

Evaluation of Thermal Comfort in Urban Parks in Guangzhou City

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Abstract: Thermal comfort evaluations for Yuexiu Park, Lushan Park, and Baiyun Lake Park in Guangzhou were conducted using field meteorological data collection, visitor questionnaires, and literature reviews. It analyzed the impact of green coverage, water body layout, and facility configuration on thermal comfort. The results showed that good green and water body design effectively lowered the temperature in the park and improved the thermal comfort of visitors, but the insufficient facility configuration in some open areas affected the experience. The visitor's experience is closely related to the natural environment and facility layout of the park. Therefore, in the future, park design should pay more attention to the rational configuration of shading, ventilation, and cooling facilities to improve thermal comfort, and encourage citizens to participate in the construction and management of parks to improve ecological quality and user experience. This study provides a reference for the improvement of thermal comfort in urban parks in Guangzhou and aims to promote the sustainable and human-oriented development of urban park design.

Keywords: Guangzhou City; Urban parks; Thermal comfort; Microclimate; Green coverage; Water layout; Sustainable design

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1. Introduction

1.1. Background and purpose of the study

Global climate change has led to an increase in extreme weather events and the urban heat island effect, which causes the temperature in urban centers to be higher than in suburban areas, affecting the comfort and health of residents. Urban green spaces, especially parks, have become an important means of alleviating the urban heat island effect. Parks not only provide leisure spaces but also improve the urban microclimate by increasing vegetation and promoting air circulation, thereby enhancing thermal comfort. However, as urban populations grow and expand, optimizing the layout and design of parks to maximize their role in alleviating the urban heat island effect has become an important topic in urban planning.

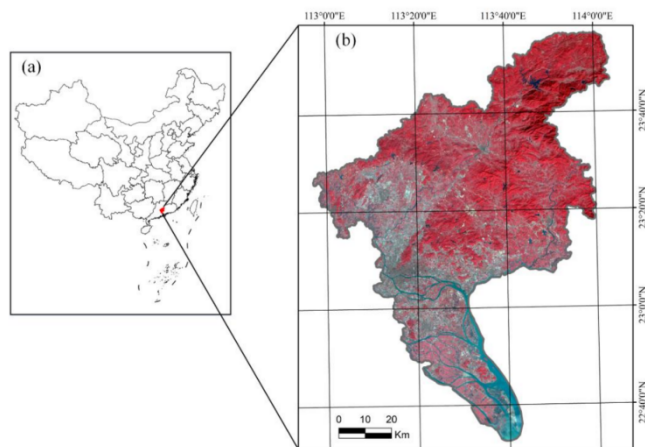


Figure 1. Remote sensing satellite positioning of Guangzhou

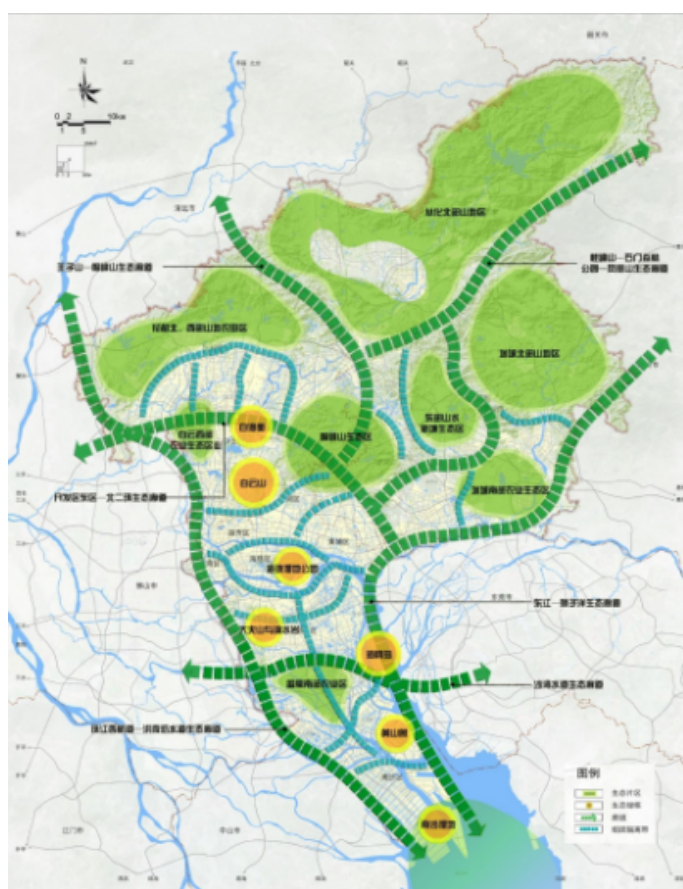


Figure 2. Urban ecological corridor morphology in Guangzhou

Guangzhou, as a subtropical city, experiences high temperatures and humidity in summer, challenging the thermal comfort of its residents. Urban parks are important facilities for mitigating the urban heat island effect, and their thermal comfort research is of great significance for improving the quality of life for citizens and providing reference for similar climate cities^[1]. This paper takes urban parks in Guangzhou as the research object and evaluates their current thermal comfort status and influencing factors through field investigation and data analysis. It draws on domestic and foreign experiences to propose improvement suggestions, providing theoretical support and practical guidance for future park design and construction.

2. Objective and scope of the study

2.1. Subject of the study

This study focuses on the evaluation of thermal comfort in urban parks in Guangzhou City. Several representative parks in Guangzhou were selected as case studies, including Yuexiu Park, Luhu Park, and Baiyun Lake Park. These parks differ in terms of area, geographic location, function, and green coverage, and thus can better reflect the performance of different types of urban parks in Guangzhou in terms of thermal comfort [2].

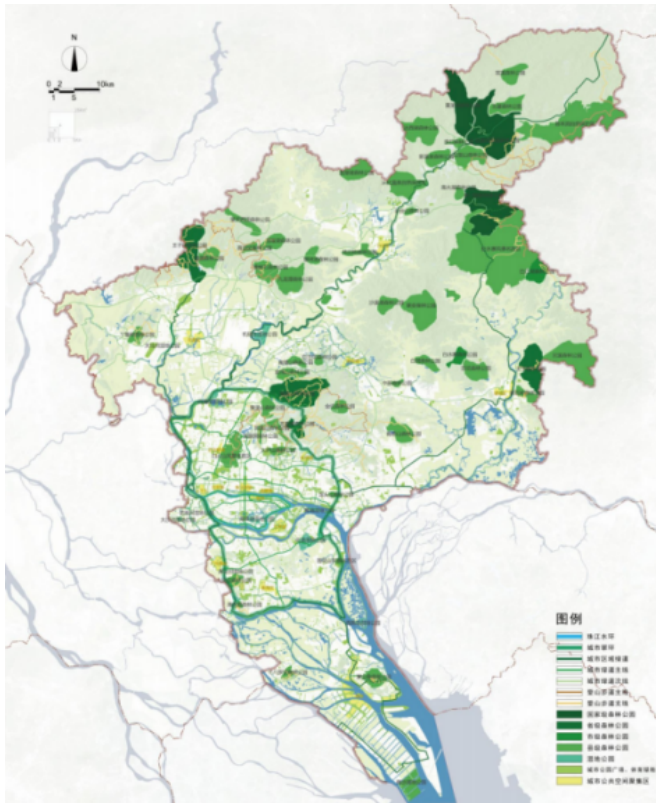


Figure 3. Distribution of urban parks in Guangzhou

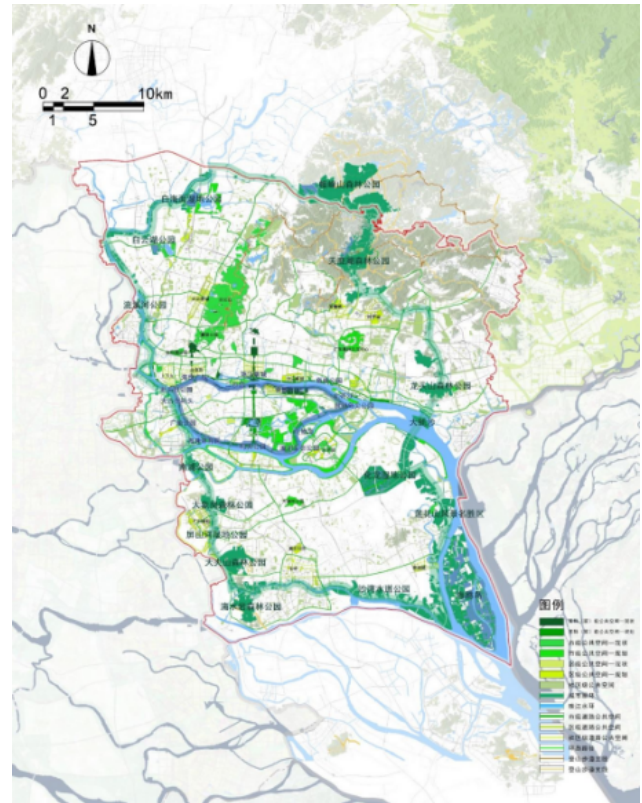


Figure 4. Distribution of parks in core urban areas of Guangzhou

Yuexiu Park, Luhu Park, and Baiyun Lake Park are three urban parks with their own characteristics in Guangzhou City, which provide diversified cases for the study of the thermal comfort of urban parks.

Yuexiu Park, located in the city center, with a total area of 88 hectares, is one of the oldest and largest parks in Guangzhou. Its rich vegetation, especially the arrangement of trees and shrubs, provides sufficient shade for the park, effectively reducing local temperatures and improving air humidity. However, the high density of surrounding buildings and traffic has a complex effect on the park's microclimate.

Luhu Park is located north of the city center and is known for its vast body of water and mountainous landscape. The green coverage rate of the park is high, with a large number of trees, shrubs, and flowers. The ecosystem composed of water area and green space plays a significant role in regulating microclimate. In addition, pavilions, walkways, and leisure facilities in the park provide good shade and cooling effects for visitors. Its high terrain and mountain location provide an advantage in airflow, creating a comfortable recreational environment for visitors.

Baiyun Lake Park is a relatively new urban park in Guangzhou, located outside Baiyun District, with a water area of more than 100 hectares. The park is mainly composed of artificial lakes and surrounding green belts, which have a significant influence on the microclimate of the surrounding area. It is located in the suburbs

and close to the natural environment, the air quality is superior, and the temperature is slightly lower than in the urban area. The park is rich in vegetation species, distributed with many tree-lined paths and sunshade facilities, providing a good summer place for visitors.

Through the investigation and analysis of these three parks, this paper aims to explore their microclimate regulation effect and thermal comfort performance and provide a basis for the design and planning of urban parks in the future.

2.2. Research methodology

This study adopts a variety of methods to systematically assess the thermal comfort of urban parks in Guangzhou City, including the field survey method, comparative case analysis method, and literature review method. Through diversified research tools, combining quantitative and qualitative analyses, it seeks to provide a comprehensive and in-depth discussion on the thermal comfort of parks.

2.2.1. Field survey methodology

Field survey is one of the main methods in this study, aiming at obtaining microclimate data and visitors' subjective perception of thermal comfort in urban parks in Guangzhou. We selected Yuexiu Park, Luhu Park, and Baiyun Lake Park for data collection in different seasons and periods ^[3]. The data collection includes the following.

- (1) Temperature, humidity, wind speed, and solar radiation: Professional meteorological equipment was used to collect meteorological data in different areas of the park, focusing on temperature, humidity, and wind speed under the shade of trees, in open spaces, and near water bodies. Each measurement point is collected at least three times to ensure data stability.
- (2) Functional zoning of parks: Focus on the differences in thermal comfort between different functional zones in each park, such as open plazas, shaded paths, lakeside areas, children's play areas, etc., and analyze the climatic characteristics of the different zones and their impact on thermal comfort.
- (3) Visitor physical comfort questionnaire: A questionnaire was used to record visitors' subjective perception of temperature, humidity, and overall comfort in the park. The questionnaire includes visitors' perceived body temperature in different areas, their satisfaction with the shading facilities, and whether or not they feel heat discomfort.

Data collection was scheduled during the hot summer period (July to August) and the mild winter period (January to February) to facilitate a comparison of the park's thermal comfort performance under different seasons. Moreover, data collection was conducted at three separate times of the day, early morning, midday, and evening, to capture the microclimate variations in the park under different sunlight conditions ^[4].

2.2.2. Comparative analysis of cases

A comparative analysis of three selected parks allows a better understanding of the differences in thermal comfort performance between different types of urban parks. The comparative case analysis method consists of the following steps.

- (1) Analysis of similarities and differences: Compare the similarities and differences between Yuexiu Park, Luhu Park, and Baiyun Lake Park in terms of their climate regulation functions. Focus on analyzing the effects of their greening design, water layout, functional zoning, and facility arrangement on thermal comfort.
- (2) Comparison of environmental factors: By analyzing the geographical location of the parks, the green coverage, the type of vegetation, and the size of the water bodies, we identified the different effects of

the parks in mitigating high temperatures, enhancing air mobility, and humidity regulation.

- (3) Microclimate data analysis: By comparing the meteorological data collected in the field, we analyze the cooling effect of each park during the high-temperature period, and explore the role of water bodies and greening design in regulating the microclimate inside and outside the park ^[5,6].

3. Research content and process

This part describes in detail the content of the field survey, the analysis of the results, and the comparative study of different types of urban parks in Guangzhou City, and puts forward targeted recommendations for improvement in the light of the microclimate regulation effect of the case parks and the subjective evaluation of thermal comfort by visitors.

3.1. Thermal comfort analysis of Yuexiu Park

3.1.1. Overview of the park

Yuexiu Park is a large and historic city park in Guangzhou, located in the city center area. With a total area of 88 hectares and a green space coverage of about 75%, the park has a rich vegetation structure of trees, shrubs, and lawns. The vegetation provides a natural barrier for microclimate regulation in the park, especially during the summer, when a large number of shaded areas in the park can significantly improve the thermal comfort experience in the park.

3.1.2. Field survey results

The survey data were concentrated in the hot summer period (July to August), and measurements were taken in the early morning, midday, and late afternoon of each day. The meteorological data collection equipment for temperature, humidity, and wind speed was used to measure the following.

- (1) Temperature: Temperatures in the shaded areas inside the park were about 3°C to 4°C cooler than in the open areas, while the cooling effect was particularly noticeable near the man-made lake, where localized temperatures were about 5°C cooler than in other open areas of the park.
- (2) Humidity: The air humidity was higher in the artificial lake area, especially along the lake shore, where it could be about 8 to 10 percentage points higher than in the open squares of the park. This contributes significantly to localized cooling.
- (3) Wind speed: The wind speed in the park was lower in the densely green area, with an average wind speed of only 0.8 m/s. In the open plaza area, the wind speed was about 1.5 m/s, which is higher than that in the densely vegetated area but has no significant cooling effect.

3.1.3. Evaluation of thermal comfort for tourists

According to visitors' feedback, more than 60% preferred to stay in shaded areas or near bodies of water in summer, mainly because of the relatively lower temperatures in these areas and their physical comfort. Additionally, visitors generally reflected that the design of pavilions, shaded walkways, and lakeside benches in the parks provided better shelter from the summer heat during hot periods, but some visitors still considered that there were insufficient shading facilities in the open areas of the parks, which resulted in a tendency to feel hot and uncomfortable when moving around in these areas.

3.1.4. Analysis and summary

The thermal comfort of Yuexiu Park is mainly due to its high green coverage and the moderating effect of the

water body. Especially in summer, the park's trees provide sufficient shade for visitors and the evaporation effect of the water body enhances the local cooling effect. However, the open plaza area of Yuexiu Park has higher temperatures and poorer thermal comfort due to the lack of shading measures. Therefore, increasing shading facilities in the open areas, such as more trees, parasols, and gazebos would further enhance the overall thermal comfort of the park.

3.2. Thermal comfort analysis of Luhu Park

3.2.1. Overview of the park

Located in the northern part of Guangzhou City, Luhu Park covers an area of approximately 50 hectares and contains a large number of natural lakes and artificial water bodies, with the lakes occupying approximately 30% of the entire park. Luhu Park is characterized by its unique landscape that combines natural landforms with man-made designs, with the combination of water bodies and vegetation providing a natural cooling effect.

3.2.2. Field survey results

Similar to the previous park, the survey data for Luhu Park was conducted during the hotter parts of the summer, focusing on documenting microclimate differences in different areas of the park, such as the following.

- (1) Temperature: The area around the lake was significantly cooler than the rest of the area, with measured temperatures around 4°C to 6°C lower than in the open spaces of the park. Especially on the walkways close to the water bodies, the visitors' body temperature was very cool.
- (2) Humidity: Humidity was significantly higher in the Lake District than in other areas, averaging 70% to 75%, well above the 60% or so measured in the open grass areas of the park. While the high humidity enhances the coolness to some extent, it may also trigger a feeling of stuffiness at lower wind speeds.
- (3) Wind speed: The wind speed was higher in the lake area, averaging 1.2 m/s, and lower in the open area, at 0.6 m/s. Higher wind speeds help to enhance airflow, leading to better ventilation and heat dissipation.

3.2.3. Evaluation of thermal comfort for tourists

Within Luhu Park, 70% of visitors found the lakeside area to be the most comfortable in terms of body temperature, thanks to the evaporative cooling of the lake and higher wind speeds. Visitors generally reported that they spent more time at the lake than in areas such as the open plaza. Some visitors suggested that their summer experience was hampered by the more complex trail design in Luhu Park and fewer pavilions and seats in some areas.

3.2.4. Analysis and summary

The thermal comfort of Luhu Park benefits from the combined effects of its water bodies and vegetation, with the lake area, in particular, providing significant cooling. However, the overall thermal comfort experience is compromised by the lack of adequate rest and shade facilities along some areas of the trail. It is recommended that shade and resting facilities in the lakeside areas be added to future park plans to meet the needs of visitors seeking refuge from the heat during hot weather.

3.3. Thermal comfort analysis of Baiyun Lake Park

3.3.1. Overview of the park

Baiyun Lake Park is a new large-scale urban park built in Guangzhou in recent years. Located on the outskirts of Baiyun District, it covers an area of more than 200 hectares, with water bodies occupying nearly half of the

park. Due to its distance from the urban core, Baiyun Lake Park has excellent air quality and a more extensive green belt design, making it an important place for people to go for hiking and leisure.

3.3.2. Field survey results

The survey of Baiyun Lake Park was also conducted during the high summer temperatures. Due to the large size of the park, the combination of water bodies and vegetation plays a significant role in regulating its internal microclimate.

(1) Temperature: The overall temperature in the park was about 2°C to 3°C lower than in the urban parks, especially in the areas where water bodies and green belts are combined, and locally the temperature was 4°C to 5°C lower than in the open spaces.

(2) Humidity: Due to the large size of the lake, the average humidity in the park reached more than 75%, with a significant evaporative effect on the water. Despite the high humidity, the winds in the lake area were fast, avoiding the stifling sensation triggered by high humidity.

(3) Wind speed: Wind speeds were higher in the water areas, averaging 1.5 m/s, much higher than in the densely green areas of the park (0.5 m/s). This contributes to enhanced physical comfort, especially during the hot summer months when high wind speeds are effective in ameliorating discomfort caused by high humidity.

3.3.3. Evaluation of thermal comfort for tourists

Feedback from visitors indicated that Baiyun Lake Park has a high overall thermal comfort level due to its extensive water bodies and green belts. Nearly 80% of visitors reported feeling noticeably cooler when lounging around the lake, especially during the high summer temperatures. Some visitors commented that the moderate wind speed of the park reduced the discomfort caused by high humidity, but due to the large size of the park, some areas lacked convenient resting facilities ^[7-9].

3.3.4. Analysis and summary

The thermal comfort advantage of Baiyun Lake Park lies in its large water bodies and extensive green belts, natural elements that play a significant cooling and moderating role during hot periods. However, there is still room for improvement in the overall configuration of the park's facilities, especially in some areas away from the water bodies, which lack the necessary shade and resting facilities, resulting in poor localized thermal comfort. It is recommended to increase the number of shade facilities and seats in the park to better serve the visitors.

4. Conclusion and outlook

4.1. The current situation of thermal comfort in Guangzhou City parks

With a high green coverage rate and water body design, Guangzhou urban parks are outstanding in improving thermal comfort. For example, Yuexiu Park, Luhu Park, and Baiyun Lake Park effectively improve the microclimate through plant shading and water evaporation, and the summer temperature was 3°C to 5°C degrees lower than the surrounding areas, alleviating the urban heat island effect. However, park design and facilities are still inadequate, such as the lack of open area shading facilities in Yuexiu and Luhu parks, resulting in low thermal comfort. Although the wind speed in Baiyun Lake Park is large, the layout of rest facilities in some areas is unreasonable. The questionnaire survey shows that more than 70% of tourists prefer cooling areas such as trees and water bodies, and have little interest in open squares and walking paths. Tourists reported that the unreasonable layout of facilities and insufficient rest areas affected the thermal comfort experience.

Therefore, the future park design should pay more attention to the thermal comfort of tourists' activity space, optimize the shading and ventilation design of open areas, rationally layout public facilities, and improve the comfort and convenience of rest areas to meet the needs of tourists in summer, and further improve the thermal comfort and use experience of urban parks^[10].

4.2. Future directions for thermal comfort in urban parks

In the face of global climate change and the intensification of the urban heat island effect, the future design and planning of urban parks in Guangzhou should pay more attention to the issue of thermal comfort. By optimizing greening design and rationally allocating water bodies and facilities, urban parks in Guangzhou can better cope with hot weather and provide citizens with more comfortable outdoor activity spaces. The following are several future directions and suggestions.

4.2.1. Combining the natural environment with technological means

The future design of urban parks should combine the natural environment and modern technology more often to enhance thermal comfort. For example, techniques such as plant walls and green roofs are used to enhance the shading effect inside the park. At the same time, intelligent climate control devices, such as automatic sprinkler systems and intelligent fans, are used to further improve the local microclimate of the park. By combining technological means with natural landscaping, urban parks can provide a more comfortable environment in hot weather.

4.2.2. Enhancement of diversified greening design

The climatic characteristics of Guangzhou require more diverse greening designs for parks. Future park planning should enhance the rational mix of trees, shrubs, and lawns to form a multi-layered greening layout to maximize shading and cooling effects. Concurrently, more plant species adapted to the local climate should be introduced to enhance the ecological resilience of the parks and improve their ability to cope with extreme weather.

5. Concluding remarks

By studying the thermal comfort of three typical urban parks in Guangzhou, it was found that the green coverage, water layout, and facility configuration of urban parks play significant roles in enhancing the thermal comfort inside the parks. However, there is still room for improvement in the current park open areas and facility configurations in response to hot weather. The future design of urban parks should fully integrate the natural landscape with modern technology to enhance the thermal comfort of parks through diversified greening designs and reasonable facility layouts to provide citizens with more pleasant outdoor leisure spaces. Simultaneously, through the participation of citizens in park construction and management, the experience of using urban parks can be further improved, and the development of urban parks in Guangzhou can be promoted in a more sustainable and humanized direction.

Disclosure statement

The authors declare no conflict of interest.

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