



Optimization of green space pattern for alleviating the urban heat island effect in Qiantang District

Gengling Wang, Hao Yang*

College of Media Engineering, Communication University of Zhejiang, Hangzhou 310018, China

*Corresponding author's e-mail:415360889@qq.com

Abstract. In the context of rapid urbanization and industrialization, the urban heat island effect has become one of the significant ecological issues affecting modern urban environments. Urban green spaces play a crucial role in mitigating the heat island effect. This study takes Qiantang District in Hangzhou City as a case study to explore the influence of green coverage rate, green space area, and green space layout on the urban heat island effect. It proposes strategies for optimizing the green space pattern, including increasing the green coverage rate, improving green infrastructure, enhancing the greenway system, and optimizing the green space layout. The aim is to provide reference for improving the heat island effect and planning the green space pattern in Qiantang District.

Keywords: urban heat island effect, green space pattern, green space layout, coverage rate.

1 Introduction

With the rapid development of urbanization and industrialization, the urban heat island effect has been intensifying and has become one of the significant ecological issues affecting modern urban environments [1-2]. Urban green spaces possess the ability to regulate urban climate and alleviate the urban heat island effect. They also play a persistent role in reducing the intensity of the urban heat island and are of vital importance in maintaining urban ecological balance [3-4].

As the urbanization development in Hangzhou City has entered a mature stage, the urban heat island effect has significantly intensified over the past 20 years, with the heat island intensity continuously rising. Qiantang District, as the economic and technological development zone of the capital city of Zhejiang Province, is surrounded by a dense road network and experiences frequent population movement. The economic and social development in this area has had a radiating effect, and the improvement of the urban thermal environment in this region will also positively impact the mitigation of heat environment in other cities in Zhejiang. Therefore, it has become urgent to address the issues in green space planning and construction in Qiantang District, optimize its green space pattern, and improve the urban heat island effect.

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2 Relevant concepts and research subject

2.1 Urban heat island effect

The urban heat island effect refers to the phenomenon where the temperature in urban areas is significantly higher compared to the surrounding rural areas [5]. It is the result of localized climate changes in urban areas caused by factors such as urban buildings, roads, population density, etc. The urban heat island effect is typically manifested by higher temperatures in the central areas of the city compared to the surrounding rural areas, especially during nighttime and in winter.

2.2 Urban green space pattern

Urban green space pattern refers to the spatial distribution and layout characteristics of various types of green spaces in the city [6]. It describes the quantity, size, morphology, location, and relationships between different green spaces within the urban area, reflecting the organizational structure of the urban green space system.

2.3 Research subject

The research subject of this article is Qiantang District in Hangzhou City. Qiantang District is located in the southern wing of the Yangtze River Delta, in the eastern part of Hangzhou City. It is bounded by the Qiantang River to the east and north, with the southern boundary defined by the Hongshiwu Line, Shierdai Henghe, and the northern channel adjacent to Keqiao District. It borders Xiaoshan District to the southwest and Donghu Road to the west. To the northwest, it shares boundaries with Linping District and Haining City, and it is contiguous with Shangcheng District to the west. The total area of Qiantang District is 531.7 square kilometers.

3 The impact of urban green space patterns on the urban heat island effect

The green coverage rate, green area, and green space layout of urban green spaces have a significant impact on the urban heat island effect. Figure 1 presents Qiantang District jianghai city planning map.



Fig. 1. Qiantang District jianghai city planning map.

3.1 The impact of green coverage rate on the urban heat island effect

Green coverage rate refers to the proportion of green spaces, including parks, gardens, forests, and other green areas, in urban areas. Increasing the green coverage rate can effectively reduce the temperature of the urban surface. Vegetation absorbs solar radiation and releases moisture through evapotranspiration, thereby lowering the surface temperature. Areas with high green coverage can create large areas of shade and vegetation in the city, providing shading effects and reducing the surface temperature exposed to sunlight. At the same time, vegetation regulates temperature by evaporative cooling, converting some of the heat into water vapor released into the air, which helps cool down the environment [7]. Areas with high green coverage contribute to improving the ventilation conditions of the city and promoting air circulation. Good ventilation helps carry away heat, reduce the temperature of surrounding areas, and alleviate the intensity of the urban heat island effect.

3.2 The impact of green space area on the urban heat island effect

Increasing green space area can provide more shading effects, reducing direct exposure to the sun on surfaces such as roads and buildings. Shading can reduce heat absorption on surfaces, lower surface temperatures, and mitigate heat transfer in the surrounding areas. Green surfaces have higher reflectivity compared to hard surfaces like concrete or asphalt, which allows them to reflect solar radiation and reduce heat absorption[8]. This helps lower surface temperatures in localized areas. Increasing green space area

can effectively alleviate the urban heat island effect, reduce heat storage and accumulation in cities, and provide a comfortable living environment.

3.3 The impact of urban green space layout on the urban heat island effect

Urban green space systems can adopt various layout forms, including circular, wedge-shaped, strip-shaped, point-shaped, and radial layouts. In terms of the cooling effect, the ranking is as follows: wedge-shaped > radial > strip-shaped > point-shaped > circular. The wedge-shaped green space layout has good connectivity and the most noticeable cooling effect. Radial and strip-shaped green space layouts can provide good ventilation and heat dissipation effects when parallel to the prevailing wind direction. Point-shaped green space layouts are scattered and small in size, with limited climate regulation effects. Circular green space layouts have poor connectivity and limited cooling effects on the surrounding environment.

In reality, cities often select different green space layout forms flexibly based on specific situations. They also combine multiple basic layout forms to create new combinations, such as radial-circular and grid layouts. The purpose of such combination layouts is to balance the ventilation and heat dissipation needs of the city while ensuring connectivity, in order to achieve the optimal effect of mitigating the urban heat island [9-10]. Therefore, adopting suitable green space layout forms based on the characteristics and environmental conditions of the city is crucial to minimize the urban heat island effect and improve the urban climate environment.

4 Principles of green space pattern optimization to improve the urban heat island effect in Qiantang District

4.1 Comprehensive principle

Comprehensive principle of green space pattern refers to considering and balancing multiple factors in urban planning to achieve integrated goals of urban development, environmental protection, and social benefits. The green space pattern should take into account factors such as population growth, spatial needs, and economic development, and allocate green space resources reasonably to meet the requirements of urban development. The green space pattern should meet the residents' needs for living, providing places for leisure, recreation, sports, and social interaction, enhancing the residents' quality of life and well-being. The green space pattern should focus on creating beautiful urban landscapes, shaping a pleasant urban environment through the arrangement of vegetation, landscape facilities, and artistic elements. The green space pattern should consider economic feasibility, making rational use of green space resources, and achieving the unity of economic and social benefits.

4.2 Balance principle

Balance principle of green space pattern refers to the rational allocation and distribution of green space resources in urban planning, avoiding obvious imbalances in green space resources. Green spaces should be distributed evenly across various regions of Qiantang District, avoiding excessive concentration or deviation in certain areas. Each region should have sufficient green coverage so that all areas of the city can benefit from the advantages of green spaces. The green space pattern should be distributed evenly in urban spaces, including in the central area, urban periphery, and suburbs of Qiantang District, to meet the needs of residents in different areas. The green space pattern should consider population density and distribution characteristics, and based on the population size and residential area, plan and allocate green space area reasonably, ensuring that different population-dense areas can enjoy sufficient green space resources. The green space pattern should determine the appropriate total green space area and green space area for each region according to the city's scale and population size, aligning green space resources with the urban scale to achieve a balanced distribution effect.

4.3 Continuity principle

Continuity principle of green space pattern refers to connecting green spaces together in urban planning to form a network of green corridors and ecological corridors, facilitating pedestrian movement and communication for residents. Green spaces should be connected through pathways, trails, roads, etc., creating green belts and green corridors, allowing people to smoothly travel from one green space to another, ensuring the continuity of green spaces. Linear spaces such as rivers, railways, and highways can be utilized as part of the green space layout, forming green corridors that connect different green spaces, enhancing their continuity and accessibility. Ecological corridors can also be established to link different ecosystems and natural landscapes, promoting biodiversity conservation and facilitating habitat and migration routes for wildlife. The connectivity of green space layout should also consider connecting green spaces with other public spaces such as schools, hospitals, commercial areas, etc., facilitating interaction and activities between different locations for residents. The continuity of green space layout can be achieved at different levels, including the ground level, underground level, and aerial level. For example, pathways and green belts can be set at the ground level, underground parks and green spaces can be created at the underground level, and sky gardens and elevated green belts can be designed at the aerial level.

4.4 Diversity principle

Diversity principle of green space pattern refers to considering different types of green spaces in urban planning to meet the needs and activities of various population groups. Various types of parks such as comprehensive parks, theme parks, and children's parks should be established to provide places for leisure, outdoor activities, and meet the recreational needs of residents. Flower beds and landscape gardens should be created in the city to add color and aesthetic appeal, providing places for residents to appreciate

flowers, take photos, and engage in related activities. Different types of sports facilities, such as basketball courts, football fields, and ice rinks, should be available to facilitate various sports and fitness activities for residents. Small gardens or courtyards should be incorporated within communities to provide spaces for residents to relax and promote community cohesion. Dining squares and open-air theaters should be set up to provide venues for dining, performances, and other activities, enhancing the cultural and entertainment atmosphere of the city. Encouraging residents to carry out greening on balconies and rooftops will increase the vertical green area of the city, improve air quality, and enhance the urban landscape.

5 Improving the green space pattern strategies to mitigate the urban heat island effect in Qiantang District

Figure 2 displays the green space system planning of Qiantang District. Improving the green space pattern strategies to mitigate the urban heat island effect in Qiantang District as follows.



Fig. 2. The green space system planning of Qiantang District.

5.1 Increase green coverage rate in Qiantang District

Optimizing the plant species composition in Qiantang District by introducing a diverse range of plant species, including various trees, shrubs, and herbaceous plants, as well as plants with different flower colors, leaf colors, and flowering periods. This can provide more food and habitats, attract more wildlife, and promote ecological balance. Different levels of plants, such as tall trees, medium-sized shrubs, and low-growing ground covers, should be incorporated in urban green spaces to create a three-dimensional greening structure. This can enhance the verticality of plant communities,

provide more habitat space, and increase oxygen production. Careful selection and pairing of plants should be considered to enhance their overall complementary effects and achieve synergistic benefits. For example, some plants can absorb air pollutants while others provide habitats and food sources. By coordinating different plants, the urban environment can be improved more effectively. Native plant species that are adaptable to the local urban environment conditions and soil characteristics should be chosen. These plants possess strong resistance and adaptability, allowing them to thrive in the climate, soil, and water conditions of the urban environment.

Expanding the three-dimensional green space in Qiantang District by utilizing the rooftop space of buildings for greening purposes, such as planting flowers, plants, trees, or even growing crops. This not only increases the green coverage area of the city but also improves air quality, regulates temperature, and provides leisure spaces and healthy food options for urban residents. Installing green plants on the exterior walls or vertical surfaces of buildings to create vertical green walls is another way to enhance greenery. Vertical greening not only beautifies the urban landscape but also purifies the air, absorbs noise, regulates urban temperatures, and provides habitats and food sources. Constructing multi-level and multifunctional green facilities, such as vertical flower beds and hanging gardens, can effectively utilize urban space and increase the green area.

5.2 Improve green infrastructure in Qiantang District

Increasing the number and size of parks, ensuring that parks cover every residential area. Renovating existing parks to enhance their greenery and landscape quality, as well as adding facilities and services. Constructing rain gardens, wetlands, and rainwater collection systems to reduce urban stormwater runoff and improve water resource utilization efficiency. Through rainwater management systems, promoting natural water circulation and improving urban water environmental quality. Encouraging residents to engage in planting activities in private areas such as courtyards and balconies, providing training and support. Developing urban agriculture and utilizing unused land for crop cultivation, vegetable gardening, and farming to increase the city's self-sufficiency. Promoting green building standards that require new constructions to meet energy-efficient, environmentally friendly, and ecologically sustainable requirements. Integrating greenery and architecture through building design and vegetation configuration.

5.3 Improve greenway system in Qiantang District

Develop a detailed greenway system plan for Qiantang District, ensuring a rational layout and connectivity. Consider factors such as pedestrian flow, traffic patterns, and landscape characteristics to determine the appropriate width, length, and shape of the greenways. Gradually expand the scope and scale of the greenway system, increasing its length and coverage area to allow more people to enjoy its benefits. Optimize the layout of urban green spaces, ensuring that the greenways connect to different green areas and public spaces, forming continuous green corridors for convenient

transportation and leisure activities. Incorporate diverse functions and facilities along the greenways, such as walking paths, cycling lanes, running tracks, rest areas, and children's playgrounds, to meet the needs of different user groups. Protect and restore the ecological environment along the greenways, including planting native plants, preserving wildlife habitats, and establishing ecological wetlands to enhance the ecological functions of the greenway system. Implement dedicated management measures to strengthen the daily maintenance and upkeep of the greenways, ensuring cleanliness, safety, and optimal conditions for their use.

5.4 Optimize green space layout in Qiantang District

Replan the existing green spaces in accordance with actual needs and suggestions from the citizens, adjusting their locations, sizes, and layouts to better align with urban development and residents' demands. For buildings that hinder the layout of green spaces, consideration can be given to demolition or relocation to free up space for green space arrangement. This can be achieved through urban renewal plans or reconstruction projects. As for nearby small green spaces, merging them into larger ones can be considered to increase the continuity and size of the green areas. Conversely, overly large green spaces can be divided into multiple smaller ones to better serve residents in different areas. Existing green spaces can be renovated and optimized by adding more greenery, landscape facilities, and activity areas to enhance their attractiveness and utility. Introducing more green elements such as trees, flower beds, and lawns in public spaces within the city, such as squares and streets, can provide citizens with more recreational and social venues. By planning and designing ecological corridors and green corridors, the green spaces in the city can be connected to form continuous green pathways that facilitate people's travel and the migration of wildlife.

6 Conclusion

Urban green spaces play a crucial role in mitigating the urban heat island effect. By optimizing the layout of urban green spaces, it is possible to effectively reduce temperatures, increase air humidity, mitigate the intensity of the heat island effect, and improve the thermal environment of the city. Considering the limited availability of land in Qiantang District, a series of measures can be implemented to increase the green coverage in the urban areas, enhance the green infrastructure, and optimize the layout of green spaces while improving the environment of the greenways. These measures are of significant importance for regulating the temperature of the entire Qiantang District, alleviating the urban heat island effect, improving the quality of the ecological environment, and enhancing the residents' comfort and quality of life.

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