

# Analysis of the Impact of Land Use Planning on Urban Heat Island Effect

Peng Li

Shaanxi Dijian land comprehensive development Co., LTD, Xi'an 710075, China

## Abstract

This paper reviews the research progress and prospects of urban heat island effect, and systematically analyzes and evaluates the formation mechanism, influencing factors and mitigation measures of urban heat island effect from three aspects: observation, simulation and mitigation. Urban heat island effect is a typical environmental problem in the process of urbanization, which has important impacts on the climate, ecology, energy, health and other aspects of the city. The research of urban heat island effect has important theoretical significance and practical value, and provides scientific basis and guidance for the sustainable development of the city. The paper summarizes the main strategies of land use planning optimization for heat island effect, including increasing green space coverage, improving surface albedo, optimizing urban morphology and structure, etc., analyzes their mechanism and applicability conditions, evaluates their effects and influencing factors, and discusses their applicability and sustainability. The strategies of land use planning optimization for heat island effect need to select and combine the appropriate strategies according to the specific situation and goal of the city, so as to achieve the best effect. At the same time, the strategies of land use planning optimization for heat island effect need to coordinate and integrate with other urban planning and management objectives and measures, so as to avoid conflicts and negative effects, and improve the applicability and sustainability of land use planning optimization for heat island effect.

## Keywords

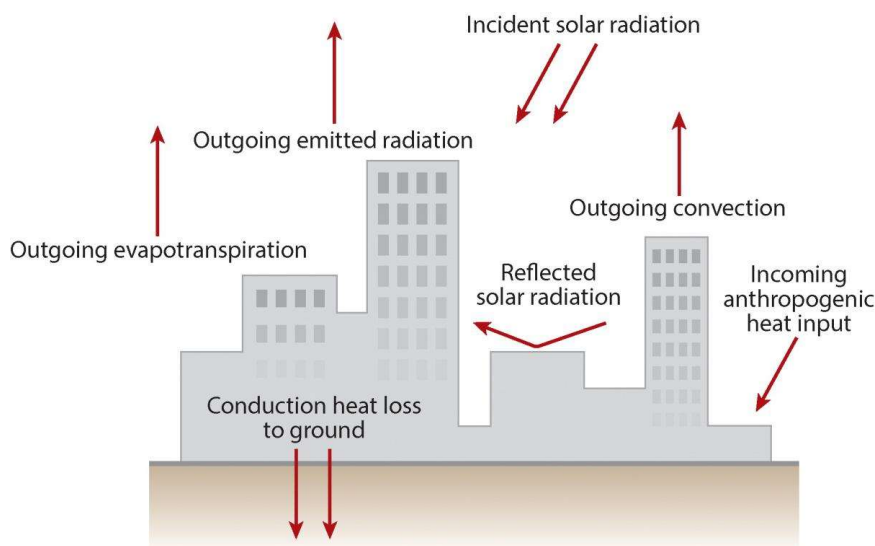
Urban Heat Island Effect; Land Use Planning; Influencing Factors; Evaluation Indicators; Optimization Strategies.

## 1. Introduction

Urban heat island (UHI) is a phenomenon that the temperature in urban areas is higher than that in rural areas, which is a typical environmental problem in the process of urbanization[1]. UHI not only affects the climate and ecology of cities, but also affects the energy consumption and health and comfort of human beings[2]. Therefore, exploring the formation mechanism and influencing factors of UHI, and taking effective cooling measures, are of great significance for improving the sustainable development capacity of cities (Figure 1).

Land use planning is one of the important factors affecting UHI. By rational land use patterns and structures, UHI can be effectively alleviated and the ecological environment quality of cities can be improved. Land use planning not only determines the spatial form and functional distribution of cities, but also affects the surface characteristics and energy balance of cities. Different land use types have different albedo, evapotranspiration, heat capacity and thermal conductivity, which lead to different surface temperatures and heat fluxes. Therefore, analyzing the influence mechanism and degree of land use planning on UHI is an important content of urban thermal environment research[4].

The purpose of this paper is to review the research progress of the impact analysis of land use planning on UHI at home and abroad, and systematically sort out and summarize the basic concepts, formation causes, influencing factors and evaluation indicators of UHI, the relationship, influence mechanism and degree of land use planning and UHI, and the principles and methods of land use planning optimization, and point out the shortcomings of existing research and future research directions, providing reference and reference for the improvement and optimization of urban thermal environment.



**Figure 1.** Relevant energy flows for the urban heat island [3]

## 2. Basic Concepts of Heat Island Effect

### 2.1. Spatial Scale of Heat Island Effect

According to the spatial scale of heat island effect, the evaluation indicators can be divided into macro scale, meso scale and micro scale. The macro scale indicators mainly reflect the average temperature difference between urban and rural areas, such as urban heat island intensity (UHII), urban heat island area (UHIA), etc. The meso scale indicators mainly reflect the temperature distribution and change within the city, such as urban heat island gradient (UHIG), urban heat island peak (UHIP), etc. The micro scale indicators mainly reflect the thermal environment and comfort at the building or street level[5], such as surface temperature (ST), wet bulb globe temperature (WBGT), physiological equivalent temperature (PET), etc[6].

### 2.2. Temporal Scale of Heat Island Effect

According to the temporal scale of heat island effect, the evaluation indicators can be divided into daily scale, seasonal scale and annual scale. The daily scale indicators mainly reflect the diurnal variation characteristics of heat island effect[7], such as daily maximum urban heat island intensity (DMUHII), daily minimum urban heat island intensity (DMIUHII), daily urban heat island intensity change rate (DUHIICR), etc. The seasonal scale indicators mainly reflect the seasonal variation characteristics of heat island effect, such as seasonal maximum urban heat island intensity (SMUHII), seasonal minimum urban heat island intensity (SMIUHII), seasonal urban heat island intensity change rate (SUHIICR), etc. The annual scale indicators mainly reflect the interannual variation characteristics of heat island effect, such as annual maximum urban heat island intensity (AMUHII), annual minimum urban heat island intensity (AMIUHII), annual urban heat island intensity change rate (AUHIICR), etc.

### 2.3. Temperature Level of Heat Island Effect

According to the temperature level of heat island effect, the evaluation indicators can be divided into surface heat island, near-surface heat island and atmospheric heat island[8]. The surface heat island indicators mainly reflect the temperature difference between urban and rural surfaces, such as surface urban heat island intensity (SUHII), surface urban heat island area (SUHIA), etc. The near-surface heat island indicators mainly reflect the temperature difference between urban and rural near-surface air, such as near-surface urban heat island intensity (NSUHII), near-surface urban heat island area (NSUHIA), etc.

## 3. The Relationship between Land Use Planning and Urban Heat Island Effect

The influence mechanism of land use planning on urban heat island effect. Land use planning affects the formation and development of urban heat island effect by changing the physical characteristics and energy balance of urban surface[9, 10]. The main influence mechanisms are as follows:

### 3.1. The Influence of Land Use Types

Different land use types have different characteristics of albedo, evapotranspiration, heat capacity and thermal conductivity, which affect the distribution and change of radiation, sensible heat and latent heat fluxes of urban surface (Figure 2)[11]. Generally speaking, natural ecological land (such as forest, grassland, water, etc.) has higher albedo and evapotranspiration, lower heat capacity and thermal conductivity, which can reduce the temperature and heat island intensity of urban surface. On the other hand, artificial construction land (such as residential area, industrial area, commercial area, etc.) has lower albedo and evapotranspiration, higher heat capacity and thermal conductivity, which can increase the temperature and heat island intensity of urban surface. Therefore, land use planning should try to increase the proportion and continuity of natural ecological land, reduce the proportion and density of artificial construction land, so as to alleviate the urban heat island effect[12].

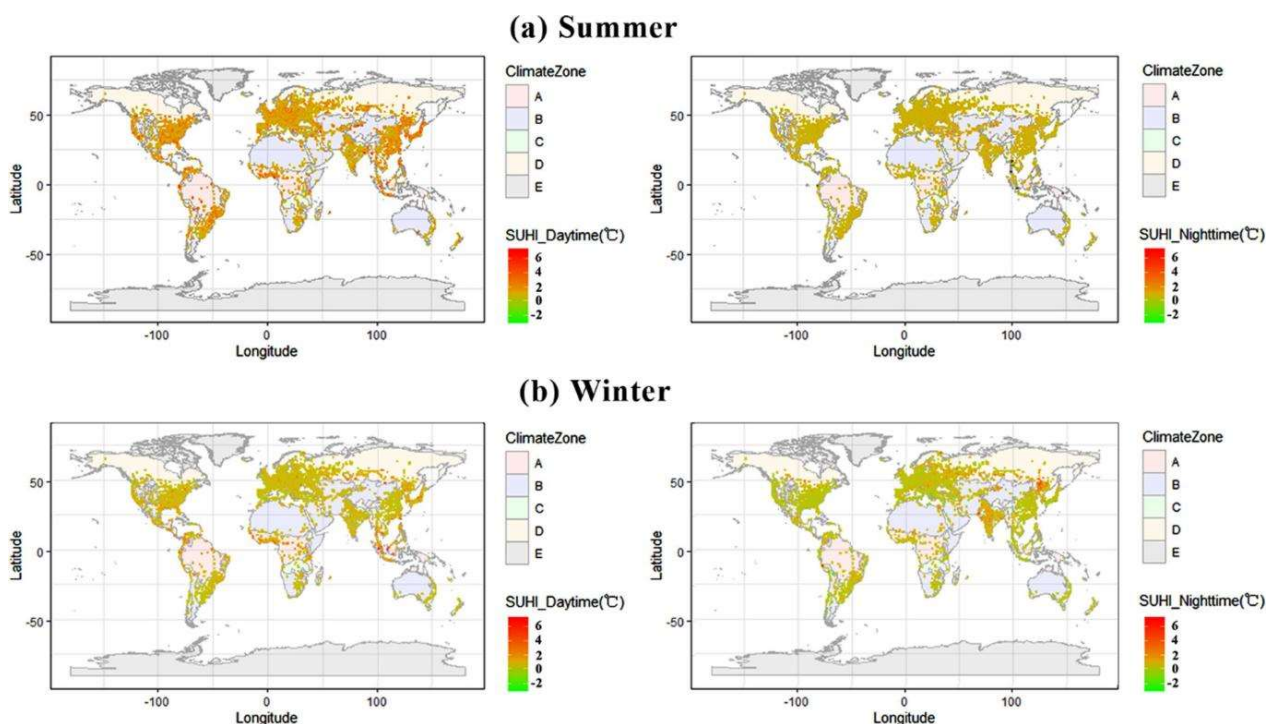


Figure 2. Map of the daytime / nighttime SUHI in different global climate zones[13]

### 3.2. The Influence of Land Use Structure

Land use structure refers to the spatial distribution and combination mode of urban land use, which affects the shape and flow of urban surface and air. Generally speaking, the irregularity and complexity of urban surface, as well as the height and density of urban buildings, will increase the roughness and turbulence of urban surface, affect the radiation and convective heat exchange of urban surface, and increase the temperature and heat island intensity of urban surface. On the contrary, the regularity and simplicity of urban surface, as well as the low and sparse urban buildings, will reduce the roughness and turbulence of urban surface, promote the radiation and convective heat exchange of urban surface, and reduce the temperature and heat island intensity of urban surface. Therefore, land use planning should try to optimize the shape and flow of urban surface and air, reduce the roughness and turbulence of urban surface, so as to alleviate the urban heat island effect.

### 3.3. The Influence of Land Use Dynamics

Land use dynamics refers to the temporal change and transfer process of urban land use, which affects the thermal inertia and thermal lag of urban surface. Generally speaking, the rapid change and expansion of urban land use will increase the thermal inertia and thermal lag of urban surface, resulting in the temperature and heat island intensity of urban surface more obvious at night and in winter.

## 4. Land Use Planning Optimization

The research methods of land use planning optimization for heat island effect mainly include statistical analysis, remote sensing inversion, numerical simulation, etc[14]. Statistical analysis is to use descriptive statistics, correlation analysis, regression analysis and other methods to explore the relationship and influence degree between land use planning and heat island effect, evaluate the effect and applicability of land use planning optimization for heat island effect, which has simple operation and strong applicability, but it is difficult to reveal the causal relationship and influence mechanism between land use planning and heat island effect. Remote sensing inversion is to use radiation correction, atmospheric correction, land surface temperature inversion and other methods to obtain the indicators of land surface temperature and heat island intensity in urban areas, simulate the scenarios and changes of land use planning optimization for heat island effect, which has high spatial resolution and wide coverage, but it is affected by many factors, and has low accuracy and reliability, and requires complex parameter estimation and model selection[15]. Numerical simulation is to establish the energy balance equation of urban surface, simulate the temperature and heat flux changes of urban surface, analyze the influence factors and mechanisms of land use planning optimization for heat island effect, predict the effect and sustainability of land use planning optimization for heat island effect, which has high accuracy and strong explanatory ability, but it requires a lot of input data and computing resources, and has high complexity and difficulty, and requires reasonable assumptions and verification.

### 4.1. The Main Strategies for Optimizing Heat Island Effect

The main strategies for land use planning optimization for heat island effect mainly include increasing green space coverage, improving surface albedo, optimizing urban morphology and structure, etc[16]. Increasing green space coverage is to increase the natural ecological land (such as forest, grassland, water, etc.) in the city, increase the evapotranspiration of urban surface, reduce the sensible heat flux of urban surface, thereby reduce the temperature and heat island intensity of urban surface, improve the urban thermal environment and human comfort, and promote the service and function of urban ecosystem. The main strategies for land use planning optimization for heat island effect. The main strategies for land use planning

optimization for heat island effect mainly include increasing green space coverage, improving surface albedo, optimizing urban morphology and structure, etc. Increasing green space coverage is to increase the natural ecological land (such as forest, grassland, water, etc.) in the city, increase the evapotranspiration of urban surface, reduce the sensible heat flux of urban surface, thereby reduce the temperature and heat island intensity of urban surface, improve the urban thermal environment and human comfort, and promote the service and function of urban ecosystem. Improving surface albedo is to increase the albedo of artificial construction land (such as residential area, industrial area, commercial area, etc.) in the city, reduce the radiation absorption and emission of urban surface, thereby reduce the temperature and heat island intensity of urban surface, improve the urban thermal environment and human comfort, and reduce the urban energy consumption and greenhouse gas emission. Optimizing urban morphology and structure is to optimize the spatial layout and building form of the city, reduce the roughness and turbulence of urban surface, promote the radiation and convective heat exchange of urban surface, thereby reduce the temperature and heat island intensity of urban surface, improve the urban thermal environment and human comfort, and increase the urban spatial efficiency and function.

## **4.2. The Influencing Factors of Optimizing Heat Island Effect**

The effect of land use planning optimization for heat island effect refers to the degree of reduction of urban surface temperature and heat island intensity, and the degree of improvement of urban thermal environment and human comfort, achieved by the strategies of land use planning optimization for heat island effect. The effect of land use planning optimization for heat island effect is influenced by many factors, mainly including the following aspects:

### **4.2.1. The Selection and Combination of Optimization Strategies**

Different land use planning optimization strategies for heat island effect have different effects and applicability conditions, and need to select and combine the appropriate land use planning optimization strategies for heat island effect according to the specific situation and goal of the city, so as to achieve the best effect. Generally speaking, the strategy of increasing green space coverage is suitable for the situation where the natural ecological land in the city is less, the urban thermal environment is poor, and the urban ecosystem is weak, which can effectively reduce the temperature and heat island intensity of urban surface, improve the urban thermal environment and human comfort, and promote the service and function of urban ecosystem. The strategy of improving surface albedo is suitable for the situation where the artificial construction land in the city is more, the urban energy consumption is high, and the urban greenhouse gas emission is large, which can effectively reduce the temperature and heat island intensity of urban surface, improve the urban thermal environment and human comfort, and reduce the urban energy consumption and greenhouse gas emission. The strategy of optimizing urban morphology and structure is suitable for the situation where the spatial layout and building form of the city are chaotic, the roughness and turbulence of urban surface are high, and the urban spatial efficiency and function are low, which can effectively reduce the temperature and heat island intensity of urban surface, improve the urban thermal environment and human comfort, and increase the urban spatial efficiency and function[17].

### **4.2.2. The Climate Conditions and Geographical Location of the City**

The climate conditions and geographical location of the city affect the radiation and convective heat exchange of urban surface, thus affecting the effect of land use planning optimization for heat island effect. Generally speaking, the more favorable the climate conditions and geographical location of the city are for the radiation and convective heat exchange of urban surface, the better the effect of land use planning optimization for heat island effect is. For example, the higher the temperature, the lower the humidity, the larger the wind speed, the

lower the latitude, the higher the altitude, and the flatter the terrain of the city, the better the effect of land use planning optimization for heat island effect is.

#### 4.2.3. The Development Level and Scale of the City

The development level and scale of the city affect the population density and energy consumption of the city, thus affecting the effect of land use planning optimization for heat island effect[18]. Generally speaking, the higher the development level and scale of the city, the larger the population density and energy consumption of the city, and the worse the effect of land use planning optimization for heat island effect. For example, the higher the economic development level, the higher the industrialization and urbanization level, the larger the population size and density, the larger the energy consumption and greenhouse gas emission of the city, and the worse the effect of land use planning optimization for heat island effect.

## 5. Conclusion

This paper reviews the research progress and prospects of urban heat island effect, and systematically analyzes and evaluates the formation mechanism, influencing factors and mitigation measures of urban heat island effect from three aspects: observation, simulation and mitigation. Urban heat island effect is a typical environmental problem in the process of urbanization, which has important impacts on the climate, ecology, energy, health and other aspects of the city. The research of urban heat island effect has important theoretical significance and practical value, and provides scientific basis and guidance for the sustainable development of the city.

The paper summarizes the main strategies of land use planning optimization for heat island effect, including increasing green space coverage, improving surface albedo, optimizing urban morphology and structure, etc., analyzes their mechanism and applicability conditions, evaluates their effects and influencing factors, and discusses their applicability and sustainability. The strategies of land use planning optimization for heat island effect need to select and combine the appropriate strategies according to the specific situation and goal of the city, so as to achieve the best effect. At the same time, the strategies of land use planning optimization for heat island effect need to coordinate and integrate with other urban planning and management objectives and measures, so as to avoid conflicts and negative effects, and improve the applicability and sustainability of land use planning optimization for heat island effect.

## References

- [1] Oke TR. The energetic basis of the urban heat island. Quarterly journal of the royal meteorological society. 1982;108(455):1-24.
- [2] Arnfield AJ. Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. International Journal of Climatology: a Journal of the Royal Meteorological Society. 2003;23(1):1-26.
- [3] Phelan PE, Kaloush K, Miner M, Golden J, Phelan B, Silva H, et al. Urban Heat Island: Mechanisms, Implications, and Possible Remedies. Annual Review of Environment and Resources. 2015;40(1): 285-307.
- [4] Voogt JA, Oke TR. Thermal remote sensing of urban climates. Remote sensing of environment. 2003;86(3):370-84.
- [5] Mohajerani A, Bakaric J, Jeffrey-Bailey T. The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. Journal of environmental management. 2017;197:522-38.
- [6] Manoli G, Fatichi S, Schlöpfer M, Yu K, Crowther TW, Meili N, et al. Magnitude of urban heat islands largely explained by climate and population. Nature. 2019;573(7772):55-60.

- [7] Zhou D, Zhao S, Liu S, Zhang L, Zhu C. Surface urban heat island in China's 32 major cities: Spatial patterns and drivers. *Remote sensing of environment*. 2014;152:51-61.
- [8] Peng S, Piao S, Ciais P, Friedlingstein P, Oettle C, Bréon F-M, et al. Surface urban heat island across 419 global big cities. *Environmental science & technology*. 2012;46(2):696-703.
- [9] Wenhui K. Advance and Future Prospects of Urban Land Use/Cover Change and Ecological Regulation of Thermal Environment. *Scientia Geographica Sinica*. 2018;38(10):1643-52.
- [10] Wang G, Zhang Q, Rongbo X, Guan D. Impacts of land use, population density and altitude on the urban heat island. 2019.
- [11] Li X, Zhou Y, Yu S, Jia G, Li H, Li W. Urban heat island impacts on building energy consumption: A review of approaches and findings. *Energy*. 2019;174.
- [12] Li X, Zhou Y, Asrar G, Imhoff M, Xuecao L. The surface urban heat island response to urban expansion: A panel analysis for the conterminous United States. *Science of The Total Environment*. 2017;605-606:426-35.
- [13] Yuan Y, Li C, Geng X, Yu Z, Fan Z, Wang X. Natural-anthropogenic environment interactively causes the surface urban heat island intensity variations in global climate zones. *Environment International*. 2022;170:107574.
- [14] Hu Y, Jia G. Influence of land use change on urban heat island derived from multi-sensor data. *International Journal of Climatology*. 2010;30(9):1382-95.
- [15] Shi Y, Katzschner L, Ng E. Modelling the fine-scale spatiotemporal pattern of urban heat island effect using land use regression approach in a megacity. *Science of The Total Environment*. 2018;618:891-904.
- [16] Zhou B, Rybski D, Kropp J. The role of city size and urban form in the surface urban heat island. *Scientific Reports*. 2017;7:4791.
- [17] Alvarez-Vázquez LJ, Fernández FJ, Martínez A, Vázquez-Méndez ME, editors. *Urban Heat Island Effect in Metropolitan Areas: An Optimal Control Perspective*. Numerical Mathematics and Advanced Applications ENUMATH 2017; 2019 2019//; Cham: Springer International Publishing.
- [18] Gago EJ, Roldan J, Pacheco-Torres R, Ordóñez J. The city and urban heat islands: A review of strategies to mitigate adverse effects. *Renewable and Sustainable Energy Reviews*. 2013;25:749-58.