



Study on the Mitigation Effect of Urban Landscape in Hangzhou City on the Urban Heat Island Phenomenon

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Abstract. With the continuous renewal and development of cities, the urban heat island effect caused by urbanization has gradually become an undeniable issue. The negative effects of the heat island effect hinder the prosperous prospects of urban development and bring inconvenience to people's lives. In order to effectively mitigate the urban heat island effect and achieve green and sustainable development, this article deeply analyzes the causes of the urban heat island effect in Hangzhou City from the perspective of urban landscape design, and proposes feasible strategies and design guidelines. At the same time, it explores and analyzes the role of urban landscape in mitigating the heat island effect, providing a scientific reference for addressing urban climate issues.

Keywords: urban heat island effect, urban landscape, environmental protection, strategy.

1 Introduction

The urban heat island effect refers to the phenomenon of relatively higher temperatures in the central areas of cities compared to the surrounding suburbs. The term "urban heat island" analogizes the city center as an island and the suburbs as the sea, indicating the phenomenon of higher temperatures in the city center compared to the suburbs [1-3]. The urban heat island effect is primarily caused by a high percentage of hard surfaces in cities, such as tall buildings and roads, which have a high heat absorption capacity and hinder the dissipation of heat from the city center. This phenomenon is particularly pronounced in rapidly urbanizing cities, such as Hangzhou in Zhejiang Province. The urban heat island effect can lead to air pollution, the generation of harmful gases and dust, negatively impacting the quality of life for urban residents, and it also has adverse effects on the health of plants and animals [4-5]. In the long run, the urban heat island effect presents a challenging task for urban development [6]. Given this specific situation, it is necessary to conduct in-depth research and analysis on how to mitigate the urban heat island effect from the perspective of urban landscape in Hangzhou City.

2 Causes of the urban heat island effect

The urban heat island effect causes Hangzhou to experience prolonged periods of relatively high average temperatures. Figure 1 presents the trend of average temperature in Hangzhou. The main reasons for the occurrence of the urban heat island effect in Hangzhou can be attributed to the following four factors.

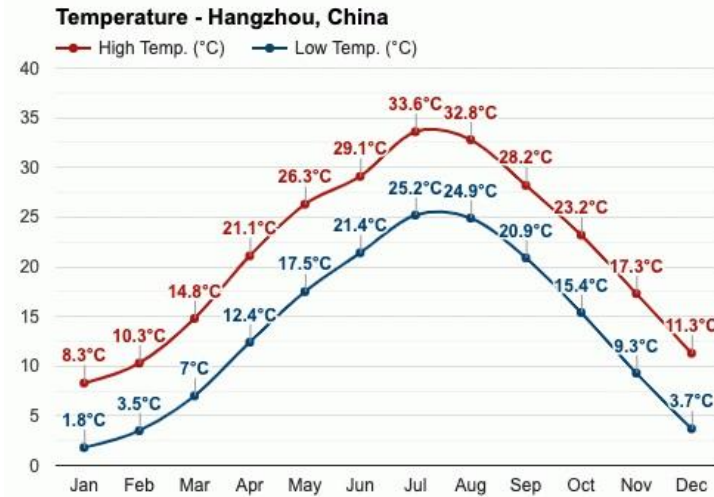


Fig. 1. The trend of average temperature in Hangzhou.

2.1 Air pollution

The impact of air pollution on the urban heat island effect is significant [7]. With the improvement of people's economic conditions, the number of private vehicles has increased dramatically, leading to the emission of a large amount of nitrogen oxides and particulate matter into the air. These pollutants can absorb solar radiation and convert it into heat energy, increasing the surface temperature in urban areas. Particulate matter and gaseous pollutants in the atmosphere can also alter the transmission and reflection characteristics of solar radiation, further affecting the surface energy balance and exacerbating the heat island effect.

2.2 Anthropogenic heat sources

Anthropogenic heat sources are significant driving factors of the urban heat island effect [8]. When engaged in various industrial, transportation, and building activities, humans release a large amount of waste heat and thermal radiation. This heat enters the atmosphere through various emission forms, leading to an increase in temperature in urban areas. Therefore, reducing the emissions from anthropogenic heat sources and implementing energy-saving measures are of great importance for mitigating the heat island effect.

2.3 Role of underlying surfaces

Underlying surfaces play a crucial role in the urban heat island effect [9]. Common building materials in urban environments, such as concrete and glass, have low reflectivity, allowing them to efficiently absorb solar radiation. These hard surfaces often have low thermal conductivity, which hinders the rapid dissipation of absorbed heat into the surrounding environment, leading to localized temperature increases. Especially at night, these buildings and paved structures slowly release the absorbed heat, resulting in sustained elevated temperatures in urban areas. As urbanization accelerates and a large population migrates from rural areas to cities to meet their basic needs including housing, education, and work, there is a constant need for expanding housing supply. Residential land in cities gradually replaces green areas, and many squares and roads replace existing green spaces and water bodies. This lack of natural underlying surfaces reduces the elements that can absorb heat while increasing those that release heat, creating a vicious cycle. This further exacerbates the urban heat island effect, negatively impacting people's lives. Artificial underlying surfaces in urban areas tend to warm up faster than natural ones after absorbing solar radiation. This is because the materials used in artificial structures have higher heat absorption capacity and lower thermal conductivity, contributing more to the urban heat island effect in urban environments.

2.4 Impact of wind

The urban heat island effect is influenced by the speed and direction of the wind [10]. When buildings in urban areas are densely packed, it can reduce wind speeds, causing a stagnation of hot air in that particular area of the city. This prevents the dispersion of heat and pollutants to other areas, hindering ventilation and mixing, thereby exacerbating the heat island effect. If winds originate from the surrounding heat island areas, they may bring heat and pollutants into the city, further intensifying the heat island effect.

3 Hazards of the urban heat island effect

3.1 Hazards to human

In recent years, urban climate issues have not only prolonged the duration of the heat island effect but also led to rising temperatures. High temperatures have a particularly severe impact on the elderly, as their ability to regulate body temperature is weaker, making them more susceptible to extreme temperatures. Heatstroke is a severe heat-related illness that can lead to heat exhaustion and organ failure. Additionally, the accumulation of air pollution in heat island areas has adverse effects on people's health. Under high temperature conditions, pollutants in the air are more likely to accumulate and interact with the heat, increasing the risk of various health problems.

3.2 Hazards to ecological environment

The urban heat island effect has negative impacts on the local ecological environment. With the increase in urban temperatures, the habitats of animals and plants are compressed, leading to fluctuations in phenological events and threats to biodiversity. Additionally, buildings, roads, and external surfaces in the city absorb and release a significant amount of heat, causing an elevation in water temperature after rainfall. This thermal pollution seriously affects aquatic organisms, such as fish and shrimp, endangering their survival and reproduction. Therefore, reducing the urban heat island effect is crucial for maintaining ecological balance.

4 Measures taken by Hangzhou city to alleviate the urban heat island effect

Hangzhou, as a modern city, has experienced rapid economic growth but also faces challenges posed by the urban heat island effect. In order to mitigate the negative impacts of the urban heat island effect, Hangzhou has vigorously promoted low-carbon development and environmental protection, while also establishing regulations to define the scope of urban ecological conservation. Hangzhou has accumulated advanced experiences in addressing the issue of mitigating the urban heat island effect. By studying the measures taken by Hangzhou, we can gain valuable insights to tackle this problem.

4.1 The utilization of remote sensing and geographic information system (GIS) technology

The use of remote sensing technology to monitor and analyze the urban heat island effect. By obtaining satellite images or aerial photographs, surface temperature data of different areas within the city can be analyzed. These data can be used to identify hotspots and assess the intensity and spatiotemporal variations of the heat island effect. Remote sensing technology also enables wide-scale heat island monitoring, helping decision-makers understand the extent of the heat island effect. When combined with geographic information system (GIS) technology, remote sensing data allows for spatial analysis and modeling of the heat island effect. By overlaying different spatial data layers, including topography, land use, building density, etc., quantitative analysis of the mechanisms behind the formation and propagation of urban heat island can be conducted. By establishing heat island models, it becomes possible to simulate the heat island effect under different urban scenarios and assess the influences of various factors on its intensity. This aids in predicting future heat island trends and guiding urban planning and management.

4.2 Increase green space and vegetation coverage

Hangzhou actively promotes the construction of public green spaces and increases the city's green coverage. For example, in urban planning and land use, there is a requirement to allocate sufficient green spaces and establish green indicators to ensure that new projects include a certain proportion of green spaces. The transformation of building rooftops into green areas is encouraged, increasing the green space through vegetation planting. Roof greening not only beautifies the city landscape but also helps reduce energy consumption of buildings, improve air quality, and enhance water environment. Small-scale green space construction is carried out in residential communities, such as community gardens and neighborhood parks. Vertical greening and three-dimensional greening are advocated on building facades, interior spaces, and city roads, effectively utilizing spaces and increasing green coverage. Strengthening the protection of existing green spaces and vegetation to prevent illegal destruction and deforestation. Additionally, the management and maintenance of plants are enhanced to ensure their healthy growth and development.

4.3 Improve building and road design

Hangzhou city prioritizes people's needs and experiences in building and road design, striving for human-centric design. For example, in road design, they incorporate traffic facilities such as sidewalks and bicycle lanes to provide safer and more convenient modes of transportation. In building design, emphasis is placed on spatial layout, functional rationality, and environmental adaptability. Hangzhou city encourages and promotes the concept of green building design, advocating for energy efficiency, resource recycling, and environmentally friendly building practices. This is achieved through the use of energy-saving materials, optimized building structures, and the incorporation of energy-saving equipment to reduce energy consumption and environmental pollution. Hangzhou city continuously improves road transportation facilities to enhance traffic capacity and efficiency. They alleviate traffic pressure by constructing highways, expressways, bridges, and other transportation infrastructures, while also increasing the supporting facilities of public transportation systems and encouraging residents to utilize public transportation for their travels.

4.4 Increase water coverage



Fig. 2. The average monthly rainfall in Hangzhou.

Hangzhou city has carried out comprehensive treatment and ecological restoration of rivers and lakes, including the cleaning of water sediment, wetland restoration, and vegetation recovery. Through these measures, the quality and function of water bodies have been improved, and the water surface area has increased. The construction of green spaces along water systems, such as riverbank greening and lake parks, has been promoted. Figure 2 presents the average monthly rainfall in Hangzhou. By planting aquatic plants and creating wetlands, the self-purification capacity of water bodies is enhanced, while also providing more recreational and leisure spaces. Relevant policies and plans for water body protection have been formulated to strengthen water pollution control and supervision. The discharge of wastewater and waste into water bodies is strictly prohibited, and efforts are made to control water pollution sources to protect the ecological environment of water bodies. Artificial wetlands are constructed to utilize natural filtration and purification processes, improving water quality. Artificial wetlands can absorb and degrade pollutants in the water, while also providing ecological habitats and increasing biodiversity. Mechanisms for water system planning and development control have been established to strictly regulate the impact of construction projects on water bodies and plan for the protection of water system areas. Through proper planning and control, the integrity and ecological function of water bodies are preserved.

5 Hangzhou city's strategies for mitigating the urban heat island effect

After conducting research and analysis on the methods used by Hangzhou city to address the urban heat island effect, considering urban landscape design perspectives and the current development situation, the following methods have been summarized for mitigating the urban heat island effect.

(1) Establish ventilation corridors. In urban planning, a reasonable layout of roads and streets is implemented to avoid densely built and enclosed areas. The roads are designed with a certain width, ensuring sufficient space between buildings for air circulation. When arranging urban buildings, the spacing and positioning between them are considered to avoid high-density clustering and promote dispersion, leaving open areas to form ventilation corridors that facilitate air flow. Squares and green spaces such as parks and flower beds are set up to break the uniformity of buildings, providing open spaces that allow for air circulation. Additionally, green spaces can absorb solar heat and mitigate the heat island effect. Open spaces are designed at urban transportation nodes such as stations and subway entrances to facilitate air circulation and convenient access to public transportation for citizens. The use of green roofs and vertical greening technologies is encouraged to increase green spaces within the city, providing more vegetation coverage that aids in air circulation and temperature reduction. Wind channels, such as open streets, corridors, and pedestrian walkways, are appropriately incorporated into urban planning to guide natural airflow into urban areas and create ventilation corridors.

(2)Control land use and construction density.Establishing building height limits and plot ratio restrictions to control building density. By limiting the height and plot ratio of buildings, sufficient natural ventilation and sunlight can be ensured, reducing the heat island effect. Developing scientifically reasonable land use planning to determine the nature and purpose of land in different areas, including residential, commercial, industrial, and public facilities, and creating a reasonable layout of various types of land to avoid concentrated high-density construction in large areas and maintain diversity and balance in land use. Emphasizing the provision of public spaces and facilities such as public squares, streetscapes, and community parks in urban planning. These areas can alleviate building density, provide places for leisure and recreation, and improve the living environment for urban residents. By guiding reasonable distribution and mixed-use of land, reducing the singularity of residential, commercial, and industrial areas, and encouraging the development of functionally diverse regions in urban planning, different types of land use can overlap with each other, thereby reducing traffic congestion. Establishing corresponding building energy-saving standards and regulations, encouraging the use of energy-saving technologies, green materials, and renewable energy sources to reduce buildings' energy demand and mitigate the heat island effect.

(3)Sponge city design.Establishing a rainwater collection system, including rain gardens, rainwater harvesting facilities, and rainwater infiltration systems, which can collect, store, and utilize precipitation, reducing stormwater runoff and flood risks. Increasing urban green spaces and wetlands, such as wetland parks, artificial wetlands, and wetland filtration systems, which contribute to reducing flood risks, improving water quality, and providing benefits of rainwater retention and natural ecosystem services. Using permeable pavement materials, such as pervious concrete and permeable bricks, to increase surface water permeability, reducing pooling of water and surface runoff within the city. Restoring abandoned or fragmented natural watercourses within the city and conducting ecological restoration of these water channels, which can enhance water quality, increase natural flood overflow capacity, and improve water resource regulation. Implementing measures such as greywater recycling, rainwater utilization, and ecological water treatment to achieve water recycling and conservation, for example, using greywater for toilet flushing and plant irrigation, reducing reliance on freshwater resources. Establishing natural protective zones, such as riverbank greening, wetland areas, and vegetation belts, to mitigate flood threats, absorb and retain rainwater, and protect rivers and the city. Setting up flood detention areas and reservoirs in urban planning for temporary storage and regulation of precipitation, which can reduce flood threats and protect low-lying areas within the city. Encouraging community participation in sponge city projects, providing relevant education and training, and enhancing public environmental awareness and knowledge to strengthen the community's capacity for sustainable development.

6 Conclusion

This article takes Hangzhou City as an example to study the strategies and effects of tackling the urban heat island effect. Several effective methods suitable for most areas to improve the heat island effect are summarized. Urban landscape design plays an important role throughout the process. Measures such as building urban green spaces, increasing green coverage, protecting water sources, and promoting low-carbon transportation provide comprehensive regulatory strategies for curing a sick city. However, improving urban climate issues cannot solely rely on administrative regulations; it requires instilling environmental awareness in everyone's hearts and motivating them to protect the environment voluntarily.

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