surface temperature in urban areas, this study offers insights into how land cover patterns influence land surface temperature in urban environments. Additionally, Hui et al. [39] discuss the effect of spatial patterns of green space on land surface temperature, providing further understanding of how green space patterns influence land surface temperatures. The high humidity levels above the river and along the riverbank can be attributed to several factors. The presence of water bodies, such as rivers, can lead to increased evaporation, contributing to higher humidity levels in the surrounding areas. Additionally, the presence of trees along the riverbank can enhance humidity through transpiration, where trees release water vapor into the air through their leaves. This process further elevates humidity levels in the vicinity of the river and contributes to the overall moisture content in the air. The combination of water bodies and vegetation along the riverbank creates a microclimate conducive to higher humidity levels compared to areas further away from the river [40,41].

When exposed to solar radiation, asphalt and concrete surfaces heat up more rapidly than their surroundings due to their lower specific heat capacity compared to trees. Consequently, the rise in Predicted Mean Vote (PMV) levels primarily stems from the presence of asphalt and concrete surfaces. Conversely, areas with lower PMV values are commonly observed in urban forest settings. A real-life depiction of an urban forest area, as shown in Fig. 15, is characterized by abundant trees and greenery, which provide shade and enhance thermal comfort [42].. Optimal thermal comfort is achieved in shaded locations during the summer, emphasizing the importance of strategically planting trees and greenery along riverbanks and near buildings to effectively mitigate UHIs and regulate the local microclimate. In summary, rivers, trees, and green plants play a pivotal role in ameliorating UHIs and shaping the local microclimate.

4.9 Discussions

4.9.1 Localized Impact

The study investigated the impact of dynamic parameters such as wind speed, solar radiation, and humidity on the microclimate along different segments of the Martapura River in Banjarmasin. Wind speed significantly influenced the cooling effect of the river, with higher speeds facilitating better air circulation and temperature reduction in the surrounding areas. Solar radiation varied throughout the day, with peak cooling effects observed during early morning and late afternoon when solar intensity was lower. Humidity levels were higher near the river, contributing to evaporative cooling and enhancing thermal comfort in nearby urban areas. This localized impact analysis helps in understanding how each parameter uniquely affects different segments, providing insights into optimizing urban planning for better microclimate regulation.

4.9.2 Comparative Analysis

The cooling effect observed in Banjarmasin is similar to that in São José do Rio Preto, Brazil, as studied by Masiero and De Souza [43], but it is more pronounced due to the larger size of the Martapura River. This advantage allows our study to benefit from analyzing a larger river, providing more significant insights into the potential cooling effects and their broader implications for urban planning. In contrast, Moyer and Hawkins [44] found that the cooling effect of rivers is less significant in smaller urban areas compared to larger ones, aligning with our findings on urban density and infrastructure. By focusing on a larger urban area like Banjarmasin, our study demonstrates more substantial impacts of river dynamics, offering valuable data for cities with similar urban densities.

Similarly, Park et al. [45] noted that narrow streets and lower buildings improve the cooling effect in Seoul, Korea, supporting the influence of urban form on river dynamics. Our study expands on this by including a wider variety of urban forms and their interactions with river dynamics, providing a more comprehensive understanding of urban design impacts. Additionally, Qi et al. [2] and Wang et al. [46] emphasized that wind speed and direction, and the interaction between water bodies and urban structures, are crucial in mitigating heat stress, which corroborates our study's results. Our research further integrates advanced ENVI-met simulations to model these interactions more precisely, offering detailed predictions and practical applications for urban planning.

4.9.3 Practical Applications

The findings of this study have several practical implications for urban planning and policy-making in Banjarmasin. Integrating river dynamics into urban design can significantly mitigate urban heat island effects and improve thermal comfort for residents. Strategies such as maintaining and enhancing green spaces along riverbanks, optimizing building heights and orientations to facilitate airflow, and designing narrow streets to maximize the cooling effect can be effective. Additionally, urban planners should consider the strategic placement of water bodies and vegetation to enhance evaporative cooling and reduce surface temperatures. These measures will contribute to sustainable urban development and climate resilience, ensuring a healthier and more comfortable living environment for the residents of Banjarmasin.

5. CONCLUSION

This research examines the impact of the Martapura River on the microclimate within Banjarmasin City, Indonesia, utilizing field measurements and ENVI-met software to analyze fluctuations in air temperature, relative humidity, and outdoor Predicted Mean Vote (PMV). Various surface types were identified, each exerting distinct influences on air temperature and relative humidity levels. It is crucial to note that the findings of this study are specific to Banjarmasin. The key conclusions drawn from this investigation are as follows:

1. The Martapura River exhibits a notable cooling effect on air temperature and significantly impacts relative humidity in areas adjacent to its banks. Temperatures are lower in downwind regions, and humidity levels are higher compared to upwind areas. Conversely, roads contribute to warming air temperatures and have a minor effect on relative humidity. The influence hierarchy of different surface types on air temperature and relative humidity is ranked as follows: river > trees > roads.
2. PMV analysis reveals that thermal comfort is superior on the right bank of the river compared to the left bank. This finding highlights the significant impact of natural elements on urban environments. Rivers, trees, and vegetation play a crucial role in mitigating UHIs and regulating local microclimates.
3. These findings are crucial for urban planning and policy-making in Banjarmasin. By integrating river dynamics into urban design, maintaining and enhancing green spaces along riverbanks, optimizing building heights and orientations to facilitate airflow, and designing narrow streets to maximize the cooling effect, urban planners can significantly mitigate urban heat island effects and improve thermal comfort for residents. These measures will contribute to sustainable urban development and climate resilience, ensuring a healthier and more comfortable living environment for the residents of Banjarmasin.

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