HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

URBAN LANDSCAPE OPTIMIZATION BASED ON MICROCLIMATE RESEARCH

Spatial distribution of air temperature and the influencing factors
——The Case of City Main District Zhengzhou, China

STUDENT: Zhang Yuhao

SUPERVISOR: Sándor Jombach

DATE: May, 2023

TYPE OF THESIS: Type B

Master of Arts In Landscape Architecture and Garden Design Program

INSTITUTE OF LANDSCAPE ARCHITECTURE, URBAN PLANNING AND GARDEN ART

CONTENT

Abstract: Cities are areas of high population concentration, high building coverage, and high economic activity. Creating a healthy, sustainable urban environment and building ecological cities is a shared goals of today's society. In recent years extreme weather and natural disasters have occurred frequently in China, posing a significant threat to climate stability and economic development. At the same time, with rapid urbanization, urban sprawl is spreading, and green space is gradually decreasing. Urban heat phenomena are frequent, and a series of urban thermal environment problems generated by the urban heat island effect are concerned. Facing the challenges of the urban climate environment, relevant scholars have developed a series of climate-resilient countermeasures and mechanisms to mitigate the environmental problems caused by human activities. However, there are still fewer studies at the microscopic scale. This paper uses two main urban areas (Huizi District and Jinshui District) in Zhengzhou City as research sites. Two seasons, summer and winter, are selected to quantify urban air temperature and its drivers. The meteorological elements such as air temperature, wind speed, solar radiation, and humidity were measured using the mobile observation method and based on the 2017 remote sensing images of Zhengzhou city with high-fraction 2 (GF-2). Building height raster images of the main urban areas of Zhengzhou city at different scales (50m,100m,150m,200m,250m,500,750m,1000m), the extensive use of ArcGIS， ENVI, and other software were used to extract various indicators affecting air temperature. The multi-scale correlation between air temperature and various driving factors was investigated using Pearson correlation coefficient analysis and a stepwise regression model. The findings of the study include the following：

(1) The results of correlation analysis between various indicators such as building elements, green space, water bodies, meteorological elements, and air temperature at different scales show that each topic exhibits other significance at different scales. Air humidity is the most significant factor affecting air temperature, which is always negatively correlated with air temperature and is not affected by scale. Building coverage and urban air temperature are positively correlated. The effect of the percentage of impervious surfaces on air

temperature becomes more significant as the study scale increases. The wind speed in summer is also one of the critical indicators of air temperature. In general, as the study scale increases, the influence of building form, green space, water bodies, and meteorological elements on air temperature in summer becomes more significant.

(2) The effects of the types mentioned above of indicators on air temperature generally decrease in winter. However, air humidity and wind speed still significantly impact regulating air temperature. The proportion of impervious surfaces also significantly affects air temperature, showing a positive correlation. In winter, the balance of bare ground in the study area also strongly influenced air temperature, showing a negative correlation.

(3) The influence of each indicator on air temperature varies with seasonal changes. Also, the significance of the effect of each type of indicator on air temperature changed with the evolution of scale.

Keywords: microclimate, air temperature, influence factor, urban landscape planning, urban thermal environment, correlation

1. Introduction

This section presents the background and significance of the research on the heat island effect due to urbanization. The research background introduces the development process of urbanization in China and the process and characteristics of urban microclimate research.

1.1 Research Background and Significance

1.1.1 Research Background

1.1.1.1 The Process of urbanization development in China

The concept of urbanization first appeared in Serda's book "Basic Theory of Urbanization" in 1867. Since then, several scholars in China and all around the World have defined urbanization from different fields and perspectives, but there has yet to be a unified definition, partly because of the ambiguity of the urban concept.

1. Rapid Development Stage

Since the reform and opening up, China's urbanization process has entered a rapid development stage; according to the China Urban Statistical Yearbook, the reform of urban economic systems, the implementation of small-town development strategies, the widespread establishment of economic development zones, and the rise of township enterprises have driven the rapid development of urbanization levels since the 1980s. Research shows that China entered the mid-acceleration stage in the 1980s when the urbanization level reached around 25%; the average annual growth rate of urbanization fluctuated around 2.6% from 1978 to 1999, with a moderate increase, and by 1996, China's urbanization level reached 30.48%, entering the acceleration stage of urbanization.

2. Accelerated urbanization stage

The 16th National Congress in 2002 established the principle of "insisting on the coordinated development of large, medium, small and medium-sized cities and small towns, and taking the road of urbanization with Chinese characteristics." It proposed the integrated development of urban and rural areas; urbanization and urban development have become more active than ever.

3. High-speed development stage

According to statistics, during the period from 2000 to 2013, the rapid growth of urbanization, due to macroeconomic operation and social factors such as the reform of household registration system, the urbanization process accelerated significantly, with an average annual growth rate of 4.0%, and the urbanization level exceeded 50% in 2013[1], and policies played a significant role in urbanization; among them, the Third Plenary Session of the 17th Communist Party of China (CPC) Central Committee in 2008 pointed out that "At present, China has generally entered the development stage of promoting agriculture with industry and bringing rural areas with urban areas, and has entered an important period of making efforts to break the dual structure of urban and rural areas and form a new pattern of integrating urban and rural economic and social development"; in 2012, the report of the 18th Party Congress pointed out that "we should increase efforts to coordinate urban and rural development, enhance the vitality of rural development, and gradually narrow the gap between urban and rural areas. The report of the 18th Party Congress in 2012 pointed out that "we should increase efforts to coordinate urban and rural development, enhance the vitality of rural development, gradually narrow the gap between urban and rural areas, and promote common prosperity in urban and rural areas." In 2014, the Central Committee of the Communist Party of China (CPC) and the State Council promulgated the National New-type Urbanization Plan (2014-2020) to guide the national urbanization development plan from a macroscopic, strategic, and fundamental perspective. After 2014, China's urbanization development entered a new era, which is an urbanization stage unique to China and in the mid-to high-speed development; this stage breaks through the limitations of the actual urbanization process, pursues the inclusiveness, coordination, and sustainable development of cities and towns, pays attention to the "quality" of development, and no longer focuses on the "quantity" of development[2]. This stage breaks through the limitations of the actual urbanization process, pursues the inclusiveness, coordination, and sustainable development of towns and cities, attaches importance to the "quality" of development, and pursues the optimal allocation of resource factors, instead of just pursuing the "quantity" of development.

4. Rural Revitalization Strategy

With General Secretary Xi Jinping as the core, the new generation of central leadership collective attaches more importance to rural development and coordinated development of urban and rural areas, and the report of the 19th National Congress (2016) put forward the implementation of rural revitalization strategy, marking the new normal stage of urbanization. In the No. 1 document of the Central Government in 2016 and 2017, the requirements for rural habitat improvement and the construction of beautiful and livable villages were put forward[3]. The focus of the new normal stage gradually shifts to the urban and rural habitat environment construction field.

Numerous studies have shown that urban areas are experiencing a stronger warming trend than non-urban areas. The local warming effect of urban heat islands is related to urban building geometry, land cover, impermeable surfaces, anthropogenic heat, vegetation, and reduced water coverage[4].

1.1.1.2 Urban microclimate research process and Characteristics

Cities are essential to human civilization; the environment is the basis of human existence. With the progress of human society and the development of science and technology, urbanization is accelerating, the scale of cities is expanding, and a large number of people are gathering in cities, which leads to the continuous deterioration of the urban climate environment. Traditional urban climatology research focuses on overall urban climate change and its effects, while research in building climatology focuses on creating and improving indoor environments[5]. The study of urban microclimatology falls between the two and has been slow to develop until the second half of the 20th century, when more and more experts and scholars paid attention to it. In recent years, microclimate research has become a hot issue in the development of landscape architecture, and scholars in the discipline of landscape architecture have begun to study the microclimate of outdoor spaces at a smaller scale based on the general context of urban microclimate. Many scholars believe landscape design elements such as topography, water bodies, plant communities, and architectural layout influence microclimate[6]. Therefore, adequate and reasonable research on microclimate theory and practice from the perspective of landscape gardening is a necessary way to improve the human living environment and enhance people's quality of life. In terms of research methods, early studies mainly used quantitative combined with qualitative description as the primary method. In recent years, computer simulation software has been used to study microclimate, which has become an essential tool for microclimate research in the field of landscape gardening, characterized by the careful consideration of microclimate influencing factors, especially the introduction of the influence of greening on environmental factors such as heat and wind. Using computer simulation software also means that microclimate research becomes more comprehensive in considering elements[7].

1.1.2 Research Significance

Urbanization has caused significant impacts on different climate elements, but related studies have mainly focused on local microclimate change. Climate change is a very complex process, and the extent of the role of urbanization in different regions and its role in global climate change need to be explained in depth by more accurate quantitative studies; in addition, climate change has a significant impact on urbanization, but the relevant studies in China only stay at the stage of theoretical studies and policy recommendations on a large scale[8]. More case studies are needed to test this.

The most widely used methods for studying the impact of urbanization on climate change are statistical analysis methods and model simulation methods. The process of categorizing and analyzing the data using statistical techniques is scientific, intuitive, and repeatable. It is the most widely used method in the study of the impact of urbanization on climate change. In general, the current research on the impact of climate change on urbanization focuses on the hindering effect of climate change, especially warming, on urban socio-economic development at the global scale. Still, the research on the impact of microclimate changes on the urban environment at the local scale is relatively limited. Therefore, this paper selects the study sites of two central urban areas in Zhengzhou City. Field measurements are conducted using the mobile observation method to investigate the drivers of urban air temperature in the horizontal dimension of 1 km, centered on the measurement points. Hopefully, this paper can provide reference suggestions for urban planning and construction and sustainable urban development.

1.2 Status of research inside and Outside China

This chapter describes the research development on this topic inside and outside China. From it, I try to identify the missing parts in today's research. And to improve the study of the missing parts.

1.2.1 Status of research inside China

Since the 1980s, with the rapid economic development and urbanization in China, more and more domestic scholars have been studying the urban thermal environment and other related issues, mainly focusing on the quantitative and qualitative analysis of the spatial pattern of the urban thermal environment. In 1982, Shuzhen Zhou et al. studied the daily and annual variation patterns of the thermal environment in Shanghai using meteorological observation data, laying the foundation for learning the urban thermal environment in China[9]. Some scholars summarized the progress of domestic research on the heat island effect and found that domestic research started in the 1980s. There was a rebound in the number of papers in 2019, attributed to the improvement of spatial and temporal resolution of remote sensing technology playing a positive role in the research. It is also found that the domestic research direction has relatively more research on green areas and the most mature research, indicating that green spaces have the most significant effect on heat islands[10]. Domestic research on the heat island effect has been conducted for more than 30 years, but it still needs to solve the problems of small-scale imprecision and discontinuity. The heat island effect is widely experienced in China, and its spatial extent will still be further expanded in the coming years. Therefore, urban planners and government officials must take this issue seriously and take more effective measures to prevent further deterioration of the environment[11].

1.2.2 Status of research outside China

The urban heat island effect was first proposed by Howard et al. in 1833, based on the phenomenon that the urban center of London was warmer than the suburbs[12]. In the 20th century, accelerated urbanization enhanced various environmental threats, increasing global temperature[13]. The difference between urban and suburban temperatures has become more apparent, among which the urban heat island effect has become one of the most prominent threats. Subsequently, Manley et al. conceptualized the urban heat island in 1958, i.e., the city's temperature is higher than that of the surrounding rural areas, which improved the theoretical basis of the urban heat island. Since then, the urban heat environment has gradually developed into one of the hot issues in urban landscape ecology research[14]. In the 1920s, Geiger, a German meteorologist, observed that the climate of the air layer immediately above the ground differed from that of other parts. Immediately afterward, in a publication of the 1940s, Geiger introduced the term microclimate and considered microclimate as a combination of near-surface environmental variables. According to the obtained data, foreign studies started in the 1960s and have a decreasing trend after 2018. It indicates that research in traditional areas is more mature and can be considered from other innovative perspectives, such as studying the interrelationship of the influencing factors. Engineering and meteorology are the main research areas, corresponding to the analysis of research techniques and the causes of heat islands[10]. In contrast, research in areas such as building construction and polymer science, which play a mitigating role in the problem of the heat island effect, is relatively scarce, which can indicate future research directions.

1.3 Problems and Shortcomings

There are more and more fundamental studies on the urban heat island effects and more advanced research methods. Still, most studies focus on describing the phenomena and characteristics of the heat island effect, and fewer studies specifically focus on ways-hods to mitigate the heat island effect. The quantitative research on the urban thermal environment on the heat island effect mitigation from the perspective of urban planning combined with urban planning theories is even less. The main problems of research in this field are as follows.

(1) Insufficient quantitative research: Domestic scholars' research on urban landscape structure to mitigate the urban heat island effect is primarily qualitative, and quantitative analysis needs to be revised.

(2) Single-scale research: Most research is on a single scale, and more comprehensive analysis on multiple scales must be done.

(3) Incomplete research: Most studies discuss single influencing factors affecting the urban thermal environment, and there needs to be more multi-factor, comprehensive and integrated analysis.

(4) Weak theoretical foundation: Currently, the field focuses on the fundamental academic research of geography and meteorology. The application-oriented, integrated geography, landscape ecology, meteorology, urban planning, and other interdisciplinary research needs to be done more.

1.4 Related Concepts and Theories

1.4.1 Theory of Urban Thermal Environment

The urban thermal environment is the physical totality of heat-related effects on urban ecosystems that directly or indirectly affect human survival and development. The urban heat island effect is a significant problem in the urban thermal environment, i.e., it refers to the phenomenon that the temperature in the city is significantly higher than that in the outer suburbs.

In 1818, Howard, an Englishman, made comparative observations of the temperature in the urban and suburban areas of London and pointed out that the temperature in central London was higher than that in the suburbs, and introduced the concept of "urban heat island" for the first time in his book "The Climate of London" (Howard, 1833). For more than 200 years, the urban heat island effect has been of great concern, and scholars from different countries and regions have identified and confirmed this phenomenon. Especially after the 20th century, with the acceleration of global warming and urbanization, studying the urban heat island effect has become a hot spot with theoretical and practical significance. The urban heat island effect is when the city's temperature exceeds the surrounding countryside's. According to the research object, the heat island effect can be divided into atmospheric and surface heat islands. The urban heat island studied by applying the atmospheric temperature data is the atmospheric heat island; the urban heat island learned using the surface radiation temperature obtained from thermal infrared remote sensing is the surface heat island. This paper is concerned with the atmospheric heat island. The urban heat island effect can be classified into three kinds of studies: annual variation, seasonal variation, and daily variation study according to the study time. The spatial scale of the study can be classified into macroscale: city and above scale; mesoscale: intra-city administrative district scale; microscale: neighborhood and below scale. This paper develops the study of atmospheric heat islands at the microscopic scale.

1.4.2 Microclimate Theory

Microclimate refers to the climate conditions at small scales, including climate factors such as temperature, wind speed, relative humidity, and solar radiation, which are usually influenced by changes in heat transfer between the atmosphere and the subsurface. According to contemporary meteorological research, "climate" is divided into macroclimate, mesoclimate, regional, and microclimate according to scale[15]. Microclimates, or microclimates, are small-scale regional climates closely related to human life and can be easily controlled by artificial means. According to the classification of urban climate scales by previous scholars, it is known that urban microclimate is the climate indicator that describes the city within 1km in the horizontal dimension and 120m in the vertical size[16]. In recent years, the research on microclimate in China can be divided into two main areas.

1. Theoretical research on microclimate comfort evaluation models; 2. Microclimate laws and applications[17]. Atmospheric and environmental sciences have covered research on

urban climate for a long time. In addition to the influence of natural meteorological elements such as solar radiation, wind speed, wind direction, atmospheric temperature, and humidity, the hydrothermal processes between the urban substrate, buildings, vegetation, and the atmosphere, and artificial heat emissions, are important causes of urban microclimate[18].

Although China has not experienced a long time in small-scale urban microclimate research, the methods and technical means of study at this scale are relatively mature. However, there is still a need to deepen further the research on translating the results into practical applications in urban planning and architectural design and to make them normalized[19].

1.4.3 Correlation Analysis

Correlation analysis is an analysis of the degree of correlation between two variables. There are three ways to calculate correlation analysis, namely Pearson correlation coefficient (for quantitative data and data satisfying normal distribution), Spearman correlation coefficient (used when data does not meet normal distribution), and Kendall's tau -b correlation coefficient (ordered definite class variables). The Pearson correlation coefficient, also known as the product-difference correlation coefficient, is a statistical indicator of the degree and direction of linear correlation between two variables. The symbol r represents the correlation coefficient of the sample, and the overall correlation coefficient is represented by the Greek letter ρ (English rho, pronounced /ro/). The calculation formula is:

$$r = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2\sum(Y-\bar{Y})^2}} = \frac{l_{XY}}{\sqrt{l_{XX}l_{YY}}}$$

Among them:

$l_{XX} = (X-\bar{X})^2 = \sum X^2 - \frac{(\sum X)^2}{n}$, denotes the off-mean-sum-of-squares of X

$(Y-\bar{Y})^2 = \sum Y^2 - \frac{(\sum Y)^2}{n}$, denotes the off-mean-sum-of-squares of Y

$l_{XY} = \sum(X-\bar{X})\,(Y-\bar{Y}) = \sum XY - \frac{(\sum X)(\sum Y)}{n}$, denotes the off-mean-sum-of-squares of X

and Y.
The correlation coefficient is a dimensionless statistical indicator with a range of $-1 \leq r \leq 1$. A correlation coefficient less than 0 is a negative correlation, greater than 0 is a positive correlation, and equal to 0 means no correlation. The larger the absolute value of the correlation coefficient, the closer the correlation between the two variables.

1.4.4 Multiple Linear Regression Analysis - Stepwise Regression Analysis

Regression is a statistical method that allows us to understand the relationship between the independent and dependent variables. Stepwise regression is a process of filtering variables in regression analysis. I can use stepwise regression to construct a regression model from a set of candidate variables, automatically allowing the system to identify the influential variables. Stepwise regression analysis is a type of multiple linear regression analysis. The process involves introducing variables individually, provided their partial regression sum of squares test is significant (i.e., valid variables that pass the correlation analysis). After introducing each new variable, the variables included in the regression model are tested individually. Those not considered significant are removed to ensure that each variable in the resulting subset of independent variables is essential. This step is repeated several times until no more new variables can be introduced. Using regression statistics, it was possible to filter out which influences significantly affected air temperature at different study scales and exclude those with low correlation. This provides more intuitive suggestions for creating a cooler urban environment and mitigating the urban heat island effect in the future urban planning process.

1.5 Research Content, Methodology, and Technical Route

1.5.1 Research Content (Framework and Objects)

The research framework of this paper is divided into four major parts: discovering the problem, investigating the issue, analyzing the problem, and summarizing the situation.
The first part is to discover the problem, which firstly starts from the background, i.e., discusses the research background through three questions: why should I pay attention to

the urban heat island effect, the harm of the heat island effect, and why I choose the central city of Zhengzhou as the research area, to determine the direction of the research. Secondly, I start from the core, i.e., I clarify the research object and the subject of discussion through the core research object – the urban heat island effect and clarify the ideas and contents to be studied. Finally, I cut from the value, i.e., I sort out the research objectives and significance to indicate the next research direction.

The second part is the survey question. One of the survey angles in this part is to summarize the current research progress on the heat island effect in cities, i.e., what research has been done by scholars today on urban thermal environment-related issues, what theories have been combined and applied, and what results have been obtained, to grasp the cutting-edge research dynamics and further clarify the research concept, research scope and depth of this paper; the second survey angle is to get the city profile The second angle of investigation is to grasp the city profile, propose research methods and technical lines suitable for this study area, and interpret them. Finally, using the high-fraction-2 (GF-2) images of the main urban area of Zhengzhou, the raster images of the buildings in the central metropolitan area of Zhengzhou, and the satellite images are supervised and classified. The influence factors are extracted, etc., and then the correlation and stepwise regression analysis between the influence factors and air temperature are conducted. The changes of the independent and dependent variables at different scales are explored, and then solid data samples are provided for the subsequent analysis of the problem.

The third part analyzes the problem, mainly to investigate the causes and strategies of the data samples between the above two main urban areas of Zhengzhou regarding air temperature and impact factors. The analysis is carried out in three aspects: 2D/3D building form, landscape type, and meteorological elements, i.e., how building form, green areas, water bodies, bare land, impervious surfaces, and meteorological factors (humidity, wind speed, and solar radiation) affect air temperature, respectively. Based on this, strategies to cope with the urban heat island effect are further proposed.

The fourth part summarizes the problem. This part is mainly a comprehensive overview of the overall research ideas and contents of the dissertation and the prospect of the research, distilling the core results of the research and summarizing the shortcomings in the research process.

The main object of study chosen in this paper is the air temperature in the city’s urban center. Air temperature is one of the most critical indicators to represent thermal characteristics and is an essential parameter for thermal resource analysis, natural zoning, and agricultural production potential estimation[20]. Air temperature is also a key parameter in the energy and moisture cycle of the Earth's atmospheric system. It is increasingly essential in terrestrial process models, climate, and numerical weather forecasting regional or global models. Therefore, air temperature is chosen as the dependent variable in this study. The interaction between air temperature and the influencing factors is explored by selecting the influencing factors in different fields around air temperature.

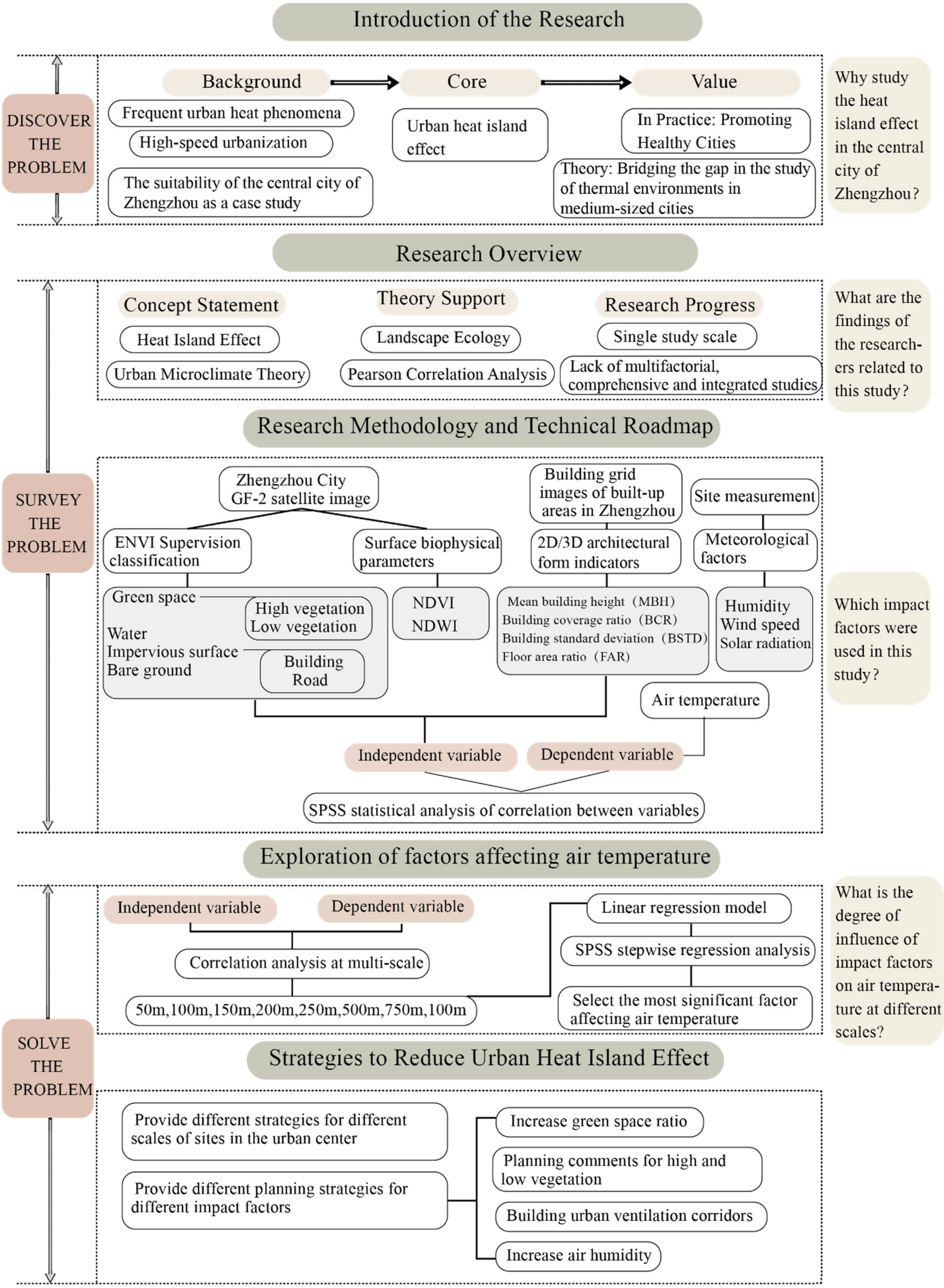


Figure 1 Research Framework

1.5.2 Research Methodology

The study combines different research contents and needs at each stage and integrates various research methods. At the methodological level, a research method combining reading and practice from rational knowledge construction to perceptual cognition is adopted; at the technical route level, a combination of qualitative and quantitative approaches is used to analyze the influencing factors of urban air temperature by applying the remote sensing image analysis function of ENVI, the data analysis function of ArcGIS, the correlation analysis and multiple linear regression function of SPSS, etc., to provide a solid support for the research conclusions The study is expected to provide substantial support for the research conclusions.

(1) Quantitative analysis method

The 'quantitative analysis method' is a data-based method for analyzing phenomena' characteristics, relationships, and changes. It is conducive to quantitatively revealing and describing phenomena' interactions and development trends and making the research more concrete. Based on quantitative values helps the research to interpret the problem and phenomena more fully. The quantitative analysis method is commonly used in previous studies of the urban heat island effect. This paper mainly focuses on field measurement meteorological data and GF-2 satellite images. I used ENVI and ArcGIS software to supervise the classification of satellite images and extract each factor affecting air temperature. Pearson correlation analysis and multiple linear regression (stepwise regression analysis method) based on SPSS were used to summarize the relationship between the influencing factors and air temperature. The study combines qualitative conclusions from literature reading with quantitative analysis of problems and phenomena.

(2) Field measurement method

Field measurements are flexible and can monitor daily changes in meteorological factors, a standard research method for microclimate and local climate[21]. Moreover, the meteorological elements measured on the ground directly related to human thermal comfort and environmental health[19]. The field measurement method is the most original and direct, and the data obtained are accurate and reliable, which is also the reference basis for verifying and comparing other research methods. Therefore, the field measurement method is used in this study. There are several means to obtain data through field measurement methods: urban weather station observation values, comprehensive comparison of urban and suburban weather station observation values, network observation values with urban center and surrounding weather stations, simultaneous analysis of portable weather instruments and weather station observation values, and micro-scale gradient climate observation values. Due to the complexity of the urban microclimate environment characteristics and the diversity of neighborhood-built environments, the data collected from actual accurate measurements can better compare and verify the results of other research methods. The collection of empirical data varies in different research programs. Depending on the study's purpose and the study area's climatic characteristics, a large amount of data collection is needed to support the microclimate study by selecting a typical day or month in winter, summer, or transition season. In the specific measurement plan, the accuracy of the test tools, the size of the test range and the amount of data, the control of the period for data collection, the selection of the test site, and the power of the weather and human influencing factors should be carefully arranged to ensure the absolute reliability of the measured values.

(3) Mobile observation method

The migratory route observation method is an urban climate observation method pioneered by an Austrian (W. Schmidt) in 1927. This method has a vital role in investigating the effect of vegetation on air temperature over a larger area. Using this observation method, meteorological data from many observation points can be obtained quickly, solving the problem of multi-point observations on the surface.

Sensor-based developments and significant advances in mobile sensors provide opportunities to quantify air temperatures at the intra-urban scale where data are sparse[22]. While fixed sensor networks are excellent for characterizing the broad patterns and temporal dynamics of urban heat islands, mobile sensors facilitate access to hard-to-sample areas of the city and allow measurements along continuous land cover gradients[23]. To this end, I used a custom-built bicycle mobile weather station to characterize intra-urban heat in a medium-sized city. In most studies, meteorological data are observed at a single point, with a limited number and uneven distribution of meteorological stations, poor spatial representation, and some problems with application in regional scale models. To avoid this problem, I carry portable weather stations for mobile observations.

(4) Multi-scale research

Scale is the unit of space or time used in studying an object and is one of the core issues in ecological research [24]. Each landscape element has its unique scale, reflecting its characteristics and influence on neighboring areas. The main traditional models for quantifying the relationship between urban surface temperature and landscape patterns are correlation coefficient, regression analysis, principal component regression, and spatial analysis[25]. Most of these models study the influence of landscape pattern indices on the surface temperature at a single scale, ignoring the multi-level structure and scale dependence of landscape patterns[26]. Landscape patterns and ecological processes are scale-dependent and may exhibit different characteristics at different scales[27]. Multi-scale observation and study of correlations among various environmental factors are essential for the validity of the results and their implications. Therefore, multi-scale analyses are needed to reveal the variation characteristics of the effects of landscape patterns on the urban thermal environment at different scales. To make the results more convincing, this paper uses a multi-scale study approach, with each measurement location as the central point and different distances as the radius to create buffer zones (50m, 100m, 150m, 200m, 250m, 500m, 750m, 1000m).

1.5.3 Technical Route

The study is based on multiple data sources for analysis. Firstly, field measurements were made using the mobile observation method to obtain meteorological data (air temperature, wind speed, humidity, and solar radiation) in the study area. Influence factors affecting air temperature were extracted based on GF-2 satellite images of Zhengzhou City in 2017. It has been shown that surface biophysical parameters, which contain much spectral information and are easily accessible from remotely sensed images, are usually considered influencing factors for surface temperature studies. Therefore, surface biophysical parameters (NDVI, NDWI) were extracted using GF-2 satellite images to determine the condition of vegetation and water bodies and to calculate building morphology indices. I use ENVI to supervise the classification of remote sensing images, extract information from remote sensing images, and obtain information on surface vegetation, buildings, and roads. The digital elevation model (DEM) of the central city of Zhengzhou was obtained from the USGS website for topographic analysis. Finally, correlation and multiple linear regression analyses were performed using SPSS software.

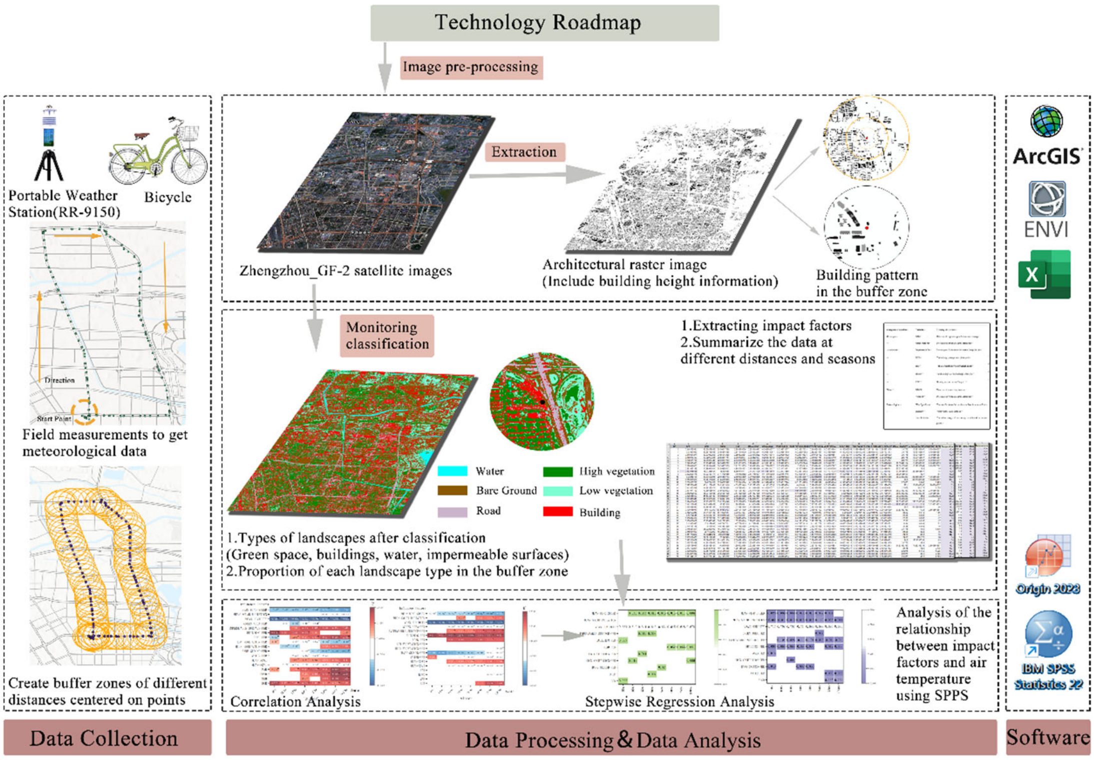


Figure 2 Technical Route

2. Materials and Methods

This chapter describes the overall condition of the study site, including geographic location, topography, road system, and site classification. The second section presents the basic data used in this study.

2.1 Research Area Overview.

Urban public activities mainly occur in outdoor spaces. The city center is the most concentrated area of urban activities, with a dense population, heavy traffic, and variable building types. It is also the area with the most severe thermal environment problems. As the capital of Henan Province, Zhengzhou is a typical city with a climate of cold winters and hot summers. In contrast, Huizi and Jinshui districts are also specific high-density areas in the city's center. At the same time, Zhengzhou is a distinct fast-developing metropolitan area in China undergoing rapid industrialization and urbanization. Therefore, Zhengzhou is well suited to assess the dynamic changes of the urban heat island effect. It is typical to study the thermal environment problem in the city's central metropolitan area by covering the two major urban regions in Zhengzhou.

2.1.1 Geographic Location

It is typical to use the central city of Zhengzhou as a case study of the air temperature change pattern of the heat island effect.

First, Zhengzhou is located in the southern part of the North China Plain, and the urban space is in the shape of a grid, a typical plain city. Unlike plains cities, towns with basin and valley topography are prone to forming an "inverse thermosphere" over them. The distribution of settlements is constrained by natural factors such as topography and slope. The study of the heat island effect in plains cities can help to exclude the complex constraints of the topography and climate conditions on the carbon and oxygen balance in the regional ecological environment and to interpret the links between anthropogenic activities and urbanization processes with urban development, spatial structure, and environmental setting.

In addition, Zhengzhou City is located in the north of China, in the middle and north of Henan Province, at the boundary between the middle and lower reaches of the Yellow River, with a total area of 7,567 square kilometers, 744.15 square kilometers of built-up area in the central city, 1,342.11 square kilometers of built-up area in the city, and an urbanization rate of 79.1%. As a major national city and the capital city of Henan Province, Zhengzhou City has experienced rapid urbanization in recent years, and the size of the major city has expanded more than six times in 40 years. In 1990, Zhengzhou City had a green coverage area of 2,638 hectares, with a green coverage rate of 35.25%, ranking first among the provincial capitals in China. The streets and alleys were widely planted with French sycamore trees, making it a "green city.” At the beginning of the 21st century, with the full implementation of the Central Rise and Central Plains Economic Zone strategy, Zhengzhou experienced unprecedented urbanization and significant land-use changes, leading to ecological problems and social conflicts. The increasingly prominent environmental conflicts have led Zhengzhou to focus on urban ecological development. Several studies and practices have been conducted since 2009, such as constructing forest parks, wetland parks, country parks, and green exhibitions. At present, Zhengzhou is still actively promoting greening work, such as the renewal of the streets of "one ring, ten horizontal and ten vertical" and the "demolition of walls and greenery" in parks, etc. The urban heat environment problem has been alleviated, and in January 2020, Zhengzhou was named "National Eco-Garden 2019" by the Ministry of Housing and Construction of China. In January 2020, the city was named "2019 National Ecological Garden City" by the Ministry of Housing and Construction. From the "Green City of the Central Plains" to the "City of Furnaces" to the "National Eco-Garden City,” Zhengzhou has experienced the balance and game of environment and development at different stages of urban development. It has Zhengzhou has achieved significant results in various stages of urban development and has outstanding characteristics of urban development. Therefore, selecting Zhengzhou city center as the study area is of general reference and significance for understanding the air temperature change pattern in the urban heat island effect.

The two main urban areas of Jinshui District and Huizi District in Zhengzhou City (113°38'15"-113°42'6 "E, 34°47'14"-34°52'50 "N) were selected as the study area of this paper. The overall topography of the region is flat and located north of the central part of the main city of Zhengzhou. Therefore the local climate change generated by the topography is not considered in this study for the time being.

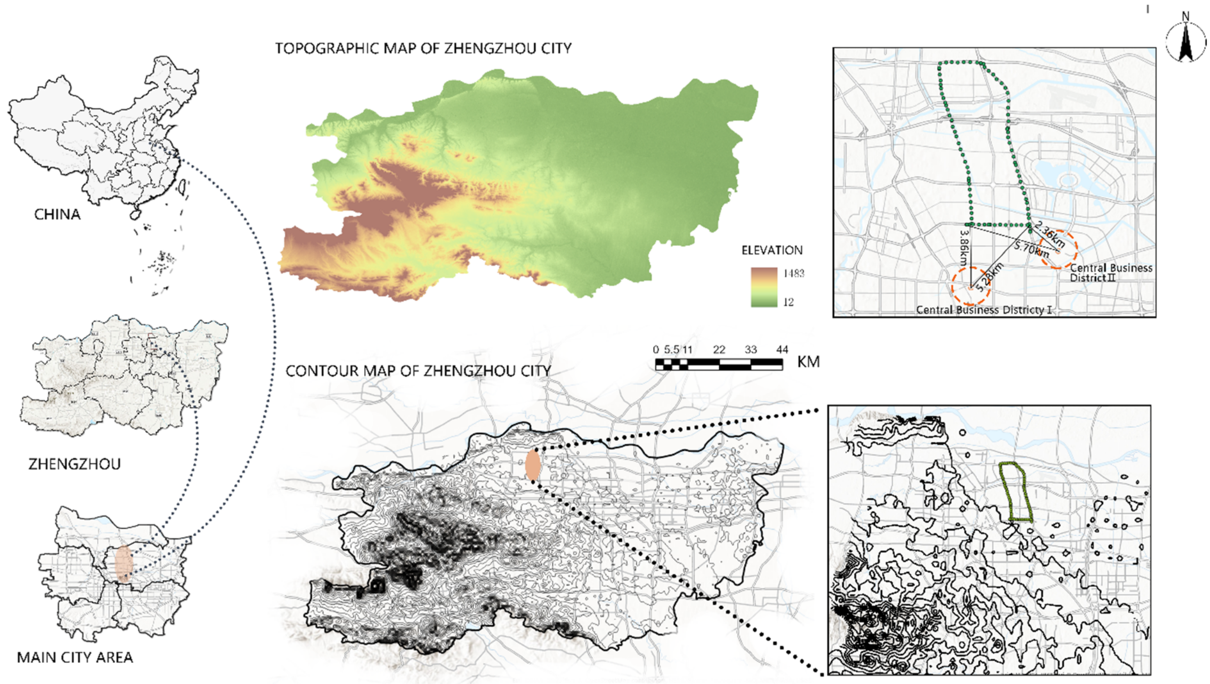


Figure 3 Location & Topography

2.1.2 Climatic Conditions

Regional climatic conditions are the most critical and direct elements affecting urban microclimate changes. They are the prerequisite for studying urban microclimate change patterns, a feature mentioned in almost all relevant research literature[16].

Zhengzhou City has a temperate continental monsoon climate characterized by four distinct seasons. The spring season is dry with little rain, many spring droughts, and many cold and warm winds; the summer season is hot with concentrated precipitation; the autumn season is cool and short; the winter season is long and dry with little rain and snow. The annual sunshine time is about 2400 hours. The average yearly temperature in the Zhengzhou area is between 14.3 and 14.8°C, with 14.3°C in Zhengzhou city and 220 days of frost-free period. Due to its geographical location, Zhengzhou City has poor diffusion conditions. Zhengzhou city is located in Henan Province, east of the Taihang Mountains and the Fuyu Mountains, north of the Dabie Mountains, and the terrain is high in the west and low in the east. Due to the influence of the El Niño climate, the cold air is less active in winter, and the air pollution diffusion conditions are poor, resulting in the frequent occurrence of heavy air pollution in winter. Therefore, it is essential to investigate the air temperature change pattern in the central city of Zhengzhou to alleviate the urban heat island effect.

2.1.3 Socio-economic

Zhengzhou's leading industrial sectors include mining, agriculture, industry, and services. Zhengzhou is rich in natural resources, with 34 types of proven mineral deposits and the largest coal reserves in the province, and is one of the largest oil and stone bases in China, with high-quality natural oil and stone ore. In recent years, Zhengzhou's agriculture has also been diversifying, promoting agricultural tourism and leisure industries and ecological green agriculture. Zhengzhou's air quality is average due to its economic structure, and in recent years the government has significantly improved the city's air quality after adjusting its financial system.

2.1.4 Traffic System

Zhengzhou City is very well developed in terms of transportation and is an important transportation hub city in China. Zhengzhou benefits from an excellent location, which provides the conditions for constructing a comprehensive transportation hub. Due to its superior central geographical location and well-developed railroad lines, Zhengzhou makes it very convenient and fast to reach all parts of China from Zhengzhou. Millions of people travel through the city daily as one of the top ten central cities and the largest land transportation hub in central China.

The study area is located in the central city of Zhengzhou. The daily traffic carrying pressure within this area is high, with many graded roads and frequent traffic congestion during peak hours. The main city roads, Culture Road, North 3rd Ring Road, North 4th Ring Road, and Zhengzhou Avenue, pass through the area. The traffic system in the central city is in a circular radial shape, which can be summarized into five ring roads, which have developed from the earliest main point of the railway station as the origin and expanded radially outward. The study area is located between the fourth and second rings. Today, Zhengzhou's third ring is still the most densely populated area regarding urban resources. Whether medical, educational, commercial, entertainment or other supporting facilities, the third ring is much better equipped than the new area (outside the third ring). Therefore, the study area covers the old city and the new location outside the third ring. The study area can reflect the general urban microclimate characteristics of Zhengzhou, and the study results are typical.

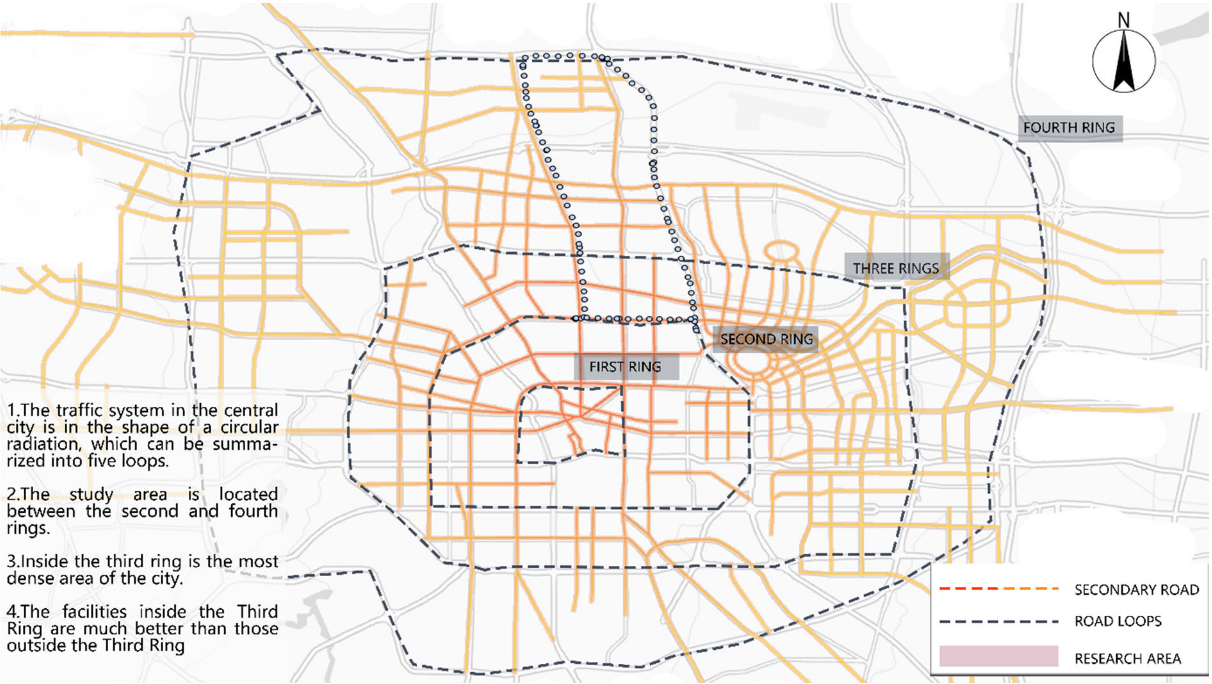


Figure 4 Road System

2.1.5 Functional Zoning

With rapid urbanization, it is crucial to determine the rationality of urban functional zoning construction for urban construction. Studies have shown that various urban functional zones can influence the urban thermal environment differently. This study uses a quantitative research method to clarify how urban functional zoning affects the urban thermal environment, which is a guide to mitigating the urban heat island effect problem. Most of the study area is residential and industrial land outside the Third Ring Road. The functional zoning within the third ring is more complex, with educational and research land, residential land, commercial land, and industrial land all densely distributed in the area.

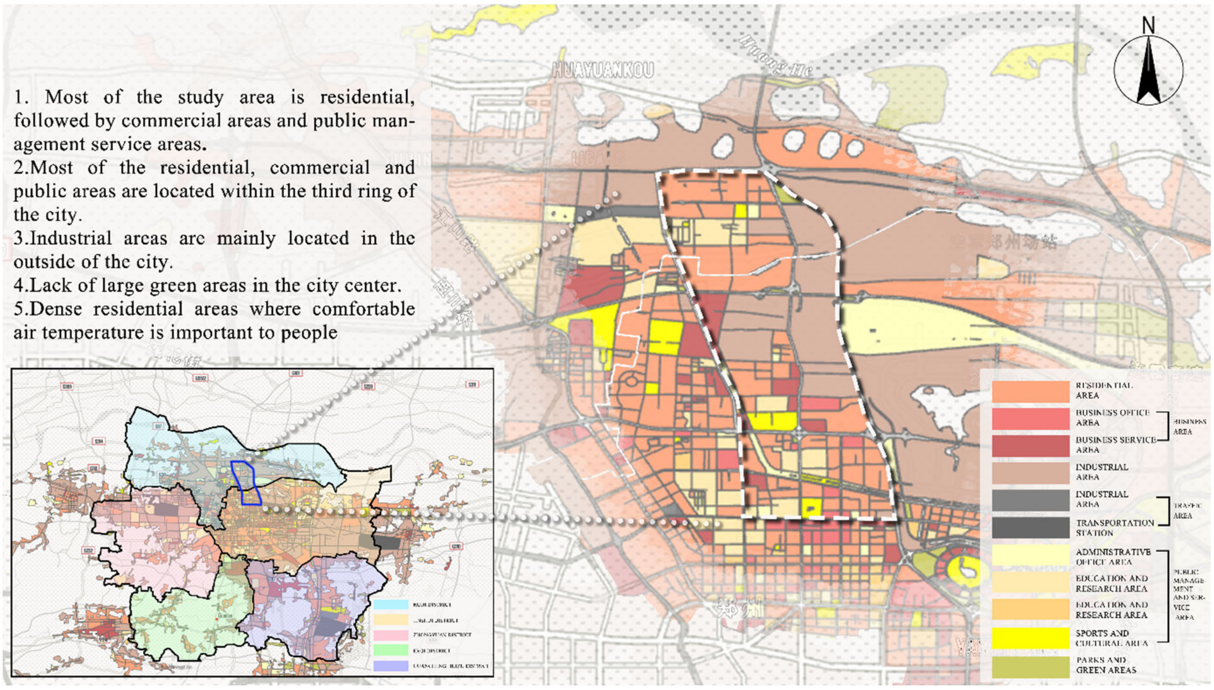


Figure 5 Land classification

2.2 Data Sources

2.2.1 Remote Sensing Image

2.2.1.1 Remote sensing image selection

The image selected for this study is the 2017 Zhengzhou domestic high-fraction-2 (GF-2) remote sensing image. The Gaofen-2 satellite is the first civil optical remote sensing satellite with spatial resolution better than 1 m developed independently by China. The platform has two high-resolution 1-meter panchromatic and 4-meter multispectral cameras featuring sub-meter spatial resolution, high positioning accuracy, and fast attitude maneuverability, effectively enhancing the comprehensive observation effectiveness of the satellite and reaching the advanced international level.

2.2.1.2 Remote sensing image preprocessing

The raw remote sensing images cannot be directly used in this study. The HMS-2 data downloaded from the China Resources Satellite Application Center are archived as Level 1 products. They need to undergo a series of pre-processing, which mainly includes: radiometric calibration, atmospheric correction, and image cropping.

(1) Radiation calibration

Radiometric calibration converts the recorded raw DN values to apparent reflectance and the image brightness grayscale values to absolute radiometric brightness. Radiation calibration is performed using the Bathmath and Radiometric Calibration tools in the ENVI 5.3 software.

(2) Atmospheric correction

Atmospheric Correction is the conversion of radiant brightness or surface reflectance to actual surface reflectance, eliminating errors caused by atmospheric scattering, absorption, and reflection. Use the FLAASH Atmospheric Correction tool in ENVI5.3 to start the FLAASH module for atmospheric correction.

(3) Image cropping

The shp. Data from the study area boundary was used as the mask file, and the image was cropped using the Region of Interest tool in ENVI5.3 software to preserve the study area image.

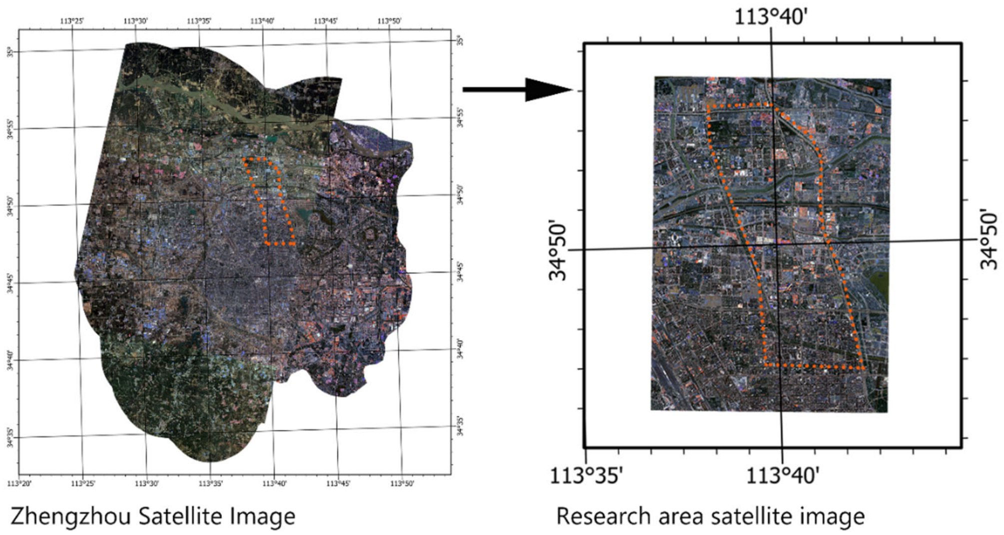


Figure 6 Satellite image processing

2.2.2 Architectural Images

(1) Zhengzhou city building raster image acquisition

Based on the remote sensing image to obtain the building raster image, the building outline and height information are extracted from the image. It is used as the base image for the subsequent study on the correlation between the building grid and air temperature.

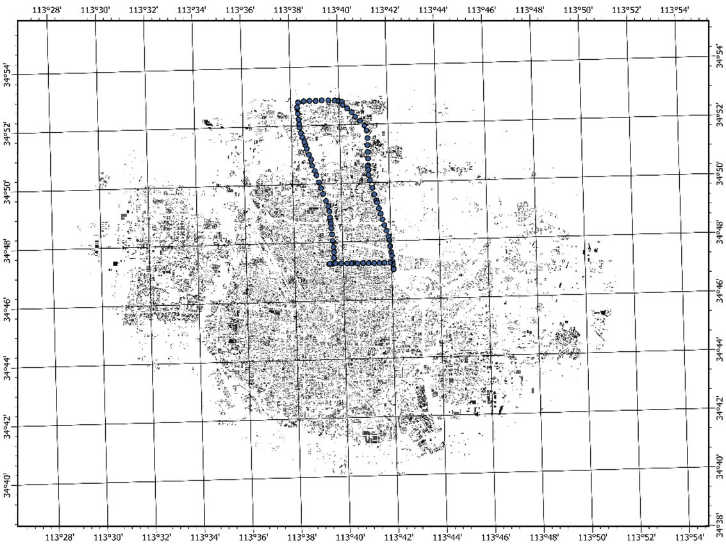


Figure 7 Zhengzhou building raster image

2.2.3 Meteorological Data

(1) Field measurements for meteorological data

This research used the mobile observation method to obtain basic meteorological information about the site. The specific route was as follows: Henan Agricultural University Culture Road Campus as the starting point, cycling with equipment along the Culture Road north to the North Fourth Ring Road, and then east along the North Fourth Ring Road to the Garden Road, south along the Garden Road to the Agriculture Road, and finally west along the Agriculture Road back to Henan Agricultural University. Meteorological data were collected from the field measurements, and a typical day with clear weather and wind below level 3 was selected. 2021-12-16 and 2022-06-01 were chosen as typical days for field measurements. The experiments were carried out by vehicle-mounted data collection equipment with GPS while driving constantly. Based on the results of the field measurements, 105 sample points were measured at the study site in winter and 105 in summer. Using a sample method, a circular buffer zone with different radius was created at the center of these sample points to investigate the correlation between various influencing factors and air temperature.

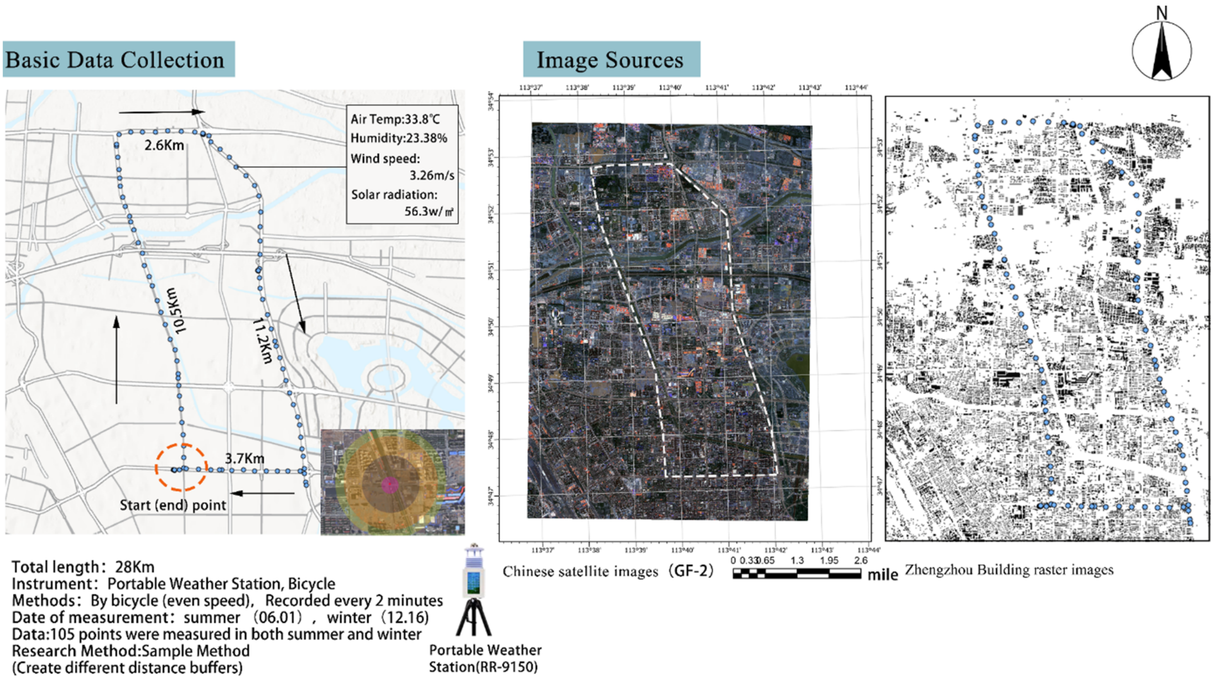


Figure 8 Data Collection

3. Data Processing

3.1 Selection of Seasons

Zhengzhou has a warm temperate sub-humid monsoon climate. The four seasons are distinct, with rain and heat in the same period and dry and cold in the same season. With the change of the four seasons, the essential climatic characteristics of spring are dry with little rain, summer is hot and rainy, autumn is sunny with long sunshine, and winter is cold with little rain and snow. The seasonal characteristics change more obviously. The contrast is higher when summer, the highest average temperature of the year, and winter, the lowest average temperature, are selected as the study seasons. Therefore, picking winter and summer as the study seasons has research value.

3.2 Selection of Influence Factors

In general, the factors widely concerned in the study of urban air temperature can be broadly classified into the following three categories: (1) surface biophysical parameters. Due to the richness of land use and land cover information, surface biophysical parameters have been widely used in urban air temperature-related analyses. For example, the normalized difference vegetation index (NDVI) and normalized difference water index (NDVI) shows an excellent linear relationship with urban temperature. (2) Landscape composition, diversity, and configuration factors. Urbanization has dramatically changed urban landscapes' structural composition, diversity, and spatial patterns. Landscape components characterize the different compositions and richness of landscape types and are usually quantified regarding the proportion of land cover types. (3) Socio-economic factors. Most changes in the natural landscape result from human activities, and the influence generated by socio-economic factors should also be considered in the study of air temperature.

Previous studies should have considered the effects of green landscapes, water bodies, landscape patterns, and socio-economic factors on urban air temperature in an integrated manner. Therefore, in this paper, 12 influencing factors were selected as the explanatory variables of seasonal air temperature comprehensively among the three major categories of factors, respectively. On this basis, the strength of the influence of urban landscape features on urban air temperature at different distances was analyzed.

3.2.1 Green Space, Water, and Bare Ground

Green space area is widely proven to have a nonlinear relationship with surface cold island intensity and radiation effect, i.e., the power of green space cold island gradually increases as the green space area increases[28]. Therefore, it is reasonable to select green space area as a research indicator to explore the scale correlation with air temperature. In this study, the supervised classification tool of ENVI5.3 software was used to classify green areas into high and low vegetation and to explore the different strengths of the effects of trees and scrub on air temperature. Surface biophysical parameters, which contain a large amount of spectral information and are easily accessible from remotely sensed images, are often considered influential factors in surface temperature studies. In particular, NDVI is one of the most widely used indices to characterize vegetation cover[29]. NDVI (Normalized Difference Vegetation Index), or standardized vegetation index, commonly uses remotely sensed images in vegetation and plant phenology studies. It is the best indicator of plant growth status and spatial distribution density of vegetation. NDVI can reflect the background influence of plant canopy, such as soil, wet ground, dead leaves, coarse super, etc., and is related to vegetation cover. $-1 \leq NDVI \leq 1$, negative values indicate that the ground cover is cloud, water, snow, etc., and highly reflective to visible light; 0 indicates the presence of rocks or bare soil, paved, built-up, etc., and NIR and R are approximately equal; positive values indicate the presence of vegetation cover, and increase with increasing cover. NDVI is proportional to the coverage of surface vegetation. For the same vegetation, the more extensive the NDVI, the higher the range of surface vegetation and the better the vegetation growth. Therefore, this paper selects the green area percentage and NDVI as influencing factors to investigate the dominant role of green areas on air temperature at different scales.

NDWI was proposed by McFeeters (1996) to characterize surface water coverage information and is a sensitive index for detecting surface temperature changes[30]. NDWI (Normalized Difference Water Index), which is a normalized difference process using specific bands of remote sensing images to highlight the water body information in the photos, is generally used for It is usually used for water content in the study area. Therefore, this influence factor is chosen in this paper to investigate the strength of NDWI's influence on air temperature. (Table 1)

The study shows that the distribution of large areas of bare soil on the surface seriously affects the regional ecological environment. One of the manifestations of this is the increase in surface temperature. The surface temperature will increase with the rise of bare soil. Therefore, this paper selects the proportion of bare land in the buffer zone as one of the influencing factors and tries to investigate whether the proportion of bare ground in the city impacts air temperature and the strength of the correlation between it and air temperature.

Table 1 Surface biophysical parameter calculations.

Surface biophysical parameter	Equation	Parameter interpretation

NDVI	NDVI $=\frac{(NIR-R)}{(\mathrm{NIR+R})}$	NIR is the reflection value in the near-infrared band, R is the reflection value in the red band
NDWI	NDWI$=\frac{(\mathrm{Green-NIR})}{(\mathrm{Green+NIR})}$	Green is the light green band; NIR is the near-infrared band.

3.2.2 Impermeable Surfaces and 2D/3D Building Metrics

A distinctive feature of accelerated urbanization is the rapid expansion of urban impervious surfaces, the increasing area and density of various types of buildings and structures in urban construction, the transformation of many natural characters into impervious surfaces, and the dramatic changes in urban landscapes[31]. Therefore, the study of the impact of impervious surface coverage changes on the urban thermal environment has a specific guiding significance for optimizing the urban ecosystem. As the most prominent artificial surface feature in cities, impervious surfaces refer to land cover surfaces that prevent water from infiltrating the soil, mainly including impermeable surfaces such as building roofs, parking lots, and highways. Numerous studies have shown that impervious surfaces exhibit significant correlations with the urban thermal environment, including linear and nonlinear positive correlations[32]. Therefore, this paper selects the percentage of impervious surfaces in the buffer zone as an indicator to investigate how impervious surfaces affect air temperature at different distances.

With accelerated urbanization, the three-dimensional urban form and its ecological effects have received increasing attention, and in-depth studies on the multi-scale impacts of 2D/3D building forms on urban air temperature still need to be improved. Building height standard deviation (BHSD) can reflect the level of building height variation in a particular area and the building roughness in the area, which is meaningful for studying urban air temperature. Floor Area Ratio (FAR) can reflect the intensity of land use in the area; the higher the FAR, the denser the houses and the lower the living comfort. Therefore, this paper selects two-dimensional and three-dimensional building form indicators (average building height, building coverage, standard deviation of building height, and floor area ratio) to explore their effects on air temperature.

Table 2 2D/3D building morphology impact factors.

Name	Abbr.	Description	Formulas
Building coverage ratio	BCR	The building coverage ratio of the buffer.	$BCR=\frac{\sum_{i=1}^{n} BS_i}{S_{site}}$
Mean building height	MBH	Mean building height in the buffer zone	$MBH=\frac{\sum_{i=1}^{n} BS_i \times BH_i}{\sum_{i=1}^{n} BS_i}$
Building height standard deviation	BHSD	Variation degree of the buildings of the buffer.	$BHSD=\sqrt{\frac{\sum_{i}^{n}(BH_i-BH)^2}{n}}$
Floor area ratio	FAR	Building capacity on land in the buffer.	$FAR=\frac{\sum_{i=1}^{n} c \times F}{S_{site}}$

BS_i: building projected area in the buffer zone. n: the number of buildings in the buffer. $Ssite$: area of the buffer. BH_i: height of building. F: The floor of the building. c: constant.

3.2.3 Meteorological Factors

Environmental scientists define the term 'microclimate' as a collection of 'local area climatic conditions' (temperature, wind speed, humidity, solar radiation, etc.), usually close to the ground and at a spatial scale directly related to ecological processes. The manifest microclimate indicators include temperature, wind speed, humidity, solar radiation, etc. Among them, air temperature is the main factor of the microclimate environment, which directly affects human working mood, fatigue, and physical health. In this paper, I set air temperature as the dependent variable and wind speed, humidity, and solar radiation intensity as independent variables and investigate how they interact at different scales and seasons.

(1) Air humidity

Humidity is also called air humidity. It refers to the amount of water vapor in the air. In summer, the temperature is high, and the humidity is high; in winter, the temperature is low, and the humidity is low. Humidity and temperature constitute inseparable environmental factors that have received little attention. In urban life, the amount of humidity due to water evaporation and vapor emission is generally expressed in terms of relative humidity, which is the percentage of the ratio of the actual amount of water vapor to the saturated amount of water vapor in the air at a specific temperature, directly reflecting the degree to which the air is saturated with water vapor. Under a particular temperature, the smaller the relative humidity, the faster the water evaporates. High temperatures and high humidity make people feel hot and stuffy; low temperatures and high humidity make people feel cold and gloomy.

(2) Air velocity (wind speed)

The rate of air movement relative to a fixed location on Earth is called the wind speed (m/s) and is one of the main factors in evaluating microclimate conditions. Wind speed is often used to measure the speed of outdoor air movement. The urban planning process seeks to improve the natural ventilation of the urban fabric. As pointed out in several scientific works, inaccurate urban expansion leads to changes in climatic parameters, including temperature comfort. Therefore, the wind speed was chosen as one of the meteorological factors to investigate its correlation with air temperature.

(3) Solar radiation

Atmospheric absorption, reflection, and scattering of solar radiation significantly weaken the solar radiation reaching the ground. However, many factors still affect the strength of solar radiation, so the amount of solar radiation reaching different areas varies. Solar radiation is the driving force of the earth's atmospheric motion and is the primary energy source for climate formation. Studies by many scholars have confirmed that the intensity of solar radiation in cities directly affects the level of urban air temperature. After the ground absorbs the sun’s heat energy, the environment transmits heat through radiation, conduction, and convection, the primary source of air heat. In contrast, the part of solar radiation directly absorbed by the atmosphere that increases the air heat is tiny and can only make the temperature rise 0.015~0.02 ℃. It can be seen that solar radiation is the direct cause of the daily variation of surface temperature, which in turn is the direct cause of the daily variation of air temperature.

Based on the meteorological data measured in the field, this paper investigates whether there is a direct interaction between meteorological factors such as wind speed, humidity, and solar radiation and urban air temperature using statistical and correlation analysis. This paper provides an essential theoretical basis for the proposed optimization strategies to mitigate the urban thermal environment problems.

Table 2 Influencing factors of air temperature were used in this study.

Categories	Influence factors	Meaning of influence factors
Green space	Green coverage ratio (%)	Percentage of green area in the buffer
	Normalized Difference Vegetation Index (NDVI)	Detection of vegetation growth status and coverage
Architecture	Impermeable surface ratio	Percentage of the impervious area in the buffer
	Building coverage ratio (BCR)	The building coverage ratio of the buffer
	Mean building height (MBH)	Mean building height in the buffer
	Building height standard deviation (BHSD)	Variation degree of the buildings of the buffer
	Floor area ratio (FAR)	Building capacity on land in the buffer
Water	Normalized Difference Water Index (NDWI)	Detection of a water body feature
	Water ratio	Percentage of water area in the buffer
Meteorological	Wind Speed (m/s)	The rate of motion of air relative to a fixed location
	Humidity (%)	Water vapor content in the air
	Solar Radiation (w/m^2)	The radiant energy of solar energy is delivered to various places

3.3 Influence Factor Extraction

(1) ENVI5.3 Software - Supervised Classification Tool

Supervised classification, also called training classification, is the process of using the sample image elements of the identified category to identify the image elements of other unknown types. The computer calculates the statistical or other information of each training sample area and, at the same time, uses these seed categories to train the judgment function so that it meets the requirements for classifying various subcategories, and then uses the trained judgment function is then used to classify the other data to be organized. The trained judgment function is then used to classify the additional data to be classified.

Each image element is compared with the training sample and ranked into the most similar sample class according to different rules, thus completing the classification of the whole image.

The pre-processed and cropped 2017 GF-2 remote sensing image of Zhengzhou city was used as the base image. The training area was first selected using the Region of Interest tool in ENVI5.3 software for remote sensing images. The landscape types in the main urban area of Zhengzhou mainly include green spaces, buildings, water, bare land, impervious surfaces, etc. In this paper, green places are classified into high-vegetation green areas and low-vegetation、 green areas, and impervious surfaces are classified into roads and buildings in the supervised classification step. Then the maximum likelihood method is chosen as the classification method. After the classification, the images are processed with small patches to increase the image smoothness of the classification results and accuracy.

After the supervised classification process, the classified images are imported into ArcGIS software, and the area extraction tool within the area is used to obtain the vegetation coverage (Green area-per), high vegetation-per, low vegetation-per, and impermeable surface ratio (Impermeable-per) within the buffer zone at different distances.

(2) Building raster image - Building morphology index extraction

There are four building form indicators selected for this study: building coverage ratio (BCR), mean building height (MBH), building standard height deviation (BHSD), and building volume ratio (FAR).

How can the Building Coverage Ratio (BCR) be calculated in the buffer zone? Based on the building raster image, the total number of image elements in each buffer zone and the image element size (2m*2m) of the building raster image of Zhengzhou City are counted first. The total building area is divided by the buffer zone area to get each buffer zone's building coverage ratio (BCR).

How can the mean building height (MBH) and building height standard deviation (BHSD) be calculated in each buffer? Using the 'Show Partition Statistics in Table' tool in ArcGIS software, the 'Mean' and 'Standard Deviation' were calculated for the building raster images of Zhengzhou City under different distance buffers. The average building height value and standard deviation of building height were calculated.

How to calculate the building floor area ratio (FAR) in each buffer zone, First, convert the building raster image into a vector image (shp. image), and use the calculation tool to count the floor and area of each building in the buffer zone, get the land intensity in each buffer zone, divide it by the buffer zone area, and finally get the building floor area ratio.

(3) Extraction of surface biophysical parameters (NDVI, NDWI)

Using SNAP software, the remote sensing images of Zhengzhou City were processed to obtain the surface biophysical parameters (NDVI, NDWI) needed for this paper.

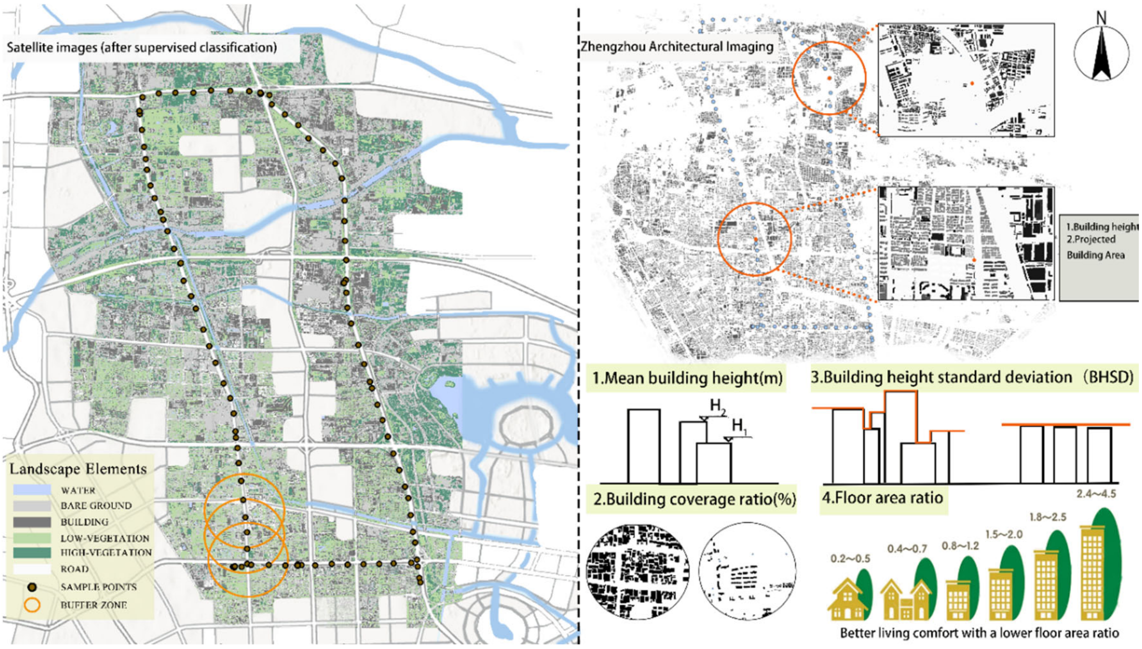


Figure 9 Influence factor extraction

4. Analysis and Results – Statistics

In the data analysis phase, the calculation results of each impact factor are summarized in tabular form for different distance buffers in summer and winter. The results of the data analysis phase are statistically presented in this chapter. Pictures such as bar graphs and histograms are drawn visually to statistically characterize the spatial distribution of these impact factors at this study site. A more intuitive way to understand the climate change characteristics and landscape distribution features of the study site provides more comprehensive basic data for the subsequent study of the contribution of each influence factor to the air temperature at the sample sites. In this chapter, firstly, the distribution characteristics of the influencing factors are statistically presented to facilitate a more comprehensive macroscopic understanding of the study site. Secondly, to better understand the change of the study site from the central city to the suburban area, I screened 40 sample points, which spread along the urban center to the periphery of the city. Based on each influence factor, I conducted statistics (represented by bar graphs) on these sample points. This lays the foundation for analyzing the results of the subsequent study.

4.1 Overall Situation of Influence Factors

This paper presents statistics on the overall situation presented by each impact factor in the study area, which is conducive to a better understanding of the overall condition of the site.

4.1.1 Building and Impermeable Surface

Firstly, I extracted the building morphological indicators (BCR, MBH, BHSD, FAR) and the percentage of impervious surfaces in the buffer zone based on remote sensing images and building raster images of the central city of Zhengzhou. One hundred five air temperature sample points were measured in winter and summer field measurements, and the sample points were used as the center to create buffer zones of different distances.

Most of the building coverage under the 50m buffer zone was less than 5%, which manual measurements may cause, and the measurement route was chosen on the sidewalk of the main urban road due to the mobile observation method. With the measured air temperature sample point as the circle's center, the buffer zone was set with a small radius and far from the surrounding buildings, so the building coverage was low within the 50m buffer zone. As the distance of the buffer zone increases, the building coverage is mostly between 10%-30% under the buffer zone with a radius of 100m-1000m. There are also individual sample points with building coverage higher than 40%.

With 105 sample points as the center, most of the average building heights in the buffer zone are in the range of 10m-60m, and there are also some very tall buildings around 100m.

Based on the building coverage and average building heights, the study area is more densely covered by buildings, with more middle and tall buildings and deeper urbanization. Volume ratio refers to the building capacity per unit land area, i.e., the ratio of building space to site area. For developers, the plot ratio determines the proportion of land cost in the housing, while for occupants, the plot ratio is directly related to the comfort of living. An excellent residential community should have a floor area ratio of no more than 5 for high-rise residential buildings, no more than 3 for multi-story residential buildings, and a green space ratio of no less than 30%. However, only some projects can do so due to the limitation of land costs. Volume ratio is an important index to measure the intensity of construction land use. The lower the volume ratio, the higher the comfort level of residents, and vice versa. Most building volume ratios in the study area are below 5, and most are between 0 and 5. There are some areas where the plot ratio is greater than 5. Therefore, the overall land use in the area is good, but some places have high land use intensity and soft comfort of residents.

Impervious surface is the most significant feature of urbanization. By counting the percentage of impervious surfaces (mainly including building roofs, parking lots, roads, etc.) in the buffer zone, it was found that the rate of impervious surfaces around most of the sample sites ranged from 10% to 50%. With the expansion of the statistical distance around the sample points, the percentage of the impervious surface around most of the sample points ranged from 20% to 40% in the 100m-500m buffer zone and up to 50% in the 750m-1000m buffer zone, with some areas having impervious surface ratios higher than 60%. The percentage of urban impervious surfaces directly impacts urban air temperature, and reducing the rate of urban impervious surfaces is an important measure to alleviate urban thermal environment problems.

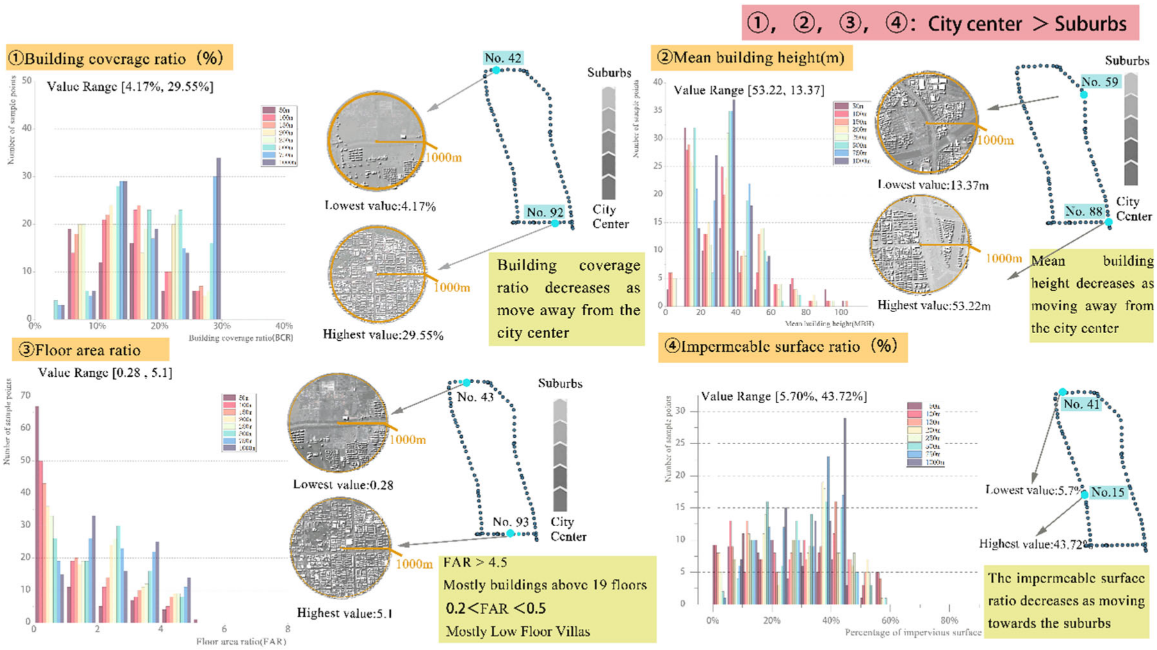


Figure 10 Overall Statistics of Architectural Influence Factor

4.1.2 Green Space and Water

This chapter counts the percentages of green cover and water within different buffer zones. Most of the areas in this study area have a green body between 20%-45%, where the proportion of high vegetation (e.g., tall trees, shrubs, etc.) is between 10%-30%, and the balance of low vegetation (e.g., ground cover, grass) is mostly between 10%-15%. It can be seen that tall trees and shrubs are predominant in the city, with less paved vegetation and open green spaces. There are fewer open green spaces, such as lawns. Reasonably dense planting and keeping open space in the forest can increase the permeability of the urban green environment. Therefore, adjusting the proper planting of high and low vegetation in the city is essential.

Rivers also cross the study area. The main rivers distributed in the study area are the Jalu River, the Wei River, and the Dongfeng Canal. The east-west flowing rivers are the Jalu River and the Wei River, and the north-south flowing rivers are the Dongfeng Canal. There are also some tiny pools distributed in the urban species, and most of the water bodies in the buffer zone are between 0% and 5%, and the water resources in the study area are relatively scarce. However, the space around the urban water bodies has a vital openness, which provides the possibility to increase the shade of trees and achieve natural ventilation.

Rational use of the open space rivers provides well for building urban ventilation corridors.

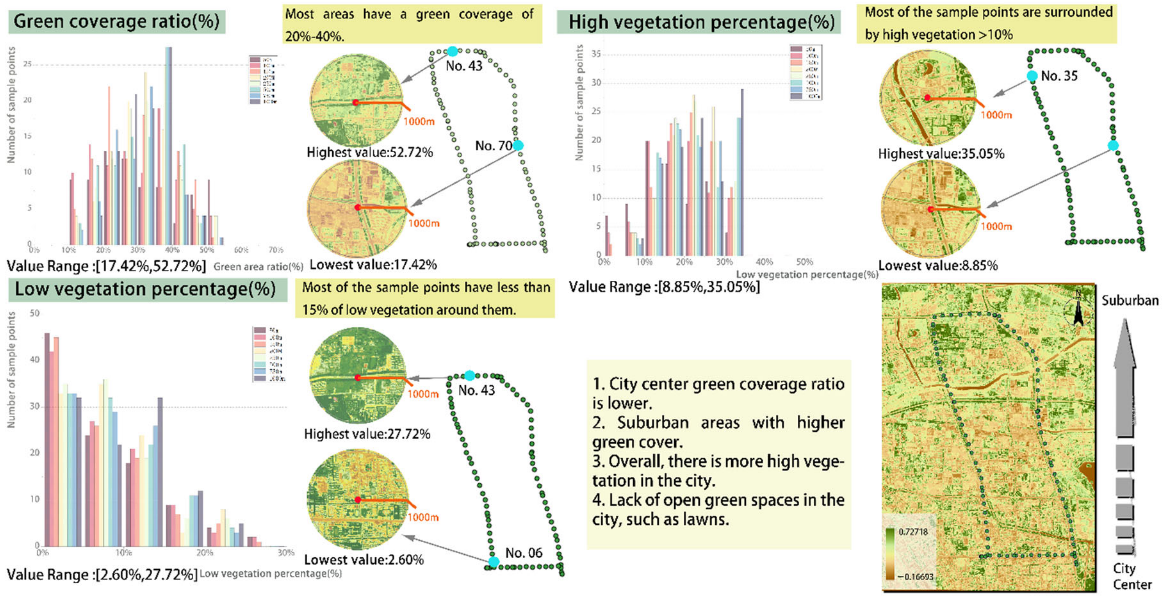


Figure 11 Overall statistics of green space influence factor

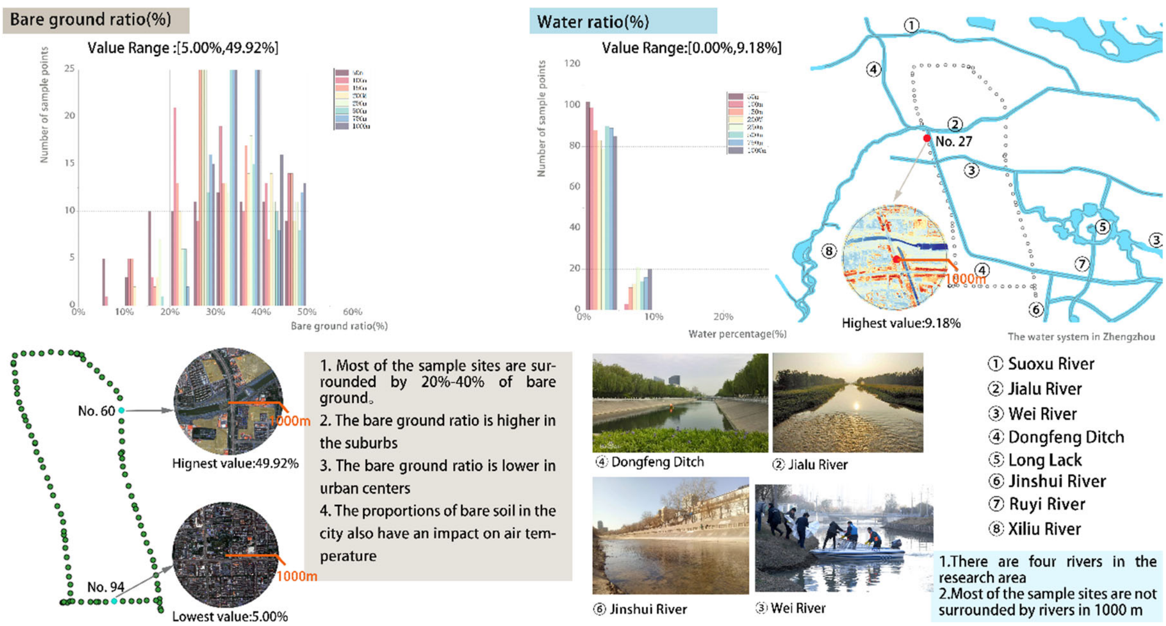


Figure 12 Overall statistics of bare ground & water

4.1.3 Meteorological Factors

The main meteorological factors affecting air temperature selected for this study are humidity, wind speed, and solar radiation. The modern urban environment and the natural environment in its original state have changed dramatically compared to the ancient urban environment, substantially changing the city's wind and air temperature characteristics.

Reducing wind speed is a characteristic of cities in the process of urbanization. The building complexes in cities increase the ground roughness, so the wind speed is generally less than in suburban areas. Most of the 105 sample locations in this study area have average wind speeds between 1m/s and 3m/s in summer and between 1.25m/s and 2.5m/s in winter. The Beaufort scale is an internationally accepted wind scale. Francis Beaufort divided the wind speed into 0-12 rankings in the early 19th century according to the magnitude of the wind's impact on the ground or the sea. Combined with the sample point data, the data were divided into the corresponding scales (Table 4). According to the wind class classification, the city has uncomfortable wind speeds.

The average absolute and relative humidity of urban air is slight in the city because the subsurface is primarily buildings and impermeable pavement, and the evaporation and transpiration are slight. Relative humidity was used in this study to measure humidity measurements. In this study area, the relative humidity around most sample sites was between 23% and 28% in summer. In winter, the average moisture around most of the sample sites was between 24%-40%, with a significant variation in humidity. According to the annual average humidity statistics of Zhengzhou City, the average relative humidity in June was 55% and 44% in December 2021, and the average relative humidity in winter was lower than in summer. This study did not consider the relative humidity trend at night in the city because the humidity measurement time was chosen during the daytime.

Weak solar radiation is also one of the urban air characteristics. Due to more sooty impurities over the city, the total annual average solar radiation is reduced by about 10-15% compared to the suburbs, and in the case of lower solar altitude angle, the UV radiation in urban areas of large cities can even be reduced by 30%, and the sunshine hours are reduced by about 5-15%. According to the solar radiation measurement results in this paper, in summer, the average daytime solar radiation around most sample points is 10 W/m^2-48 W/m^2. In winter, the solar radiation around most sample points is 75 W/m^2-125 W/m^2. There are apparent seasonal variations in the total solar radiation. The total solar radiation is the strongest in summer, and the average total solar radiation is more than double that in winter.

Table 3 Beaufort wind scale[33]

Wind Level	**Name**	**Wind speed (m/s)**	**Phenomenon description**
0	Calm	0-0.3	Quiet, smoke straight up
1	Light air	0.3-1.1	Smoke Pillars Move with the Wind
2	Light breeze	1.1-2.5	The face feels windy, and the weathervane is blown
3	Gentle breeze	2.5-4.2	The human body can feel the wind blowing
4	Moderate breeze	4.2-6.1	The human body feels uncomfortable
5	Fresh breeze	6.1-8.3	The human body can feel the wind's resistance, and the small tree starts to shake.
6	Strong breeze	8.3-10.6	Difficulty walking normally
7	Near gale	10.6-13.3	Walking inconvenience, the whole tree shaking
8	Gale	13.3-16.1	Obstacles to forward movement, difficulty in maintaining balance
9	Strong gale	16.1-18.9	People are being blown down

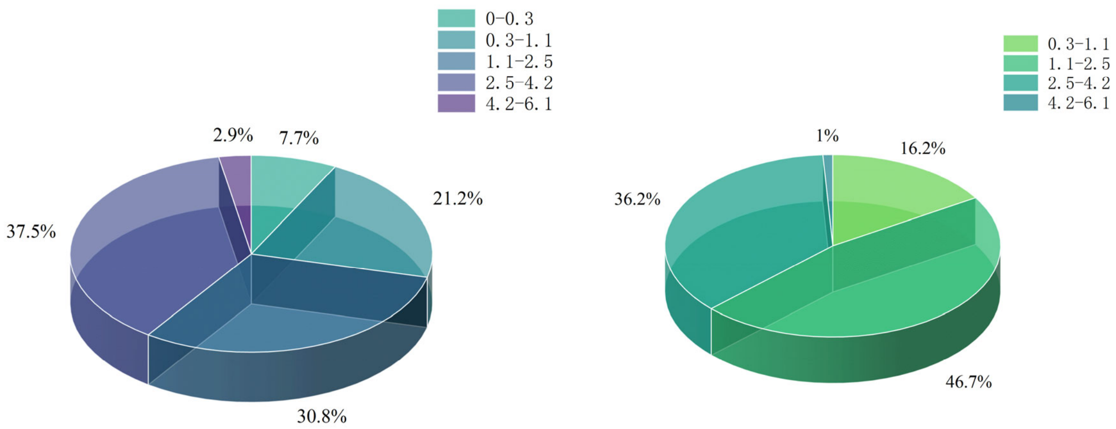


Figure 13 Summer & Winter Wind Speed Summary

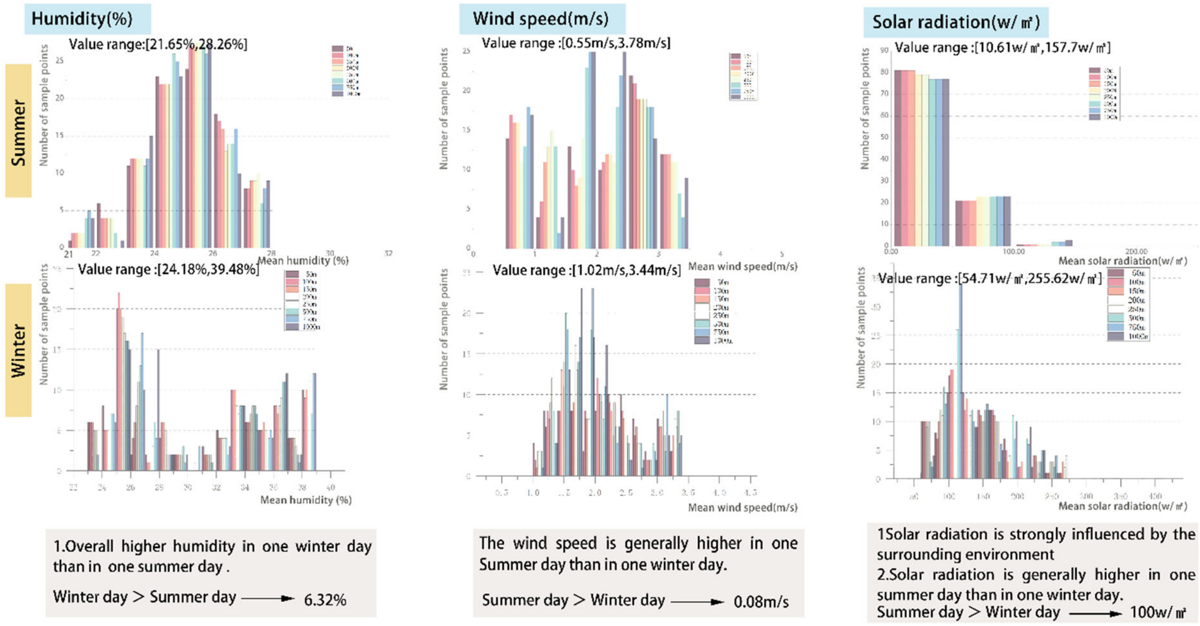


Figure 14 Overall statistics of meteorological factors

4.2 Spatial Distribution Characteristics of Influence Factors

Since the study area covers two main urban areas (Jinshui District and Huizi District), the measured sample points extend from the urban center to the suburbs to understand better the changing trend of urban air temperature from the central metropolitan area to the suburbs. This chapter summarizes the values of various impact factors in the buffer zone at different distances around all measurement points (40 in total) extending from the urban center to the periphery of the city in the study area and finds the trends of various impact factors in the process of developing from the urban center to the suburbs by analyzing the change patterns of the measured data. The figure below shows the temperature change from the city center to the suburbs during a day in winter and summer. As can be seen from the graph, the air temperature gradually increases from the city center to the suburbs during the day in summer. It progressively decreases from the city center to the suburbs during the day in winter.

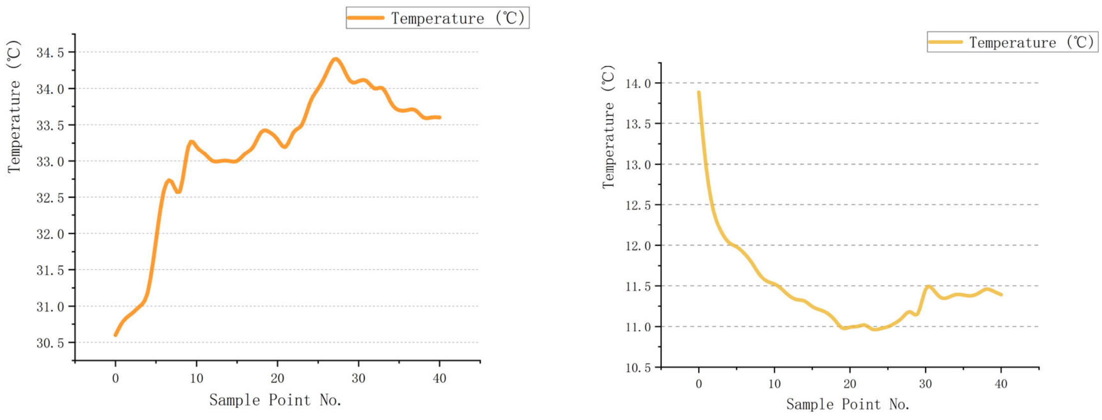


Figure 15 Summer & winter temperature trends (from urban centers to suburbs)

4.2.1 Architectural Factor

By summarizing the statistics of building impact factors in cities, this study found a significant trend change in building impact factors from urban centers to suburban areas. The average building height (MBH) does not show a significant trend change along the city center to the suburbs. Most buildings have an average height size of 20m-40m, mostly mid-rise buildings with 10-18 stories, which shows the area's high population density and high residential housing demand. The building coverage ratio (BCR) within the buffer zone decreases gradually from the urban center to the suburbs. Urbanization in the city center is significantly higher than in the suburbs, which have more unused land. The building volume ratio (FAR) in the city gradually decreases from the city center to the suburbs, and the larger the volume ratio, the lower the comfort level of the residents. It can be seen that the land intensity in the suburbs is significantly lower than that in the city center, and the land area per capita is higher than that in the city center. Hence, the residential areas in the suburbs are primarily low-rise buildings or villas, and the comfort level of the residents is higher. The building height standard deviation (BHSD) has no noticeable trend change from urban centers to suburbs. The larger the BHSD value is, the greater the building height is staggering in the city, which can describe the spatial characteristics of the city to a certain extent.

In summary, the buildings in the city center are dense, and the intensity of land use is significantly higher than in the suburbs. But the comfort of living in the urban center is lower for residents.

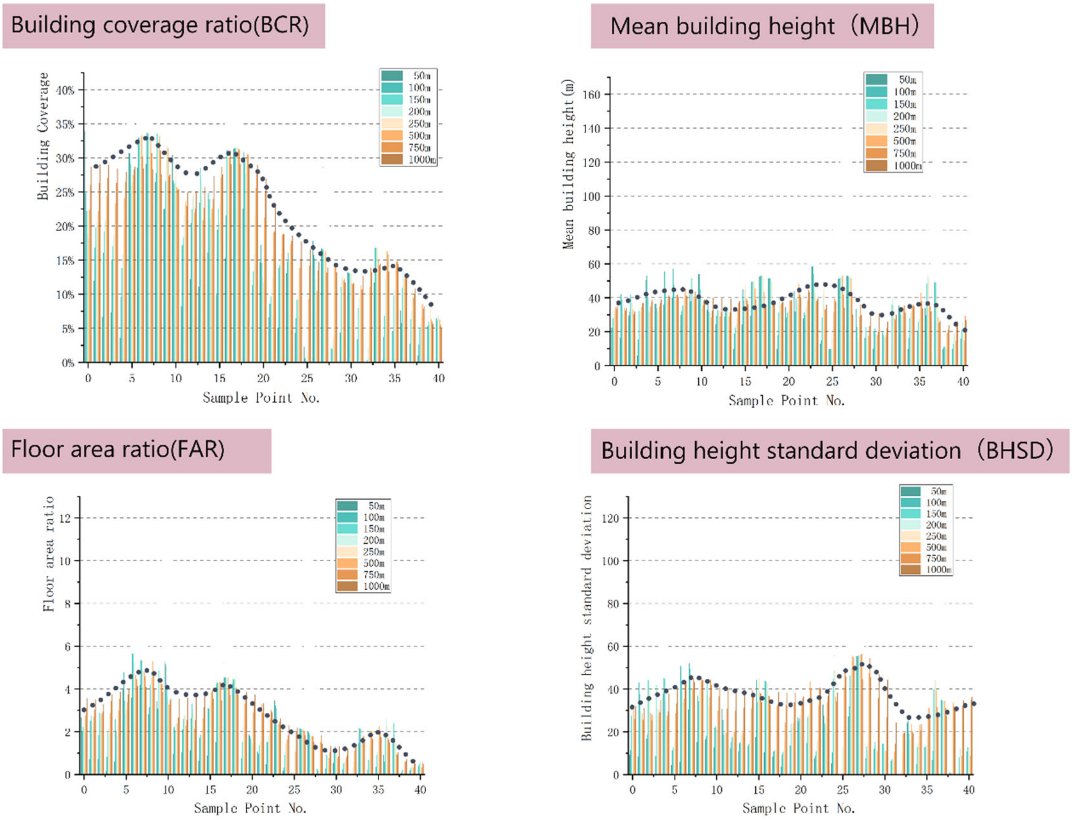


Figure 16 The trend of architectural factors (from urban centers to suburbs)

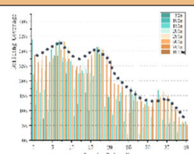
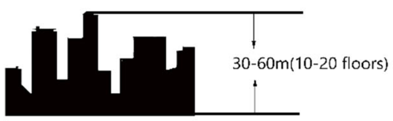
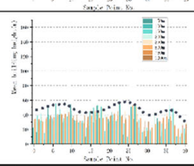
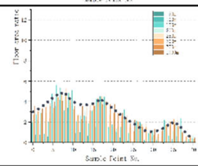
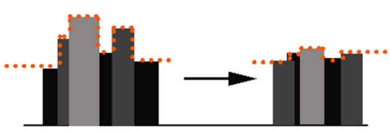
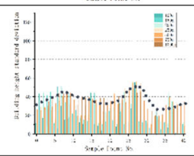
	Influence Factors	From city center to suburbs	Trends	Note
Architecture	Building coverage ratio(%)			The city center has a high density of buildings
	Mean building height（m)			Most of the buildings in the city are high-rise buildings
	Floor area ratio			Suburbs are more comfortable to live in
	Building height standard deviation			City Center Building Spatial Structure Variety

Figure 17 Architectural factor change characteristics (from urban centers to suburbs)

4.2.2 Landscape Elements

This paragraph summarizes the trends of the influence factors of different landscape elements from urban centers to suburban areas, from which some patterns are found.

This study divides the city's green spaces into high-vegetation green spaces (tall trees, tall shrubs) and low-vegetation green spaces (low shrubs, paved plants). I found that the trend of green space change from the urban center to the suburbs was independent of the season, and the direction of vegetation change during the spread along the urban center to the suburbs was the same in both summer and winter. The study found that the urban green cover increased significantly with the diffusion to the urban periphery. The high vegetation in the urban center was more significant, and the high vegetation in the suburbs was relatively small. The proportion of low vegetation increases significantly with moving to the urban periphery, which shows that the metropolitan suburbs have a larger area of open green space.

Regarding the proportion of bare land, according to the results of the study, it is found that the rate of bare land in suburban areas is higher than that in urban centers, which is closely related to the level of urbanization development. The urbanization development process in urban centers is faster than in suburban areas. The intensity of land use in urban centers is more significant than that in suburban areas, so the percentage of bare land in suburban areas is higher. According to the study, large areas of bare ground also significantly affect urban air temperature, which further explains that the air temperature in suburban areas is higher than in urban centers during the summer day.

Regarding the percentage of impervious surfaces, I found that the rate of impervious surfaces in the city decreases substantially as I move toward the urban periphery. This corresponds to the more significant percentage of bare land in the suburbs in the above content. In general, urban centers are significantly more urbanized than suburban areas.

The proportion of water depends mainly on the distribution of urban water systems. I found that the water bodies are mainly distributed outside the city's third and fourth rings, from the city center to the suburbs. Three rivers run through this area (Dongfeng Canal, Jalu River, and Wei River), so the proportion of water around the sample points distributed in this area is high. It is well known that rivers positively affect regulating urban air temperature.

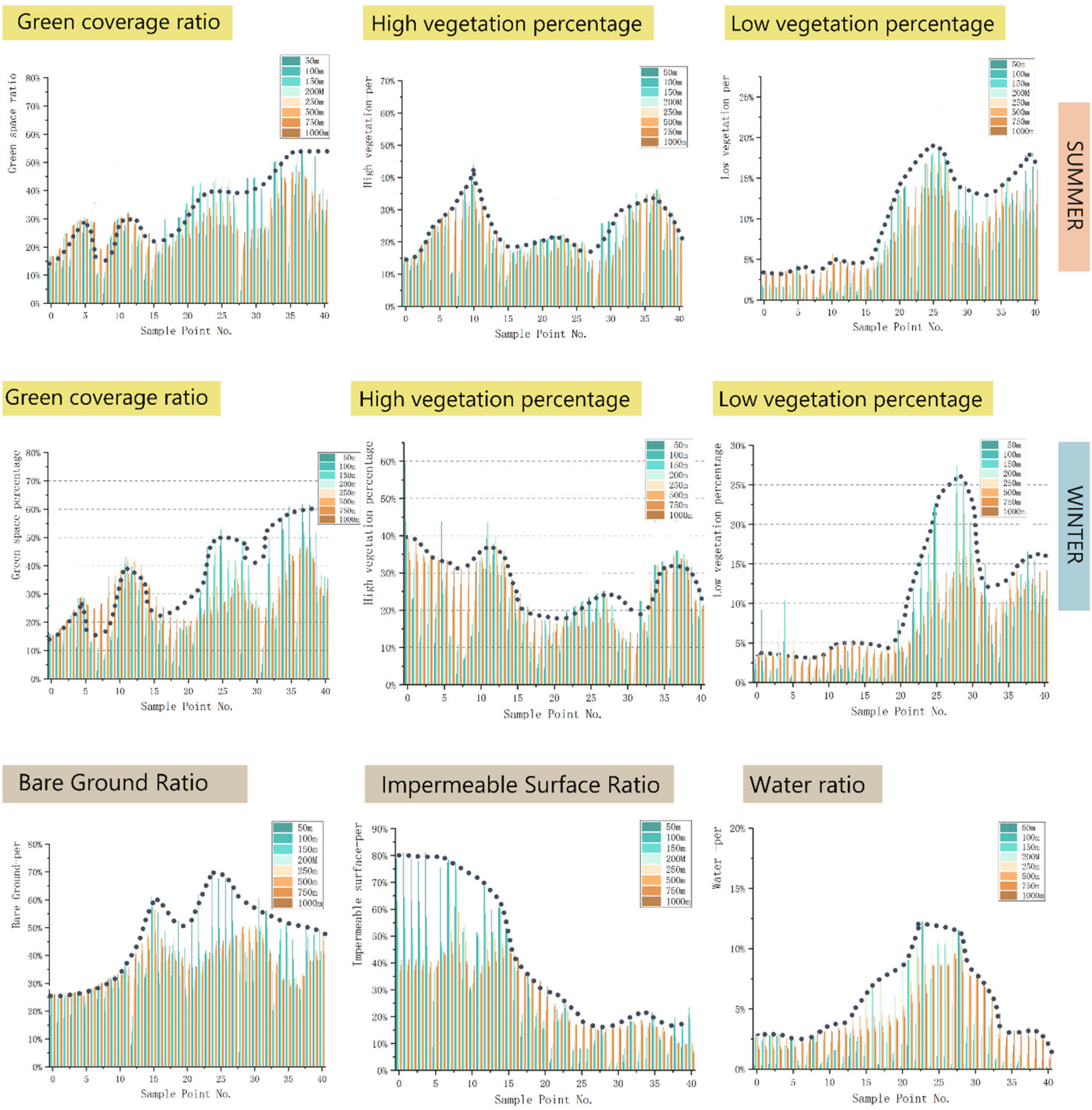


Figure 18 Trends in landscape elements (from urban centers to suburbs)

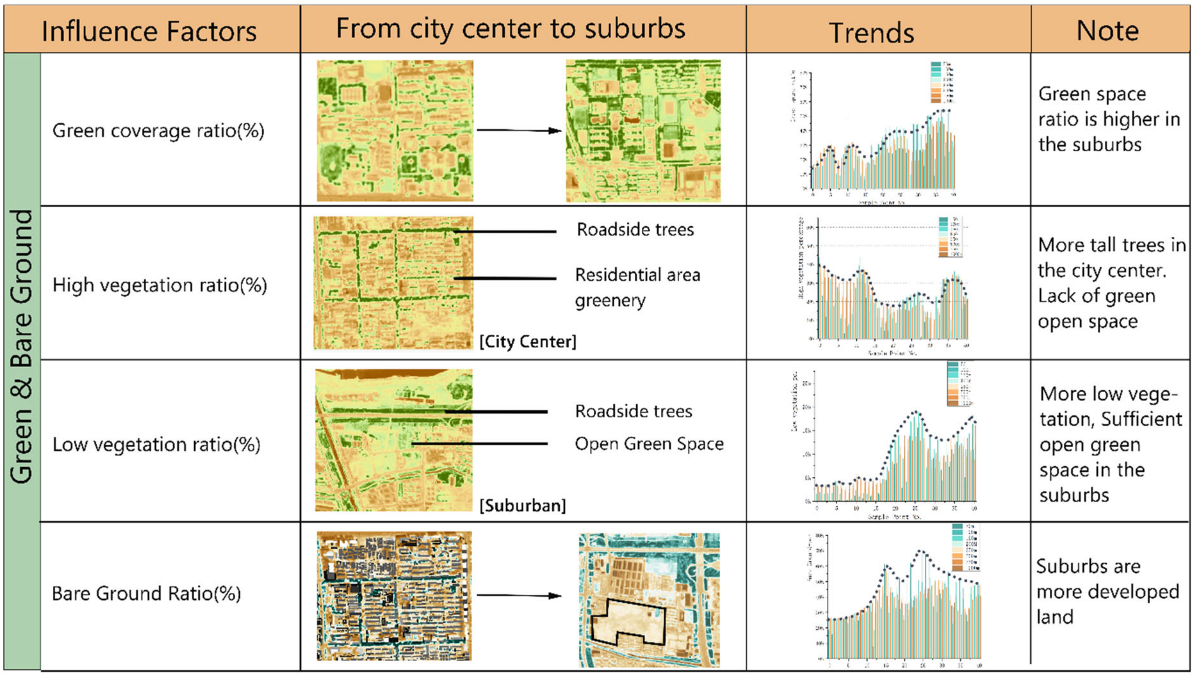


Figure 19 Landscape elements change characteristics (from urban centers to suburbs)

4.2.3 Meteorological Factors

Based on the results of field measurements, I summarized the mean values of meteorological factors within the buffer zone of each sample site. I found a clear trend of meteorological factors in the city as well.

The city's humidity trend from the urban center to the suburbs shows completely different directions in summer and winter. In summer, the humidity in the urban center is highly urban peripheral and decreases as it moves toward the urban periphery. In winter, the humidity in the urban center is lower than in the urban edge and gradually increases as one moves towards the urban fringe. This may be because the high summer heat and temperature, the overall lower building density in the suburbs, the open space, and the rapid evaporation of moisture from the air cause lower humidity in the suburbs in summer.

The spatial trend of wind speed in the city during a day is independent of the season, as the histogram shows the same direction with spatial variation in winter and summer. The wind speed gradually increases as it moves toward the city’s periphery. The wind speed in the urban center is lower, the ventilation could be more efficient, and the air circulation could be better. This leads to many air pollutants, and car exhaust stays in the air, reducing air quality and affecting residents' comfort. The reason for this may be the high density of buildings in urban centers and more spatially complex surface constructions, which indirectly affect the ventilation environment of cities so that the wind speed in urban centers is significantly lower than that in suburban areas.

Solar radiation in cities also varies according to its spatial distribution. I found the same spatial distribution trend of solar radiation in summer and winter. The value of solar radiation gradually increases as I move toward the suburbs. This phenomenon may be because suburban areas have large bare land and open space, where most of the surface is under direct solar radiation. Therefore, solar radiation values are higher in suburban areas than urban centers. This also causes the temperature in the suburbs to be generally higher than in the urban centers in summer.

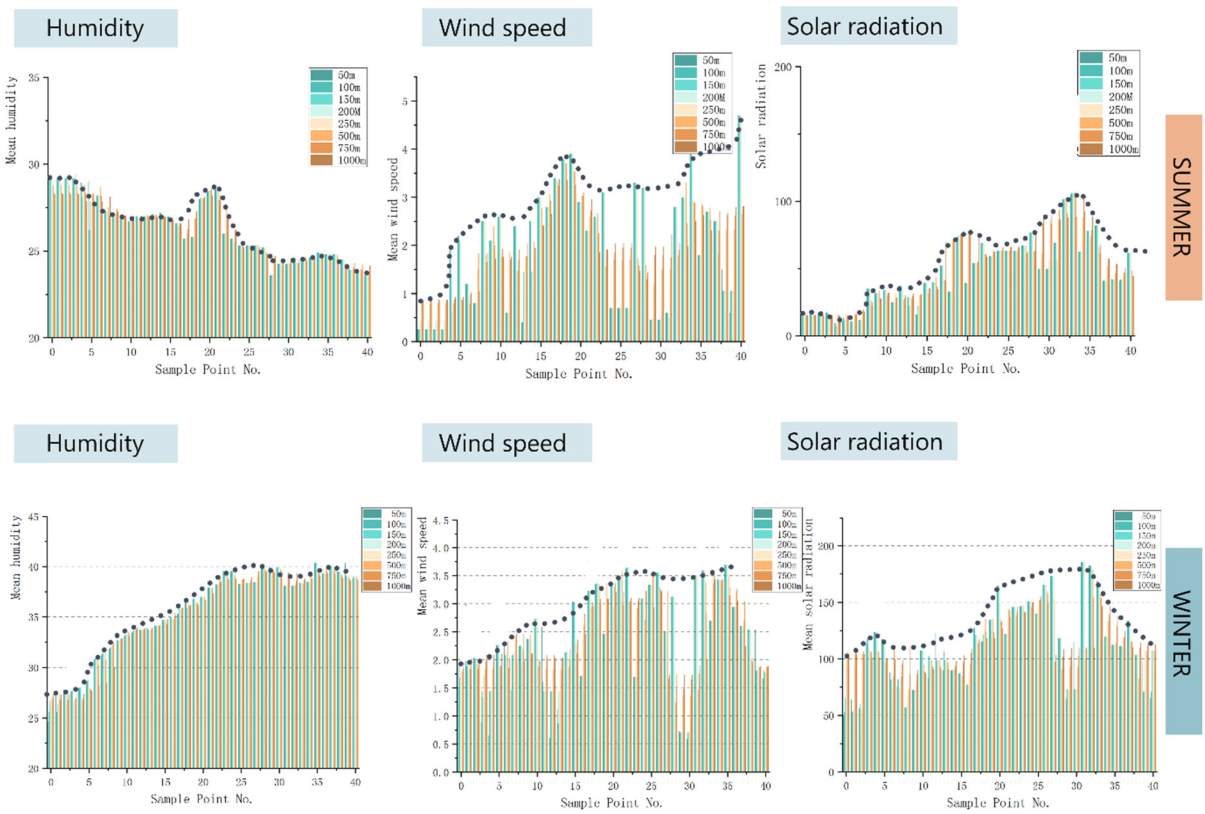


Figure 20 The trend of meteorological factors (from urban centers to suburbs)

4.3 Summary

This chapter analyzes the trends of different impact factors in the city and finds that the factors mentioned in this paper are regularly distributed. Our field study spans two main urban areas from the city center to the suburbs. Based on the results obtained from the research measurements, I found that the impact factors have a regular trend in the city. This phenomenon suggests that buildings and landscape elements such as green areas and water bodies on the urban surface significantly determine the city's structural form, which in turn affects the meteorological factors in the city and influences people's living environment. Therefore, finding the interaction between the influencing factors and air temperature is essential to improve the urban thermal environment.

5 Results and Analysis - Correlation Analysis

To clarify the contribution of different influencing factors to the air temperature at the sample sites, this chapter uses SPSS statistical analysis software. The analysis method I used is Pearson correlation coefficient analysis. In this analysis, the independent variable is the 12 influencing factors mentioned in this paper, and the dependent variable is the air temperature at the sample sites. I conducted a correlation analysis between the impact factors and air temperature in summer and winter, respectively, and found that the effect of impact factors on air temperature varies according to the season.

5.1 Summer & Result

1. Building factor

Urban building coverage strongly correlates with air temperature in summer, especially at small scales (50m-250m). The average building height in cities also affects urban air temperature, and the correlation between average building height and air temperature becomes stronger as the study scale increases. The standard deviation of building height has a more significant effect on large-scale air temperature. The higher the standard deviation of building height, the higher the urban air temperature. Similarly, the volume ratio also correlates positively with the air temperature at large scales. The higher the building volume ratio, the higher the urban air temperature.

2. Vegetation

In summer, the city's high vegetation (tall trees) significantly affects air temperature; the higher the proportion of high vegetation, the lower the air temperature. Similarly, the larger the proportion of low vegetation, the lower the air temperature. Therefore, increasing the city's vegetation proportion can effectively reduce air temperature. Improving vegetation growth conditions and vegetation status can also reduce urban air temperature, and vegetation growth conditions and vegetation status (NDVI) negatively correlate with urban air temperature.

3. Impervious surface and bare ground

In summer, the percentage of impervious surface is positively correlated with air temperature, and the larger the study scale, the stronger the correlation between the two. Therefore, reducing the percentage of impervious surfaces in the city can reduce the air temperature. The proportion of bare land is negatively correlated with air temperature, especially at large scales, so creating open space in summer can increase the rate of urban ventilation and effectively reduce air temperature.

4. Meteorological factors

Based on the measured meteorological factors data in summer, I found that relative humidity always shows a strong negative correlation with air temperature. The higher the moisture in the city, the lower the temperature. Wind speed is also negatively correlated with air temperature; the higher the wind speed, the lower the air temperature. No direct correlation was found between solar radiation intensity and air temperature regarding the choice of measurement points during field measurements. Therefore, increasing the efficiency of urban ventilation and increasing air humidity in cities can reduce air temperature.

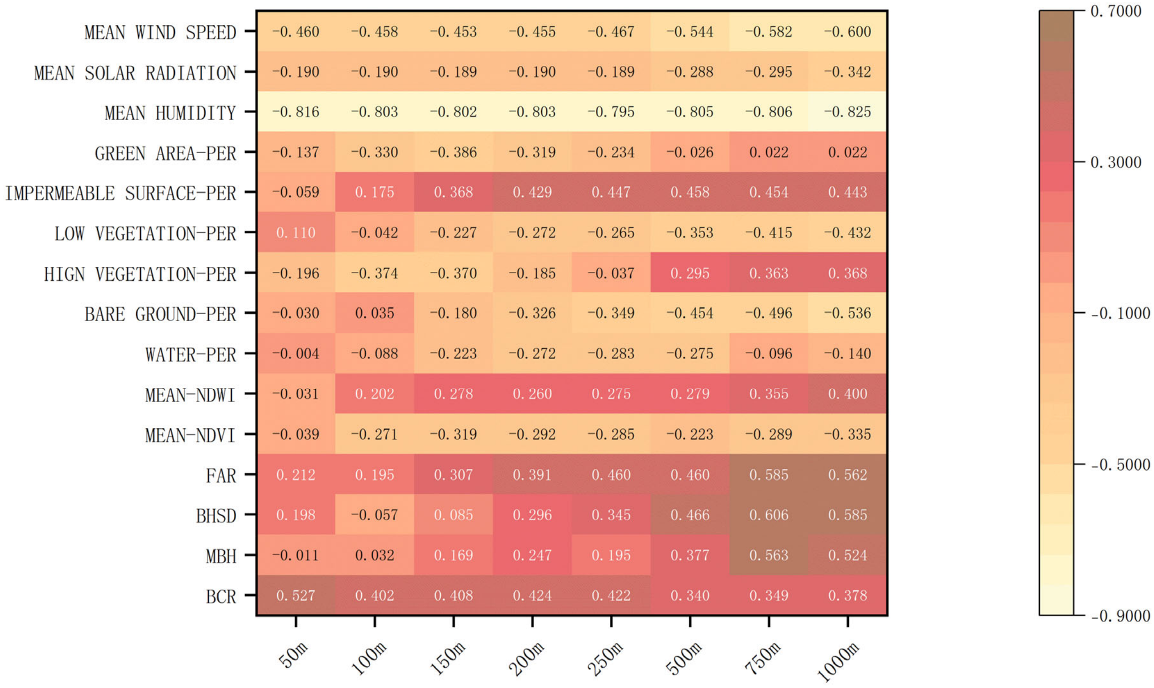


Figure 21 Correlation analysis in summer

5.2 Winter & Result

1. Building factor

In winter, building coverage was positively correlated with air temperature, and the higher the building coverage, the higher the temperature, which is the same as in summer. However, the three influencing factors of average building height, the standard deviation of building height, and the building volume ratio did not significantly correlate with air temperature. Therefore, the effect of building factors on air temperature is not significant in winter.

2. Vegetation

In winter, green space coverage significantly affects air temperature, and there is a negative correlation between them. The higher the green space coverage, the lower the urban air temperature. Among them, I found that low vegetation (grasses, shrubs) did not contribute prominently to air temperature in winter; on the contrary, high vegetation strongly correlated with winter air temperature. Vegetation growth status (NDVI) was negatively correlated with air temperature, consistent with the summer results. Therefore, improving vegetation growth conditions and optimizing vegetation status in cities can effectively reduce the air temperature in both summer and winter.

3. Impervious surface & bare ground

In winter, the percentage of the impervious surface shows a negative correlation with air temperature. The more significant the portion of the impervious surface, the lower the air temperature, which is consistent with the conclusion obtained in summer. The bare ground rate is also negatively correlated with air temperature, especially in the small-scale range.

4. Meteorological factors

In winter, the relative humidity in the air still has a strong negative correlation with temperature. Increasing the relative humidity in urban air can significantly reduce the air temperature in both winter and summer. There is a negative correlation between solar radiation intensity and air temperature; the stronger the solar radiation, the higher the air temperature. There is a negative correlation between wind speed and air temperature in winter; the higher the wind speed, the lower the air temperature. Therefore, in both winter and summer, improving the efficiency of urban ventilation can reduce air temperature.

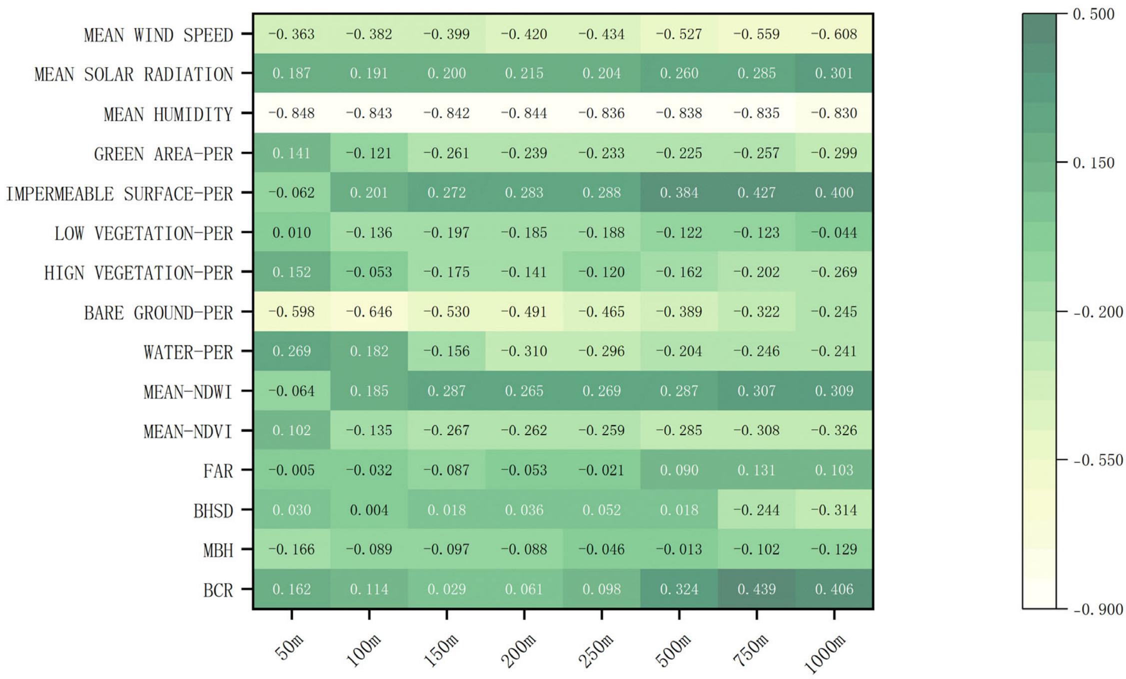


Figure 22 Correlation analysis in winter

5.3 Summary

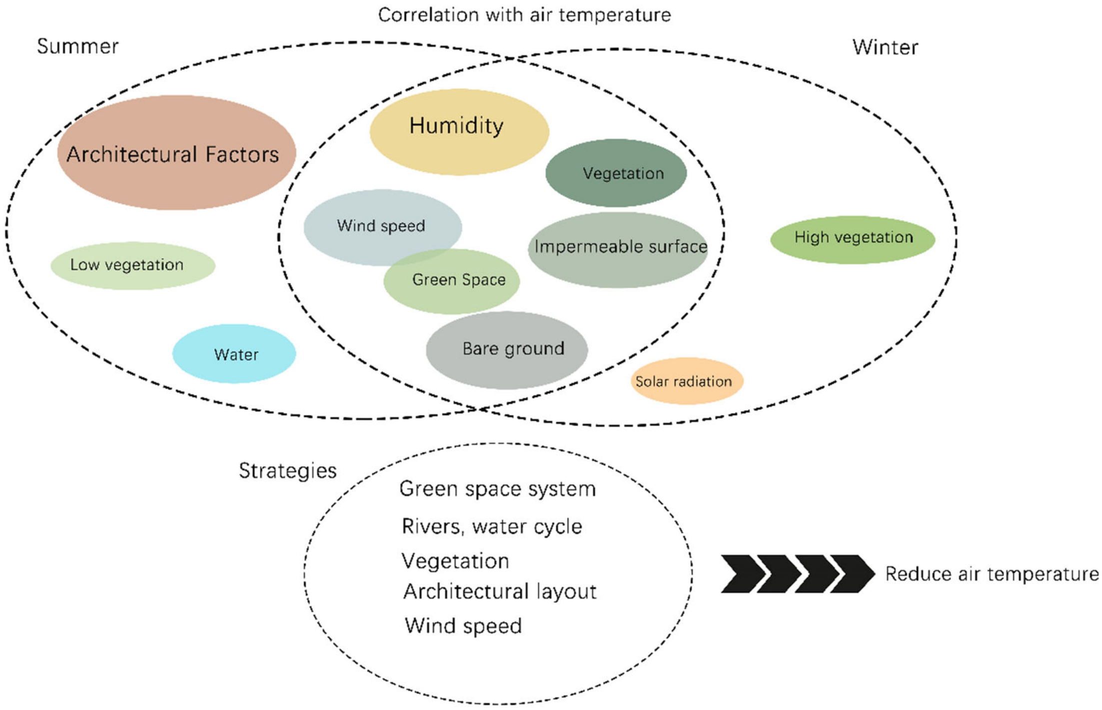


Figure 23 Linking research results to strategies

1. Conclusion analysis

The correlation between various building factors and air temperature is higher in summer than winter; therefore, adjusting the building layout and enhancing residents' living environment can reduce summer air temperature. Vegetation influence factors have an impact on air temperature, both in summer and in winter. In particular, tall trees significantly impact air temperature in summer. I suggest building open green spaces (lawns) in the city and increasing trees. The percentage of impervious surfaces in cities is the leading cause of temperature increase in both summer and winter. Therefore, strict control of the portion of impervious surfaces in cities is essential to mitigate the heat island effect. The bare ground rate in cities also impacts air temperature. I suggest that open space be preserved adequately in cities (by planting lawns on the bare ground surface) and avoiding large areas of bare soil. This will maintain the open space's ventilation capacity and increase the green space coverage. Among the meteorological factors, humidity is always an essential factor affecting air temperature in winter or summer.

2. Research Results and Strategies

Therefore, in the subsequent proposed urban planning optimization strategy, I decide the focus direction of the urban optimization strategy based on the strength of the correlation between individual influence factors and air temperature in the study results (Image 23). As can be seen from the figure, the building influence factor strongly influences air temperature in summer. Still, the correlation between the building factor and air temperature is insignificant in winter. Low vegetation percentage significantly correlates with air temperature in summer, and high vegetation percentage correlates with air temperature in winter. Therefore, improving urban green space and enhancing vegetation conditions will be one of the strategies in the follow-up strategy. The percentage of water also shows a correlation with air temperature, so improving the urban water circulation system and reusing water resources will be one of the follow-up strategies. Urban wind speed negatively correlates with air temperature in winter and summer. The higher the wind speed, the lower the urban air temperature. In the strategy, I consider wind speed and building layout together to increase the urban ventilation rate by changing the urban building layout, thus reducing the air temperature in the urban center. The overall strategy will generally propose detailed solutions through three aspects: water system, green space system, and ventilation corridor.

6 Optimization Strategies

6.1 Current Situation

I reviewed the《 Zhengzhou Planning Technical Management Regulations 》and compared the results of existing studies. I found a gap between the current situation and the critical value, supporting the above conclusion. I found that in terms of buildings, the average floor area ratio in the city is higher than the critical value specified in the regulations, so there is a real problem of poor living environment. The green space impact factor is generally lower than the critical value, increasing the green space coverage and improving the vegetation growth conditions. The percentage of water in the city is down.

The overall wind speed in the town is within the range of human comfort. Still, the humidity does not reach the standard of human comfort, and the solar radiation in local areas is far above the comfort standard. Therefore it is essential to improve the efficiency of urban ventilation, increase the humidity of the air, and increase the shading rate, thus reducing solar radiation.

Data source《Zhengzhou City Planning Management Technical Regulations》2019

	Influence Factors	Threshold	Current Situation(Mean value at 1000m buffer)		Comments
Architecture	Building coverage ratio (%)	≤20%	19.50%	√	Reach the standard
	Mean building height (m)	≤80m（Single building）	＜53m（Single building）	√	Reach the standard
	Floor area ratio	≤2.9	＜5.9	!	Low living comfort
	Impermeable surface ratio（%）	≤60%	43.6%	√	Reach the standard
Landscape Elements	Green coverage ratio (%)	≥35%	32%	!	Low green space ratio
	Normalized Difference Vegetation Index	-1≤NDVI≤1	0.14≤NDVI≤0.26	!	Poor vegetation maintenance
	Water ratio	5%	2.7%	!	Low water ratio
Meteorological Factors	Wind Speed (m/s)	0≤Wind Speed ≤4.2	0.55≤Wind Speed ≤4.43	√	Reach the standard
	Humidity (%)	30%≤Humidity≤40%	21.65%≤Humidity≤39.48%	!	Dry air, low comfort
	Solar Radiation (w/㎡)	58.2≤Solar Radiation ≤116.4	10≤Solar Radiation ≤255	!	Low shade area

Summary

①The main problems of the city are poor living environment, low green space rate, and lack of landscape elements.

② The enhancement strategy will focus on green space systems, Architectural layout, and River systems at a large scale

Figure 24 Comparison of Threshold and Current Situation

6.2 Case Studies

6.2.1 Microclimate Community Adaptation Creation in South China

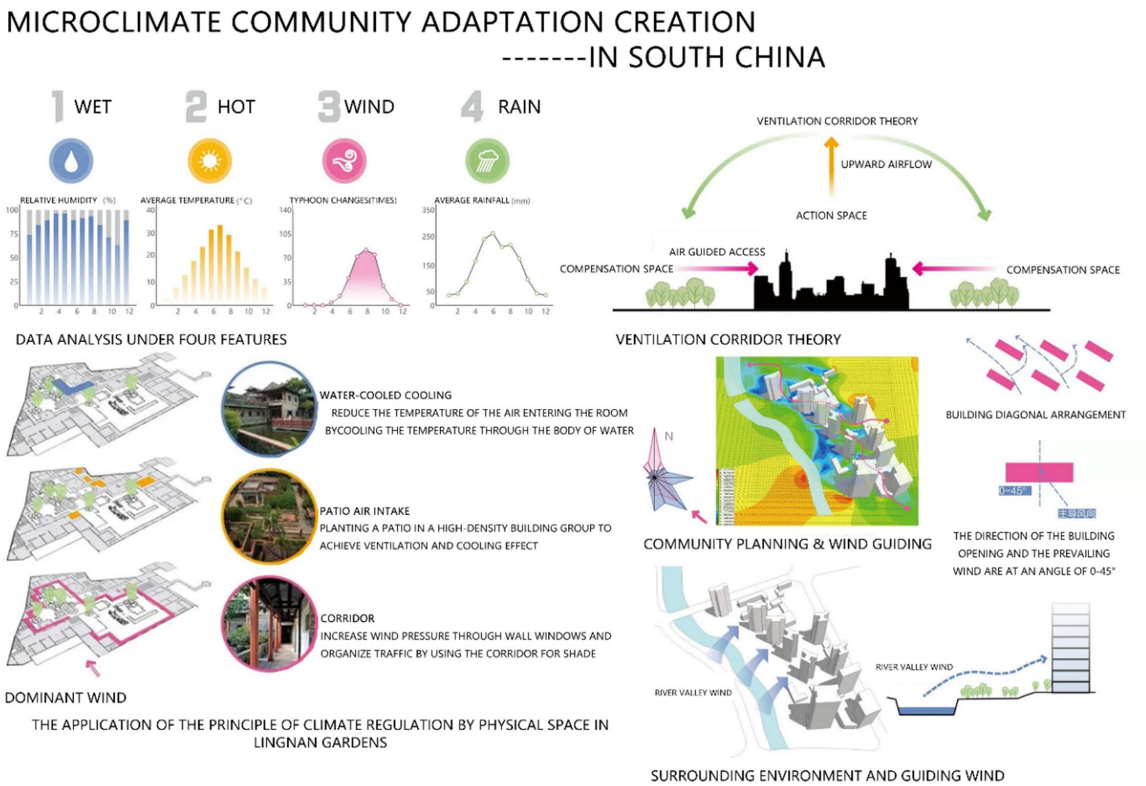


Figure 25 Case Study Ⅰ

1. Project Introduction

The climate characteristics of South China in China - hot, humid, and stormy- belong to the tropical and subtropical monsoon climate zone, with high temperatures and rain in summer, mild and less precipitation in winter, long summer, and short winter in the year. The project is located in the core area of the city. Combining with the climate characteristics of the South China region, the community design uses the principle of physical space to regulate the climate, connecting with the climate characteristics of the area and the activity rules of the people to precisely match the healthy and comfortable space environment inside and outside the house, to improve the community living quality.

2. Source of inspiration

Climate adaptive design draws on traditional dwellings. The principle of physical space regulation of temperature is used in conventional Lingnan dwellings to cope with territorialized climate characteristics and effectively enhance the comfort of the living environment. By incorporating the wisdom of traditional houses in modern community design and using non-mechanical regulating means, we can improve the living environment and reduce energy consumption simultaneously.

3. Project Practice

1) Establishing a wind corridor

The project started to establish an outdoor wind corridor from the overall planning level, controlling the direction of the wind inside the community by adjusting the direction of the community openings, sorting out the relationship between the community and the surrounding site, and establishing the angle between the buildings. a. The community openings are parallel to the dominant summer wind guide. The average wind speed is at least 1m/s at 1.5m above the ground in the central axis of the plane. b. Perpendicular to the river's flow direction, the wind is guided by variable cross-section and height differences. c. The angle between the building orientation and the dominant wind is more favorable for wind guidance. In the Huizhou area, the building orientation is appropriate, and the dominant wind into an angle of 45 degrees or less, and two columns into an angle of 10 degrees or less, which is more effective than parallel.

2) Design with temperature

The temperature of color: The different effects of color at different temperatures are determined by the calm and warm properties of the paint itself. Warm colors make people feel warm and cool colors make people feel relaxed. In the cloudless summer, the white wall temperature is slightly higher than the temperature, but the black wall temperature is as high as 60 ℃. From the actual measurement, it can be seen that white is the ideal surface reflection color in the southern region because this kind of color is a strong reflection and has less heat absorption.

The temperature of the material: the use of material heat absorption characteristics, choose light-colored stone, reduce the thermal absorption of the material; at the same time will be permeable paving porosity set at 20% to 30%, high porosity, low thermal conductivity, heat during the day does not store much heat, after sunset can be faster heat dissipation, at night and air temperature to achieve balance, creating a more comfortable living environment.

4. Summary

The project responds to the climate characteristics of "wet, hot, and stormy" in South China. The design combines nature and uses traditional and technological means to regulate the microclimate of the community. Through careful planning and layout, the urban heat island is alleviated; the community's outdoor activity time is extended through the climate elements adjustment. We keep exploring to create a better society and give users more living temperature; even if it is only 2℃, it is still a beautiful thing we aspire for.

6.2.2 Zhangjiabang Wedge-shaped Green Space Urban Design and Landscape Concept Planning

Figure 26 Case Study Ⅱ(Shang Hai)

1. Project Introduction

Zhangjiagang is the first of eight proposed "green wedge" projects in Shanghai, and when completed, it will be the largest public park in Shanghai. With a scale of 843 hectares, Zhangjiagang Park catalyzes ecological improvement and urban renewal, creating a wetland and woodland habitat that will reshape the city's natural environment and enhance the environmental level and quality of life for the residents of Pudong New Area.

The project is dedicated to improving the canal's water quality, rebuilding the aquatic ecosystem, and enhancing biodiversity. Through careful and rigorous spatial layout, topography, planting strategies, water design, and prevailing wind utilization, the project will improve air quality and thermal comfort and use microclimate creation to mitigate Shanghai's urban heat island phenomenon. In addition, the development of the adjacent areas of the project is facilitated by the multi-modal public transportation system, park revitalization plan, and the re-sewing of the urban fabric with the surrounding areas.

2. Site Background

The Zhangjiagang project faces multiple challenges: the site needs to be more cohesive by various infrastructures, such as elevated highways and high-voltage power corridors, and problems, such as abandoned land and piles of landfills. The drainage channel is made of concrete masonry so that the water quality could be better, and the biodiversity of the entire site could be much better.

3. Design Strategy

Connected to the city: The medium-density mixed land development zone around the park is integrated into a unified public open space that closely links the two urban cores. People can wander between forests, trees, wetlands with wood stacks, meadows, lawns, and various sites. The streets drain into a bio-filtration system, which serves as a buffer between the sidewalk and the carriageway, protecting pedestrians from traffic.

A pleasant microclimate: Climate conditions were carefully modeled during design to maximize thermal comfort and air quality through topographic modifications, planting strategies, and calculated spatial synergies. This includes alternating the forest canopy with water bodies to promote natural cooling by taking advantage of the prevailing southeasterly winds in the summer. At least 100,000 trees will be planted in Zhangjiagang Park to bring tangible microclimate benefits to the site and effectively reduce pollution, with temperatures in the park being 3-7°C cooler than in downtown Shanghai and the relatively deep lake in the garden taking advantage of its upwind location to promote heat transfer and evaporative cooling in the park.

4. Summary

The phased advancement of the construction process will help attract social capital, educate the public about the importance of the park's artificial habitat, and raise environmental awareness. The plant diversity of Zhangjiagang Park will require breakthroughs in the cultivation of native Chinese plants and the formation of a more integrated and informative horticultural industry. Overall, as the design progresses into the detailed design phase, the goal of the project shifts to renewing the mindset of government officials and moving away from slogans and "green make-up campaigns" to create a genuinely new urban ecology for Shanghai.

6.2.3 Air Quality, Placemaking, and Spatial Equity: The Fontana Urban Greening Master Plan

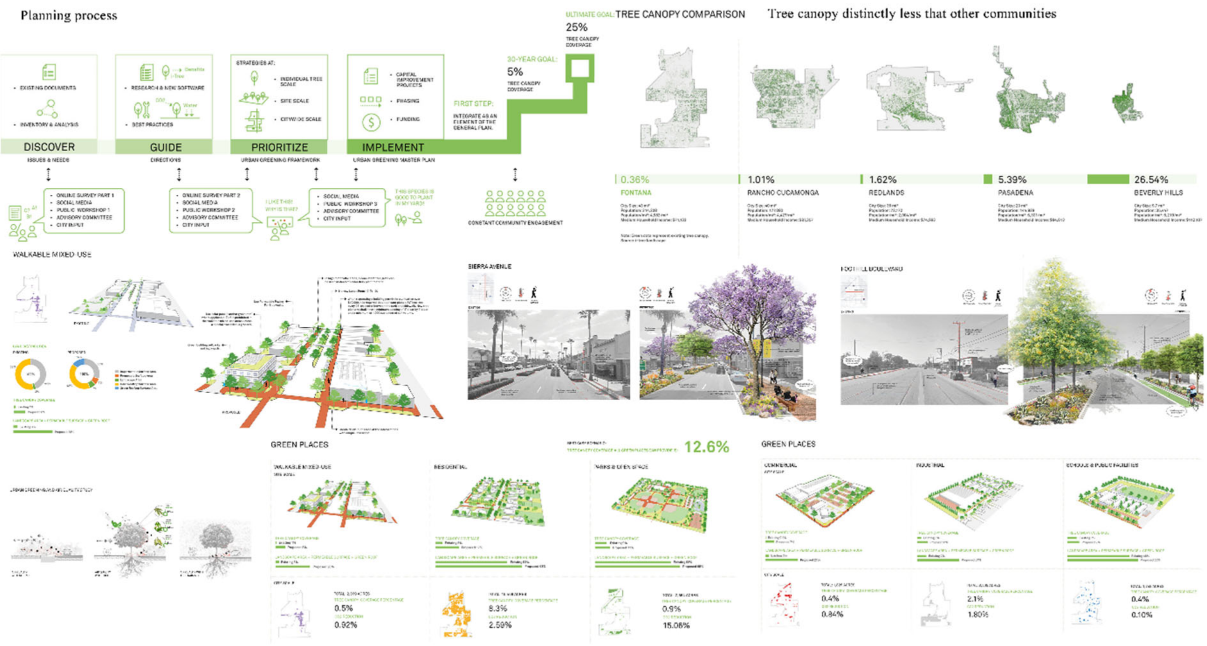


Figure 27 Case Study III (Fontana)

1. Site Background

Located in the interior of California's semi-arid Inland Empire, Fontana's residents are exposed to worse air than 95% of California's census tracts. It has only 0.36% urban forest cover, significantly less than other communities in the Los Angeles basin. Considering the impact of major transportation corridors, prominent industrial centers, frequent regional wildfires, and projected population growth, this statistic is further at risk as outdated and loose landscape regulations come under increasing development pressure.

2. Project Introduction

The Fontana Urban Greening Master Plan is based on quantitative studies that use scientific knowledge to explore the various dimensions of air quality. The plan creates a multi-scale vision of green infrastructure that influences development patterns, improves individual health, and creates a resilient future for Fontana. The design team implemented a four-step planning process through bilingual community engagement - discover, guide, prioritize, and implement. The plan's approach is transferable to other communities. Its ambitious long-term goal of increasing tree canopy coverage to 5% by 2050 - a transformational increase of more than 1,300% - achieves immediate policy change.

3. Project Strategies

Tree canopy is distinctly less than in other communities. Recognizing these statistics, the City of Fontana and The Southern California Association of Governments (SCAG) commissioned the landscape architect to craft an Urban Greening Master Plan to increase citywide tree canopy, improve multi-modal mobility, catalyze economic development, consolidate various regulations, and update policies to improve visual character, conserve water and reduce maintenance. Beyond such goals, the landscape architect elevated the project’s purpose to explore how such a plan can enhance air quality.

The Plan creates a multi-scalar, green infrastructure vision that influences development patterns, improves individual health and quality of life, and creates a more resilient future for the community and greater Basin.

4. Design Strategies

(1) At the Individual Tree Scale

The landscape architect analyzed the city's 71,574 existing street trees using the I-Tree and National Tree Benefits Calculator. Quantitative benefits, including 1) Atmospheric Carbon Absorption; 2) Stormwater Interception; 3) Property Value Increase; 4) Energy Conservation; and 5) Annual Dollar Benefits, were identified for individual species. Today, Fontana's street tree inventory accounts for $6.8 million in annual benefits. With community input, the landscape architect and arborist synthesized these measures with other environmental considerations and produced a distinct tree palette.

(2) At the Site Scale

Advancing beyond recommending individual species, the team considered how to integrate urban greening into urban morphology. The landscape architect selected a series of priority streets covering all street hierarchies and example sites from each land-use typology, then applied designs that maximized the potential for urban greening while optimizing function. Each typology was then measured in before and after scenarios. Metrics include canopy coverage, landscape area, permeable and impermeable surface, and greenhouse gas reduction.

(3) At the Citywide Scale

The Plan established a citywide framework for future implementation by taking the site-scale studies to a citywide scale. The framework incorporates green streets and green places. Green streets comprise the best scenarios of all street types, vegetated highways, and gateways, achieving a connected green system. Green places include the best methods of all land use typologies.

5. Summary

The design team implemented a four-step planning process through bilingual community engagement– Discover, Guide, Prioritize, and Implement. Transferable in its approach to other communities, the Plan achieved immediate policy change with its ambitious, long-term goal of increasing tree canopy coverage to 5% by 2050 – a transformational increase of over 1300%. Today, the Plan is becoming adopted as part of the General Plan, achieving a consolidated, visionary, and policy-reinforced guide to transform Fontana's built environment.

6.3 Strategy Framework

Based on the study results, I developed an urban planning enhancement strategy targeting the reduction of urban air temperature and mitigating urban heat island effects. In this framework, I have summarized three levels for three areas. The first level is to identify the problem, the second level is to propose a strategy, and the third level is to offer a detailed solution. The first aspect of the strategic framework is the urban green space system ＆ water circulation, the second aspect is the river system ＆ vegetation, and the third aspect is buildings＆wind speed.

1. Green space system ＆ water cycle

I investigated the distribution of green spaces along rivers, highways, and urban arteries in the study area, including parks, public open spaces, abandoned green spaces, and farmlands. I found that the overall distribution of green spaces is fragmented and lacks systematic connections. I propose three main strategies for urban green areas. Firstly, ecological corridors link parks and pleasure gardens in the city and connect various green spaces into a system. Secondly, rivers and roads will be used as a skeleton to connect green spaces. Finally, enhance the green space system.

1. River system & vegetation

The research results show a correlation between the growth condition of vegetation and air temperature in the study area, so improving the growth condition of vegetation in the study area can effectively mitigate the urban heat phenomenon. The stability of the riparian ecosystem is directly dependent on the complexity of the system structure and the diversity of species within the system. Still, the system is a transitional area of the water-land ecosystem, which is sensitive to changes in external environmental conditions and susceptible to disturbance by natural forces and human activities. The natural recovery process after the damage is long. Therefore, building a resilient riparian landscape with strong self-healing ability is necessary.

2. Building & Wind Speed

Urban wind corridors are essential for building healthy cities and alleviating the heat island effect and haze phenomenon. Urban breezeway promotes air circulation, improves the urban environment, and guarantees residents' physical and mental health. Urban planning should respond to regional climatic conditions and build wind corridors through the city's spatial configuration to alleviate the urban atmospheric environmental problems caused by urbanization. Cities at home and abroad are located in different geographical environments and climatic characteristics, and the construction purposes of their ventilation corridors also differ. Based on the climatic conditions of Zhengzhou City, the wind corridors are defined mainly according to the dominant wind direction of the town. Areas with solid ventilation capacity are selected as far as possible, where the width of primary ventilation corridors is 200 meters at maximum. The width of secondary ventilation corridors is at least 80 meters.

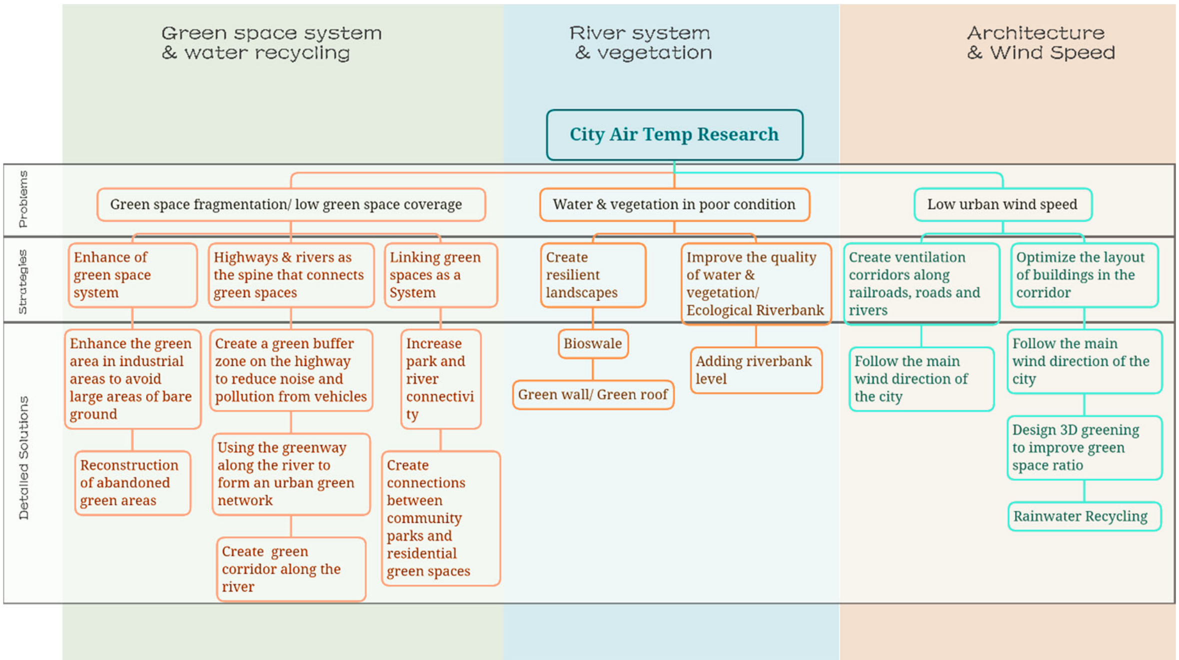


Figure 28 Strategy Framework

6.4 Green space system & water cycle

1. Background

Urban green space is a kind of urban land with vegetation as the primary medium of existence, which is used to improve ecology, protect the environment, beautify the city, and provide residents with recreational places. It has an irreplaceable role in urban development and is the leading implementation space for improving urban habitat, carrying multiple functions required for urban development. As a particular plan of the urban master plan, the primary part of urban green space system planning is to locate, qualify, and quantitatively arrange and deploy all kinds of green space holistically and systematically to form a perfect and organic urban green space system finally. Urban green space system planning has been essential in creating "ecological garden cities" and urban gardening practices in China. Its positive effect on promoting urban habitat construction is undeniable. A city's green space system plan is an essential foundation for developing urban green space and a blueprint for construction.

2. Creating a green space system

There are many types of green space in the study area, including parkland, public open green space, abandoned green space, and agricultural land. The overall distribution of green space is fragmented, so the region needs more construction of a green space system. I propose dividing the area’s green space system into two types. One is the green space system along the river, and the other is the green space system along the road. The river and the road serve as the urban skeleton to connect various types of green spaces in a series so that the green area can maximize its ability to mitigate the urban temperature.

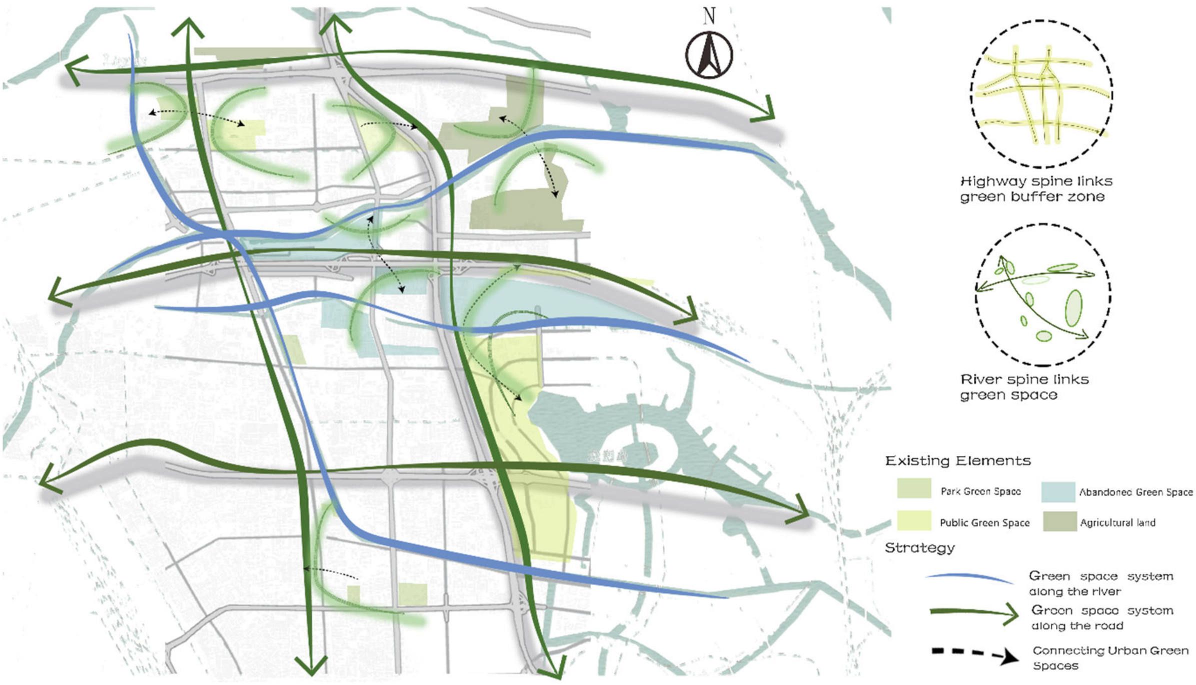


Figure 29 Green space system

3. Urban Water Cycle

Currently, many cities in China have problems with water pollution and water shortage problems, and rainwater collection and utilization have become an inevitable development trend. Reusing water with the help of rainwater is also one of the important ways to reduce urban rainwater flooding and the decline of groundwater levels, which plays a positive role in promoting urban environmental construction. The city's rainwater collection mainly includes the following two aspects:

(1) urban road rainwater collection.

Most cities have impermeable surface structures such as cement or asphalt; rainwater can not infiltrate but can be built around the building cisterns, crosswalks, motorways, parking lanes, etc.; the rainwater is pressurized to achieve the effect of storage of rainwater. The water flow formed after the rain enters the cistern through the storage pipe, effectively storing rainwater for urban ground cleaning, greening irrigation, etc.

(2) Collect rainwater from urban roofs.

Rooftop rainwater accounts for about 60% of rainwater collection; its collection is more convenient, has better water quality, and is the primary collection of urban rainwater use objects. Rooftop rainwater can provide residents with a more basic water supply after treatment, such as toilet flushing, greening irrigation, etc.

To build an ecological, stable, and sustainable urban water cycle system and improve water resources, disaster prevention, and mitigation capabilities. By constructing urban waterlogging, urban water environment, urban ecological restoration, and ecological infrastructure, we have established a drainage and flood prevention engineering system of "source emission reduction, drainage, and flooding" and gradually built a healthy water cycle system. We promote urban permeable pavement, build rainwater infiltration facilities, continuously expand the porous area of the city, and improve the overall storage and purification capacity of urban rainwater.

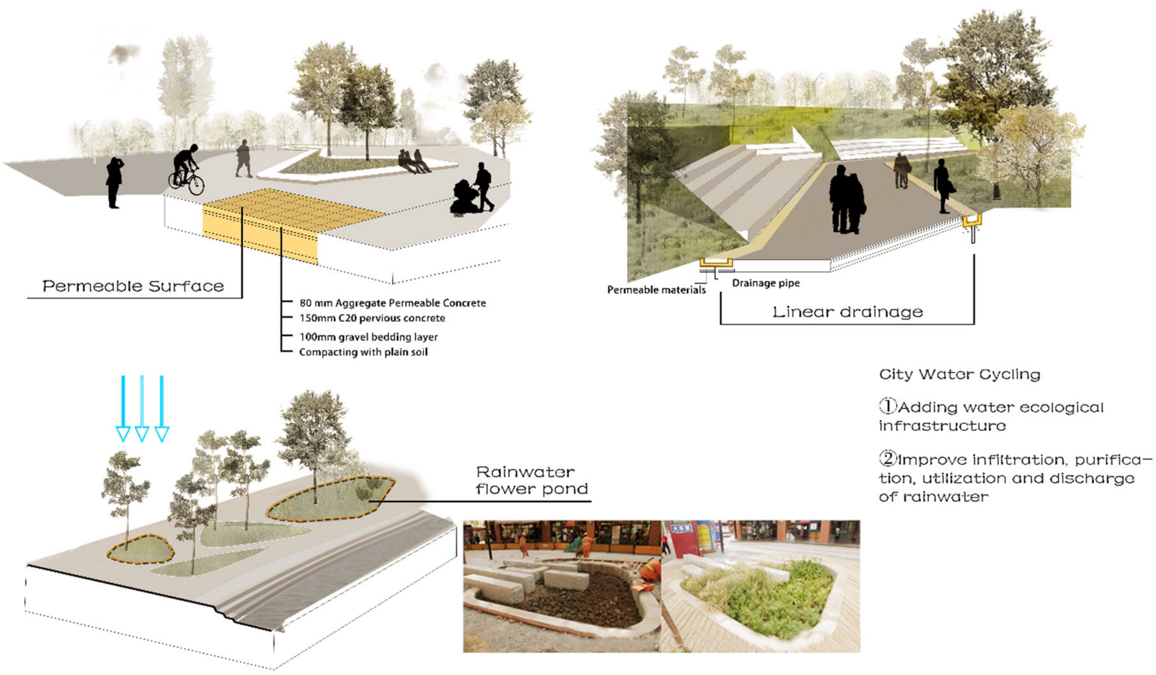


Figure 30 Water Cycle

6.5 River system & vegetation

1. River background

Three rivers run through the study area, the Jalu River, the Wei River, and the Dongfeng Canal. Jalu River and Wei are the main sewage discharge rivers in the city, and Dongfeng Canal is a vital irrigation river.

(1) The thousand-year-old Jalu River is the mother river of Zhengzhou. The total length of

the river is 256 kilometers, of which 137 kilometers are in Zhengzhou City, with a watershed area of 2,750 square kilometers. With the rapid increase of economic and social development and population, the Jialu River faces the problems of the shrinking river channel, declining function, polluted water quality, and accelerated degradation of the ecological environment along the river.

(2) Wei River, formerly known as Jialu Branch River, belongs to the Huaihe River basin and is one of the tributaries of the Jialu River, originating from the railroad grouping station in the northern suburbs of Zhengzhou City, passing through Huizi District and Jinshui District and entering Jialu River in Zhongmo, with a total length of 27.6 kilometers. Eighteen drainage ditches flow along the river, a crucial urban river in the northern city of Zhengzhou.

(3) Dongfeng Canal is a vital irrigation canal for water diversion and a significant drainage canal in Zhengzhou City. The total length is also only 19.7 meters. The Yellow River water was brought into the Dongfeng Canal in 1960 and 1961. Still, due to the excessive sediment in the Yellow River water, which caused the canal to be poor, and the secondary severe saline land caused by a large amount of water, the Henan Provincial Committee decided to stop the irrigation in November 1962. The gates were closed by one thousand nine hundred seventy-eight, and the canal north of the Sosu River was abolished, making the Dongfeng Canal the central drainage canal in Zhengzhou city.

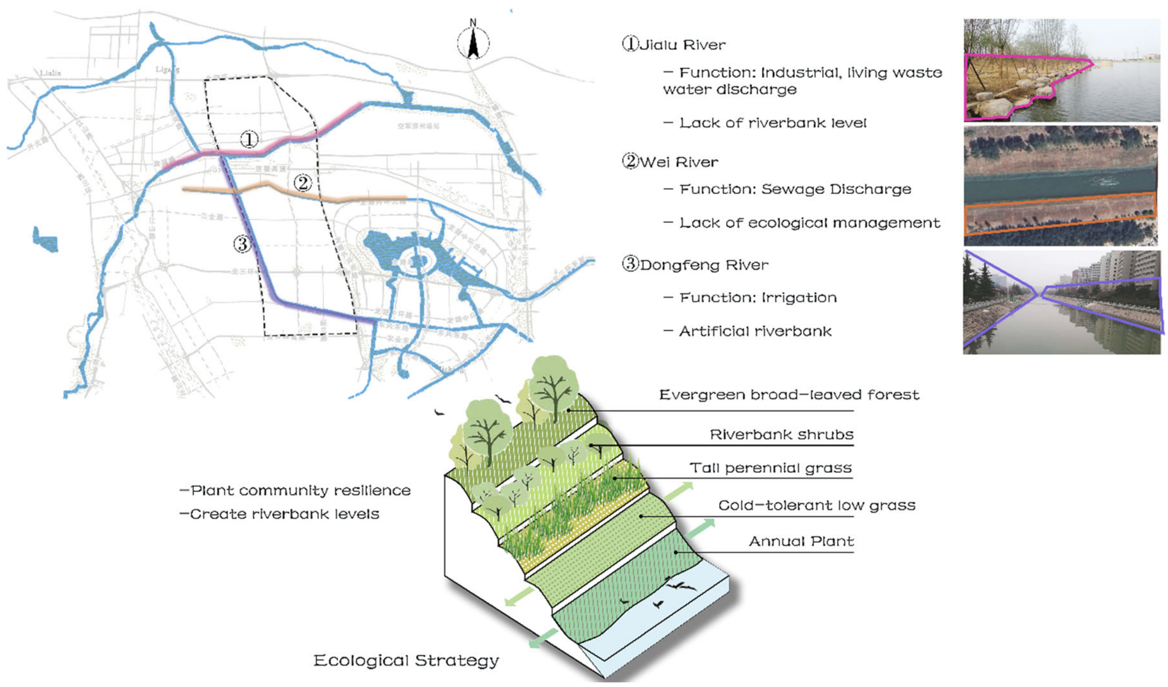


Figure 31 River background

2. Ecological shore protection construction

Traditional shore protection projects mainly use hard materials such as masonry and reinforced concrete, while ecological type shore protection uses natural stone, plants, wood, porous concrete, and other materials. According to the proportion of raw materials in riparian materials, ecological riparian can be divided into three categories: natural prototype riparian, natural riparian, and multi-natural riparian.

Natural type bank protection: Suitable plants are planted directly on the river bank, and the slope is protected only by vegetation consolidation. For example, aquatic plant protection, grass protection, protective forest protection, plant fiber mat protection, etc.

Natural type bank protection: while planting vegetation, raw materials such as wood and stone are used to protect the bottom at the foot of the slope to enhance the stability of the bank slope.

Multi-natural type bank protection: artificial materials such as reinforced concrete and metal lattice cage are used to further enhance the anti-scouring ability of vegetation bank protection, focusing on safety performance, good protection effect, soft and hard landscape combination, with certain hydrophilic and landscape functions, but the landscape is slightly worse than a natural prototype and natural type bank protection, with large engineering volume and higher investment, which can be used in river sections with considerable scouring.

Jialu River and Wei River mainly bear the sewage discharge in the city. The construction of riverbank berms should pay more attention to the plant's restoration ability and the cleaning ability of river pollution. Therefore, I suggest using more resilient vegetation planting for these two rivers. The Dongfeng Canal is the central irrigation canal in Zhengzhou City. Currently, the slopes along the Dongfeng Canal are mostly made of concrete, so I suggest using vegetation bricks instead of concrete to improve the ecological restoration ability of the river banks.

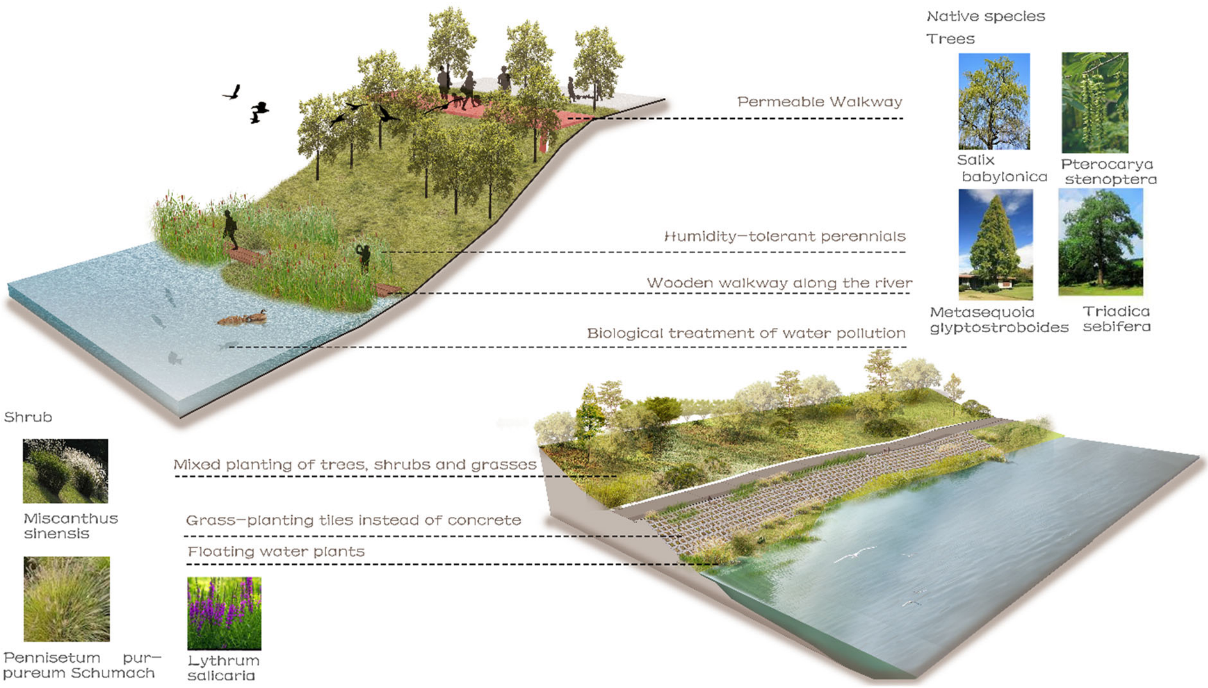


Figure 32 Riverbank Construction

3. Concrete measures

(1) Ecological approach to the upstream water source for sedimentation, filtration, and other purification treatment

We purify the upstream water source before it flows in. The upstream inlet uses biological interception to isolate large suspended materials such as household garbage, sets up sand sedimentation ponds to remove suspended particles, and optimizes the water quality through a combination of biological purification, surface flow wetlands, and underwater forests before it flows downstream.

(2) Structure underwater plants and surface flow wetlands in the whole watershed to cultivate the self-purification ability of water body

The primary vegetation is bitter grass, which can withstand cold overwintering. It is planted on the bottom of the water to provide space for microorganisms to grow. With water lilies, calamus, iris, and other water-holding plants, the underwater forest is built to increase the oxygen content of the water body.

(3) De-hardening the riverbed and restoring the natural form of the river

To solve the problem of sediment pollution and floating matter pollution inside the channel through ecological methods, to improve the water body's purification capacity, and to restore the natural meandering river form.

4. Riparian vegetation selection

Increasing plant diversity is a critical factor in enhancing ecosystem stability, and I plan to contribute to ecological restoration through a multidimensional design of plants. Through plant species selection while providing foraging possibilities for organisms, I finally listed the following list of native plant species suitable for the study area.

Category	Scientific Name	Features
Trees	*Salix babylonica*	Tall deciduous trees
	Pterocarya stenoptera	Large trees, up to 30 m tall
	Metasequoia glyptostroboides	Deciduous trees
	Triadica sebifera	Woody plant, Bark dark gray
	Styphnolobium japonicum	Large trees native to China
	Broussonetia papyrifera	Suitable for barren slopes
	Cedrus deodara	Common ornamental tree species
Shrub	*Miscanthus sinensis*	Diverse morphology and resilience
	Pennisetum alopecuroides	Perennial Graminaceae
	Iris hybrids	Humidity-loving, also drought-tolerant

	Lythrum salicaria	Perennial Herbs
	Cortaderia selloana	Perennial Herbs

Table 4 Recommended Vegetation List

6.6 Building & Wind Speed

1. Creat ventilation corridors

Urban ventilation corridors, also called urban breezeways, are corridors with strong ventilation capacity to bring fresh cool, and moist air to urban areas to alleviate the urban heat island effect and promote haze dissipation by improving atmospheric purification capacity. Available meteorological observations show that the dominant wind direction in Zhengzhou is northeast. The number of days with northeast wind accounts for 9% of the total days in a year. The Northwest westerly wind and south wind ratio is also more significant. The provincial climate center said the north along the Yellow River and the central city west to the east of the region, mainly to the east-west wind direction, the main city east to the northeast-southwest wind direction, the southwest of the city wind direction to the northwest-southeast predominantly. However, specific to the local area, the wind field also varies. The principle of confirming ventilation corridors is to select areas with strong ventilation capacity as much as possible, such as rivers, parks, green areas, roads, and low scattered building clusters. Connecting these areas promotes the exchange of hot and cold airflow.

Therefore, I intend to build three different ventilation corridors along railroads, rivers, and roads in the study area. The river-type air corridors include the Jalu River and Dongfeng Canal. The road-type ventilation corridors are Zhongzhou Avenue and Lianhuo Expressway, respectively. The railroad-type ventilation corridor is along the Beijing-Guangzhou Expressway and the green belt on both sides.

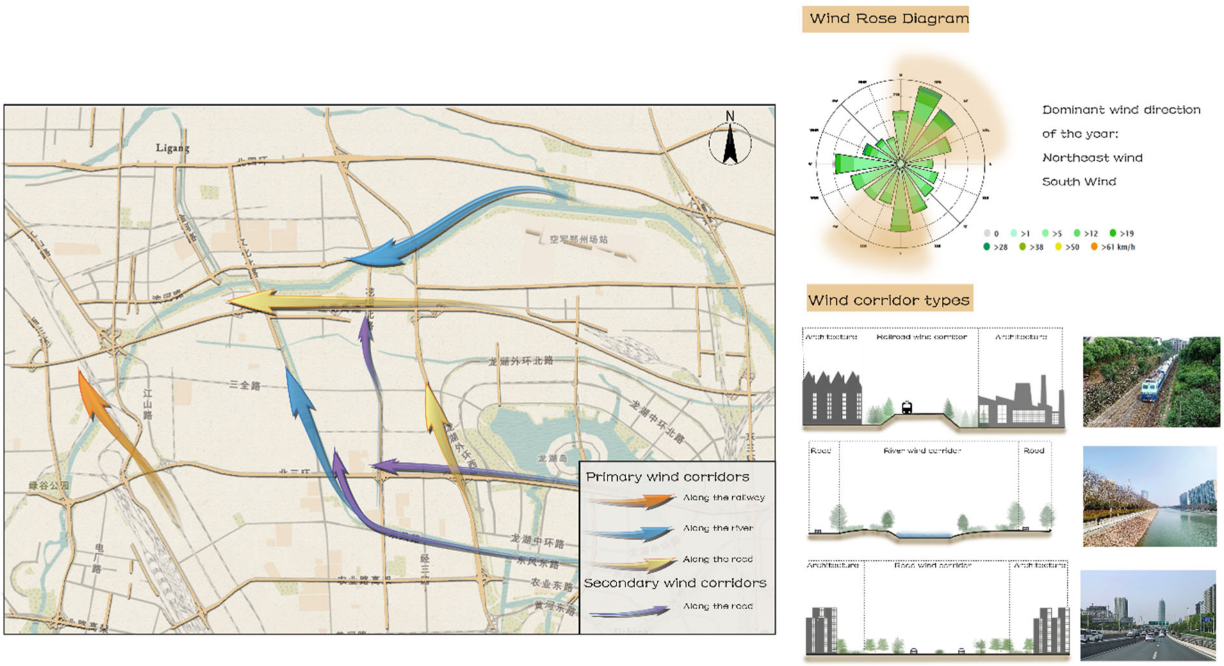


Figure 33 Wind Corridor Plan

2. Main measures

Reasonable planning measures are adopted, including limiting building density, height, and ground coverage, providing ventilation corridors, linking green and open spaces, increasing the permeability of the central city, and reducing heat load. The planning guidelines are as follows:

(1) Link as many urban parks, open spaces, etc., and widen the paths connecting significant roads.

(2) The direction and pattern of the street layout should be proposed, and the main roads should be parallel to the prevailing wind direction with an angle of less than 30 degrees as much as possible.

(3) The streets in the direction of prevailing winds should be widened in urban areas where conditions exist.

(4) High-intensity urban development zones should strategically control the clustering of building heights and use building height differences to guide air circulation.

3. Building and wind corridor

As seen from the figure below, the buildings along both sides of the ventilation corridor in the study area do not consider the city's dominant wind direction, which is contrary to the meaning of wind corridor construction. At the same time, the buildings themselves lack ventilation function. The building layout design needs to consider the city's dominant wind direction. Since the primary land use types in this area are commercial, industrial, and residential land use. Therefore, I will propose ideas to improve the urban ventilation environment for these three main land use types.

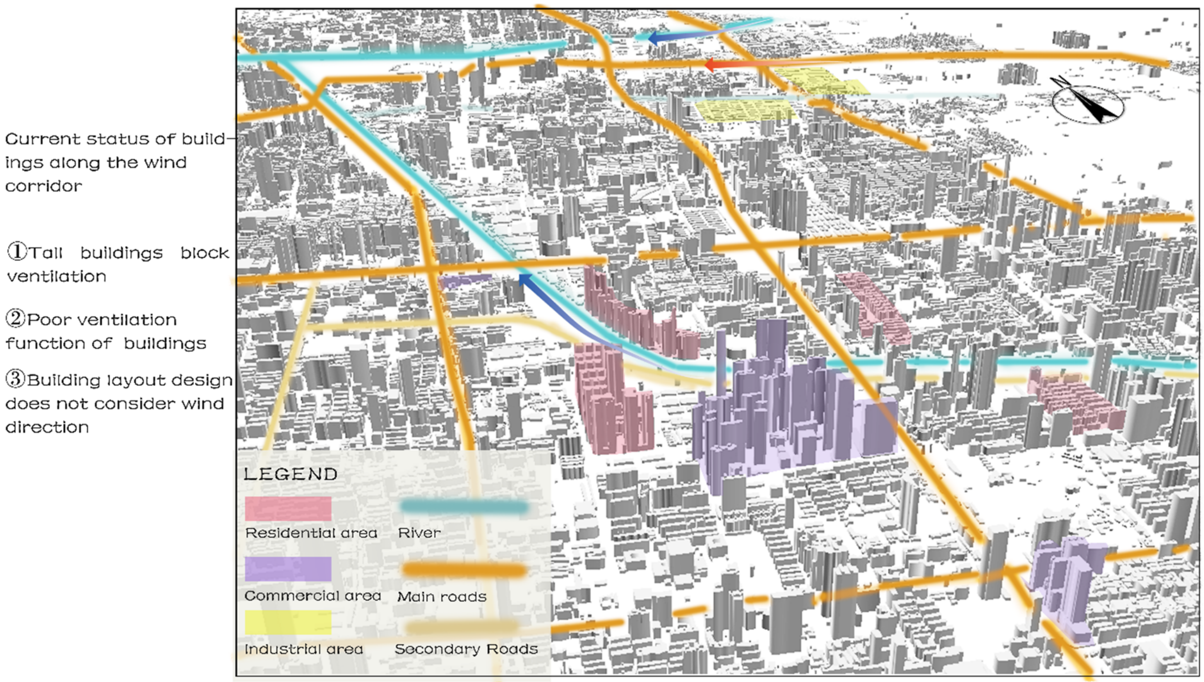


Figure 34 Current Situation of Building Layout

To further promote sustainable cooling-oriented neighborhood construction patterns, I propose construction guidelines at the neighborhood level. With openness, permeability, and close connection with natural ecology as the core elements, the guidelines show the design patterns of residential, commercial, industrial, and three typical neighborhoods to cope with hot and high-humidity climates through modeling. To promote the adaptation of Zhengzhou's streets to the local environment and to improve community comfort, resilience, and sustainability.

(1) Residential Neighborhoods

Residential neighborhoods emphasize "people" as the core. They are oriented to the thermal comfort of residents' outdoor and indoor spaces, encouraging sun and rain protection, capturing cool breezes, and opening local building spaces to the outdoors.

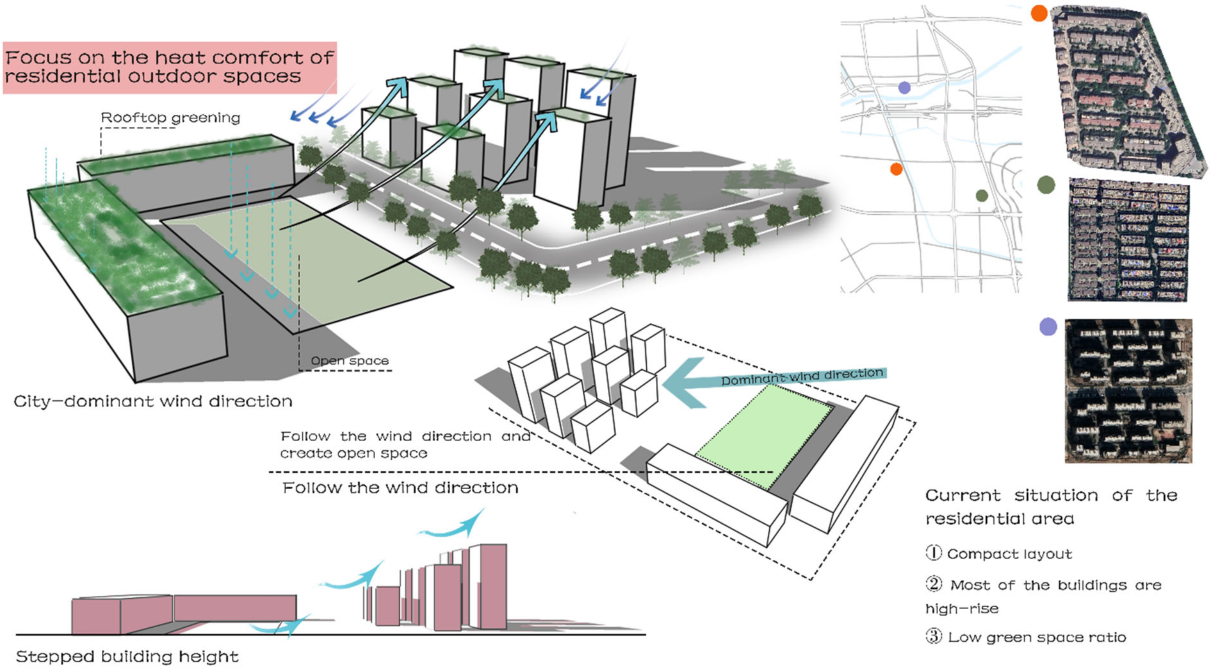


Figure 35 Residential Area Enhancement Comments

(2) Commercial District

The commercial district is centered on "business.” It is oriented to the comfort and vitality of commercial activities, encouraging breathing buildings, maximum ventilation and shading design, and a multi-dimensional green landscape.

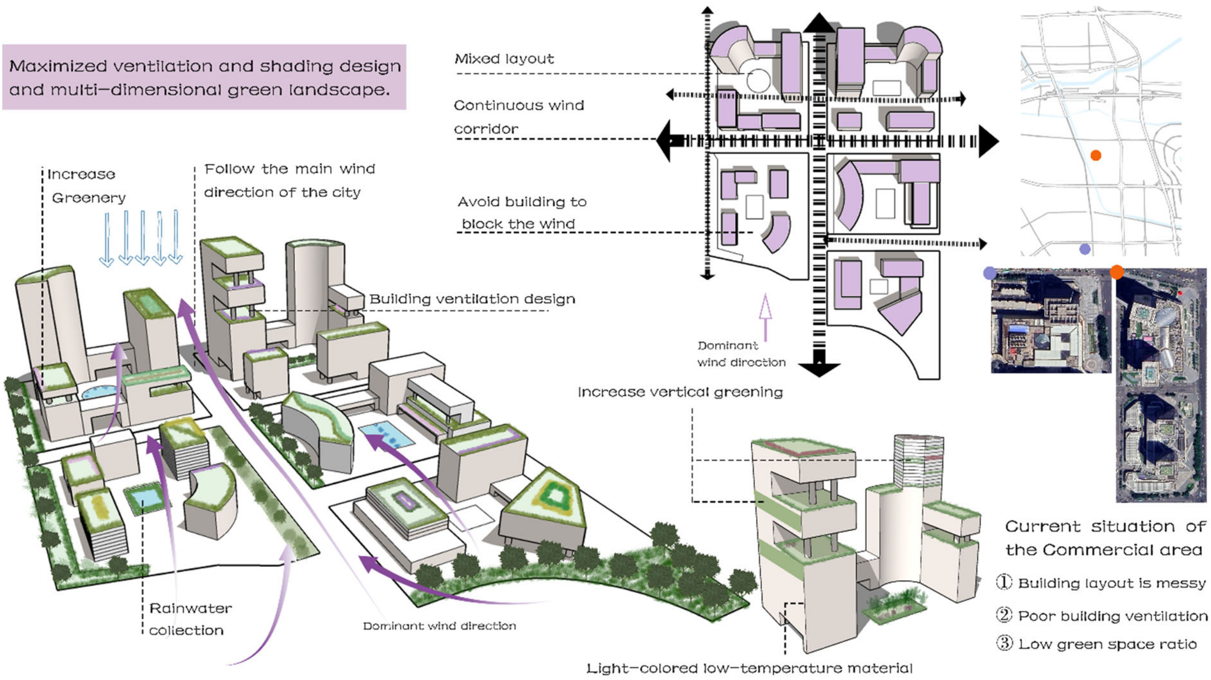


Figure 36 Commercial Area Enhancement Comments

(3) Industrial District

The industrial district is centered on "production" and oriented to the climate-friendliness of industrial production and production space, encouraging energy-efficient cooling, reducing anthropogenic heat emissions, and recycling industrial waste heat.

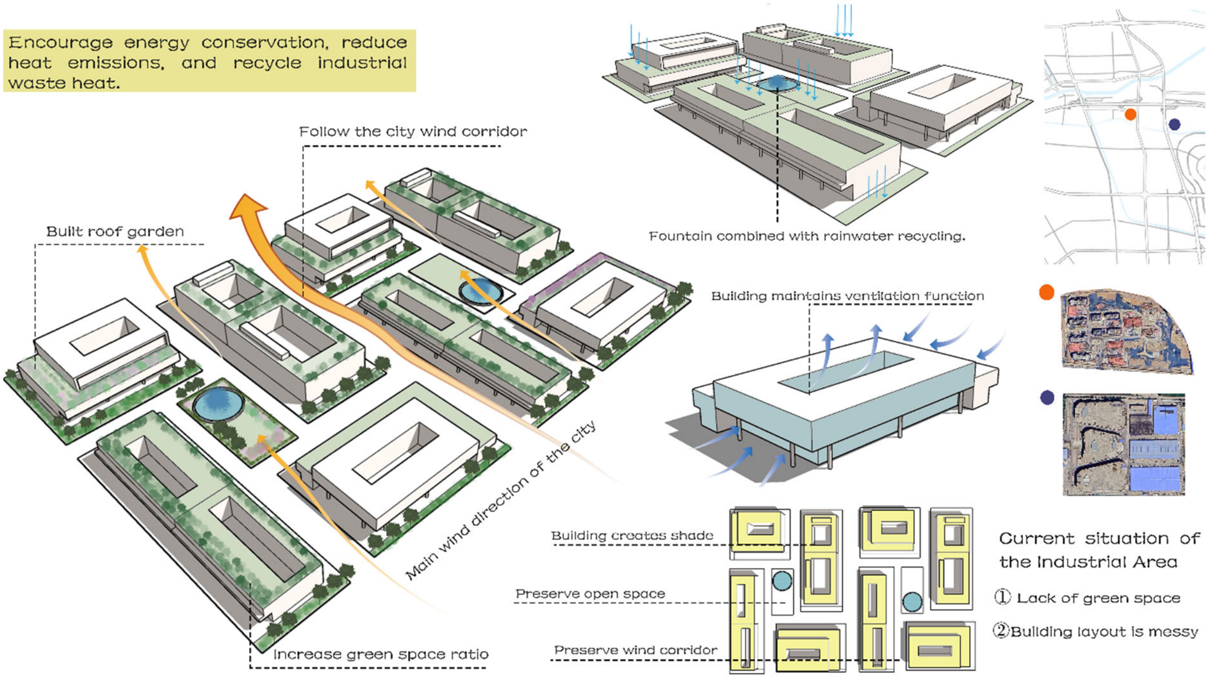


Figure 37 Industry Area Enhancement Comments

7. Summary

Urban development and the natural environment have been in opposing perspectives, and today there is a need to integrate the two. In the face of future extreme climate change, enhancing cities' resilience and tolerability is an important goal.

For a city in northern China, increasing urban air humidity is an effective measure to reduce air temperature. The urban structure, building pattern and wind speed in cities are closely related to each other. Improving the urban building pattern and optimizing the building exterior design can improve the urban ventilation rate at the root. Vegetation and green space systems are an important part of improving the heat island effect. This study finds that only systematic improvement of urban green space and vegetation growth environment can effectively reduce urban temperature.

Urban wind, water, and greenways are also part of urban ecological corridors. Together with mountains, lakes, forests, and grasses, urban ecosystems form and continue to play a role in environmental security, such as flood control, soil consolidation, clean water, and air purification. With bluer skies and more transparent water in cities, citizens will have more space for outdoor interaction and physical and mental relaxation after work. They will have a greater sense of access and happiness.

Through the research process, I found that Man-induced is still the leading cause of the heat island effect, and we can only keep optimizing. Even if there is only a 2°C change, it is still a wonderful thing we desire.

References

1. 马亚利, et al."快速城市化背景下乡村聚落空间结构变迁研究评述." 城市发展研究 21.03(2014):55-60. 【Ma, Yali, et al. "A Review of Research on Spatial Structural Changes of Rural Settlements in the Context of Rapid Urbanization." Urban Development Research 21.03 (2014): 55-60.】

2. 刘照胜, 于尚坤,and 王成新."我国城市化新时代基本特征与发展策略." 山东社会科学 .08(2019):136-140. doi:10.14112/j.cnki.37-1053/c.2019.08.020. 【Liu, Zhaosheng, Yu, Shangkun,and Wang, Chengxin." Basic characteristics and development strategies of China's urbanization in the new era." Shandong Social Science .08 (2019):136-140. doi:10.14112/j.cnki.37-1053/c.2019.08.020.】

3. Sun Y, Zhang X, Ren G, Zwiers FW, Hu T. Contribution of urbanization to warming in China. *Nature Clim Change*. 2016;6(7):706-709. doi:10.1038/nclimate2956

4. Oke TR. CITY SIZE AND THE URBAN HEAT ISLAND.

5. 杨柳.(2003).建筑气候分析与设计策略研究(博士学位论文,西安建筑科技大学).https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CDFD9908&filename=2003090620.nh【Yang, Liu. (2003). Research on building climate analysis and design strategies (Doctoral dissertation, Xi'an University of Architecture and Technology). https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CDFD9908&filename=2003090620.nh】

6. 黄海.(2008).城市绿地小气候环境效应和绿化策略研究(硕士学位论文,西北农林科技大学).https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD2009&filename=2008101416.nh【Huang, H.. (2008). Research on microclimate environmental effects and greening strategies of urban green space (Master's thesis, Northwest Agriculture and Forestry University). https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD2009&filename=2008101416.nh】

7. 吴隽宇,and 梁策."风景园林视野下我国微气候研究概述与进展." 南方建筑 .06(2019):116-123.【Wu Junyu,and Liang Ce." Overview and progress of microclimate research in China under the view of landscape gardening." Southern Architecture .06(2019):116-123.】

8. 赵守栋, et al."城市化对气候变化的影响及其反馈机制研究." 北京师范大学学报(自然科学版) 50.01(2014):66-72.【Zhao Shoudong, et al. "Study on the impact of urbanization on climate change and its feedback mechanism."

Journal of Beijing Normal University (Natural Science Edition) 50.01 (2014): 66-72.】

9.周淑贞,张超."上海城市热岛效应." 地理学报 .04(1982):372-382.【Zhou, S.C., Zhang, Chao." Urban heat island effect in Shanghai." Journal of Geography .04(1982):372-382.】

10. 刘施含, et al."城市热岛效应研究进展." 安徽农学通报 25.23(2019):117-121. doi:10.16377/j.cnki.issn1007-7731.2019.23.047. 【Liu, Shihan, et al. "Advances in research on urban heat island effect." Anhui Agricultural Bulletin 25.23 (2019):117-121. doi:10.16377/j.cnki.issn1007-7731.2019.23.047.】

11. Yang Q, Huang X, Tang Q. The footprint of urban heat island effect in 302 Chinese cities: Temporal trends and associated factors. *Science of The Total Environment*. 2019;655:652-662. doi:10.1016/j.scitotenv.2018.11.171

12. The_Climate_of_London.pdf.

13. Dwivedi A, Khire MV. Application of split- window algorithm to study Urban Heat Island effect in Mumbai through land surface temperature approach. *Sustainable Cities and Society*. 2018;41:865-877. doi:10.1016/j.scs.2018.02.030

14. Manley G. On the frequency of snowfall in metropolitan England. *QJ Royal Met Soc*. 1958;84(359):70-72. doi:10.1002/qj.49708435910

15. 黄媛.(2010).夏热冬冷地区基于节能的气候适应性街区城市设计方法论研究(博士学位论文,华中科技大学).https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CDFD0911&filename=2010184239.nh【Huang, Yuan. (2010). Methodological research on energy-efficient climate-resilient neighborhood urban design for hot summer and cold winter regions (Doctoral dissertation, Huazhong University of Science and Technology). https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CDFD0911&filename=2010184239.nh】

16. Shi Y, Ren C, Zheng Y, Ng E. Mapping the urban microclimatic spatial distribution in a sub-tropical high-density urban environment. *Architectural Science Review*. 2016;59(5):370-384. doi:10.1080/00038628.2015.1105195

17. Ooka R. Recent development of assessment tools for urban climate and heat-island investigation especially based on experiences in Japan. *Int J Climatol*. 2007;27(14):1919-1930. doi:10.1002/joc.1630

18. Pearlmutter D, Berliner P, Shaviv E. Integrated modeling of pedestrian energy

exchange and thermal comfort in urban street canyons. *Building and Environment*. 2007;42(6):2396-2409. doi:10.1016/j.buildenv.2006.06.006

19. 郭琳琳, 李保峰,and 陈宏."我国在街区尺度的城市微气候研究进展." 城市发展研究 24.01(2017):75-81. 20. 2005 年 7 月珠三角地表温度场的遥感监测分析.【 Guo, Linlin, Li, Baofeng,and Chen, Hong." Progress of urban microclimate research in China at the neighborhood scale." Urban Development Research 24.01 (2017): 75-81. 20. Remote sensing monitoring analysis of the surface temperature field in the Pearl River Delta in July 2005.】

21.李逸伦. 北京城市绿地及其周边街区热湿环境特征及影响因素[D].北京林业大学 ,2020.DOI:10.26949/d.cnki.gblyu.2020.001589. 【 Li Yilun. Characteristics and influencing factors of heat and humidity environment in urban green areas and their surrounding neighborhoods in Beijing[D]. Beijing Forestry University, 2020. DOI:10.26949/d.cnki.gblyu.2020.001589.】

22. Sustainable Urban Systems Report. Published online 2018.

23. Ziter CD, Pedersen EJ, Kucharik CJ, Turner MG. Scale-dependent interactions between tree canopy cover and impervious surfaces reduce daytime urban heat during summer. *Proc Natl Acad Sci USA*. 2019;116(15):7575-7580. doi:10.1073/pnas.1817561116

24. Morris DW. Ecological Scale and Habitat Use. *Ecology*. 1987;68(2):362-369. doi:10.2307/1939267

25. Xiao R, Weng Q, Ouyang Z, Li W, Schienke EW, Zhang Z. Land Surface Temperature Variation and Major Factors in Beijing, China. *photogramm eng remote sensing*. 2008;74(4):451-461. doi:10.14358/PERS.74.4.451

26. Wu J. Effects of changing scale on landscape pattern analysis: scaling relations. *Landscape Ecology*. 2004;19(2):125-138. doi:10.1023/B:LAND.0000021711.40074.ae

27. Cazelles B, Chavez M, Berteaux D, et al. Wavelet analysis of ecological time series. *Oecologia*. 2008;156(2):287-304. doi:10.1007/s00442-008-0993-2

28. Fan H, Yu Z, Yang G, et al. How to cool hot-humid (Asian) cities with urban trees? An optimal landscape size perspective. *Agricultural and Forest Meteorology*. 2019;265:338-348. doi:10.1016/j.agrformet.2018.11.027

29. Yuan F, Bauer ME. Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery. *Remote Sensing of Environment*. 2007;106(3):375-386. doi:10.1016/j.rse.2006.09.003

30. Jiang Y, Fu P, Weng Q. Assessing the Impacts of Urbanization-Associated Land Use/Cover Change on Land Surface Temperature and Surface Moisture: A Case Study in the Midwestern United States. *Remote Sensing*. 2015;7(4):4880-4898. doi:10.3390/rs70404880

31. 王耀斌,赵永华,韩磊,奥勇 & 蔡健.(2017).西安市景观格局与城市热岛效应的耦合关系. 应用生态学报(08),2621-2628. doi:10.13287/j.1001-9332.201708.022.【Wang, Y. B., Zhao, Y. H., Han, L., O. Y. & Cai, J.. (2017). The coupling relationship between landscape pattern and urban heat island effect in Xi'an city. Journal of Applied Ecology (08), 2621-2628. doi:10.13287/j.1001-9332.201708.022.】

32. 李苗, et al."哈尔滨市城乡结合部不透水面时空变化及驱动力分析." 地理学报 72.01(2017):105-115.【Li Miao, et al. "Spatial and temporal variation of impervious surface and driving force analysis in urban-rural area of Harbin city." Journal of Geography 72.01 (2017): 105-115.】

33. Beaufort scale. In: *Wikipedia*. ; 2023. Accessed May 4, 2023. https://en.wikipedia.org/w/index.php?title=Beaufort_scale&oldid=1144639756

DECLARATION

on authenticity and public assess of mater's thesis

Student's name: Zhang Yuhao

Student's Neptun ID: Y7IW1O

Title of the document: Urban landscape optimization based on microclimate research（Spatial Distribution of air temperature and the influencing factors —The Case of City Main District Zhengzhou, China）

Year of publication: 2023

Department: Garden and Open Space Design

I declare that the submitted master's thesis is my own, original individual creation. Any parts taken from an another author's work are clearly marked, and listed in the table of contents.

If the statements above are not true, I acknowledge that the Final examination board excludes me from participation in the final exam, and I am only allowed to take final exam if I submit another master's thesis.

Viewing and printing my submitted work in a PDF format is permitted. However, the modification of my submitted work shall not be permitted.

I acknowledge that the rules on Intellectual Property Management of Hungarian University of Agriculture and Life Sciences shall apply to my work as an intellectual property.

I acknowledge that the electric version of my work is uploaded to the repository sytem of the Hungarian University of Agriculture and Life Sciences.

Place and date: _Budapest_________2023___ year ________05___month ______03_day

Zhang Yuhao

Student's signature

STATEMENT ON CONSULTATION PRACTICES

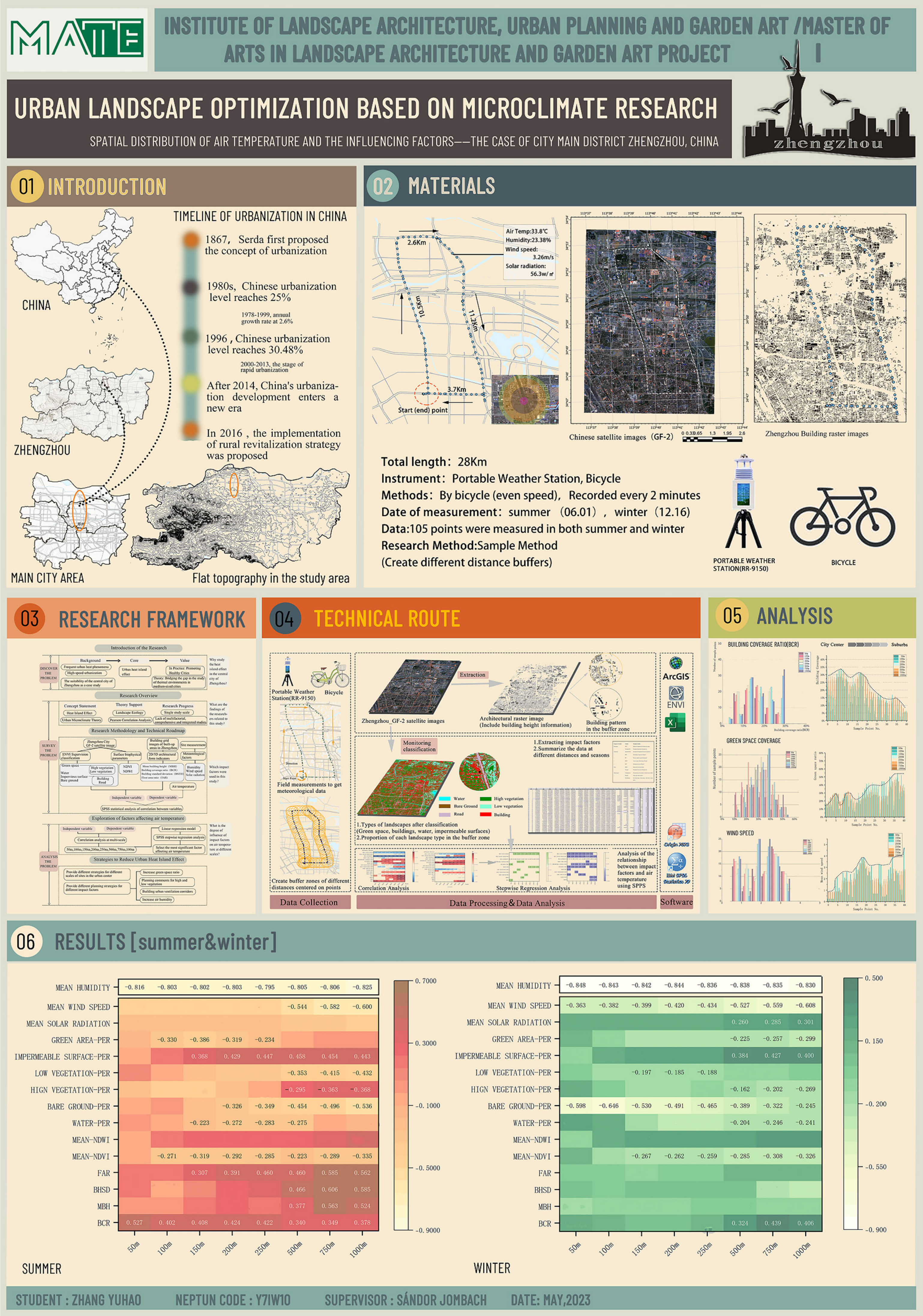
As a supervisor of Zhang Yuhao (Student's name) Y7IW1O (Student's NEPTUN ID), I here declare that the master's thesis has been reviewed by me, the student was informed about the requirements of literary sources management and its legal and ethical rules.

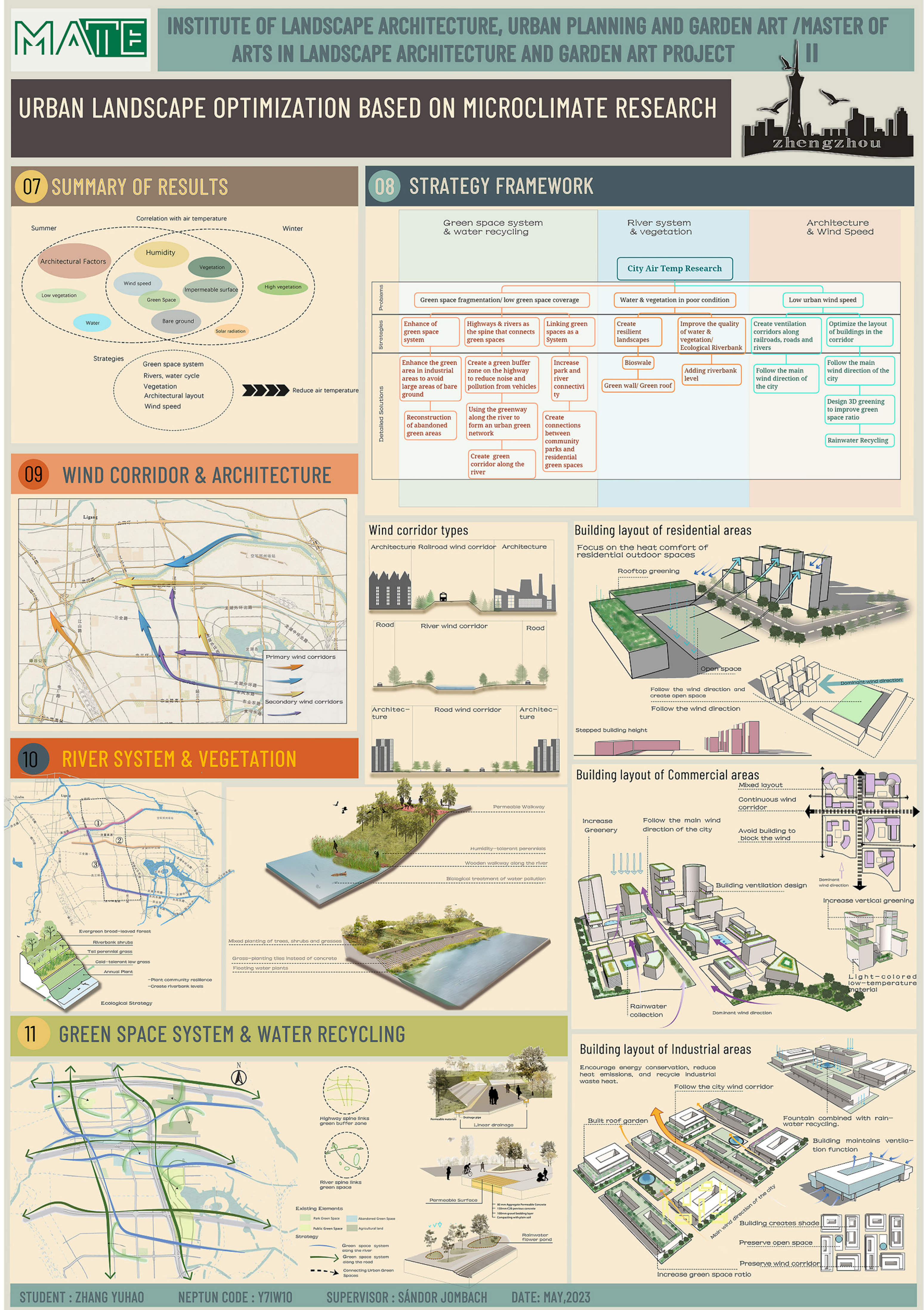
I recommend the master's thesis to be defended in a final exam.

The document contains state secrets or professional secrets: no

Place and date: Budapest 2023 year 05 month 03 day

Internal supervisor


MATE
INSTITUTE OF LANDSCAPE ARCHITECTURE, URBAN PLANNING AND GARDEN ART /MASTER OF ARTS IN LANDSCAPE ARCHITECTURE AND GARDEN ART PROJECT
I
URBAN LANDSCAPE OPTIMIZATION BASED ON MICROCLIMATE RESEARCH
SPATIAL DISTRIBUTION OF AIR TEMPERATURE AND THE INFLUENCING FACTORS——THE CASE OF CITY MAIN DISTRICT ZHENGZHOU, CHINA
zhengzhou
01 INTRODUCTION
TIMELINE OF URBANIZATION IN CHINA
1867, Serda first proposed the concept of urbanization
1980s, Chinese urbanization level reaches 25%
1978-1999, annual growth rate at 2.6%
1996, Chinese urbanization level reaches 30.48%
2000-2013, the stage of rapid urbanization
After 2014, China's urbanization development enters a new era
In 2016, the implementation of rural revitalization strategy was proposed
CHINA
ZHENGZHOU
MAIN CITY AREA
Flat topography in the study area
02 MATERIALS
Air Temp:33.8℃
Humidity:23.38%
Wind speed: 3.26m/s
Solar radiation: 56.3w/㎡
2.6Km
10.5Km
11.2Km
3.7Km
Start (end) point
Chinese satellite images (GF-2)
Zhengzhou Building raster images
Total length: 28Km
Instrument: Portable Weather Station, Bicycle
Methods: By bicycle (even speed), Recorded every 2 minutes
Date of measurement: summer (06.01), winter (12.16)
Data:105 points were measured in both summer and winter
Research Method:Sample Method
(Create different distance buffers)
PORTABLE WEATHER STATION(RR-9150)
BICYCLE
03 RESEARCH FRAMEWORK
04 TECHNICAL ROUTE
Portable Weather Station(RR-9150)
Bicycle
Field measurements to get meteorological data
Create buffer zones of different distances centered on points
Zhengzhou_GF-2 satellite images
Extraction
Architectural raster image (Include building height information)
Building pattern in the buffer zone
Monitoring classification
1.Extracting impact factors
2.Summarize the data at different distances and seasons
Water
High vegetation
Bare Ground
Low vegetation
Road
Building
1.Types of landscapes after classification (Green space, buildings, water, impermeable surfaces)
2.Proportion of each landscape type in the buffer zone
Correlation Analysis
Stepwise Regression Analysis
Analysis of the relationship between impact factors and air temperature using SPSS
ArcGIS
ENVI
Data Collection
Data Processing & Data Analysis
Software
05 ANALYSIS
BUILDING COVERAGE RATIO(BCR)
City Center
Suburbs
GREEN SPACE COVERAGE
WIND SPEED
06 RESULTS [summer&winter]
MEAN HUMIDITY
MEAN WIND SPEED
MEAN SOLAR RADIATION
GREEN AREA-PER
IMPERMEABLE SURFACE-PER
LOW VEGETATION-PER
HIGN VEGETATION-PER
BARE GROUND-PER
WATER-PER
MEAN-NDWI
MEAN-NDVI
FAR
BHSD
MBH
BCR
50m
100m
150m
200m
250m
500m
750m
1000m
SUMMER
WINTER
STUDENT : ZHANG YUHAO
NEPTUN CODE : Y7IW10
SUPERVISOR : SÁNDOR JOMBACH
DATE: MAY,2023


MATE
INSTITUTE OF LANDSCAPE ARCHITECTURE, URBAN PLANNING AND GARDEN ART /MASTER OF ARTS IN LANDSCAPE ARCHITECTURE AND GARDEN ART PROJECT
II
URBAN LANDSCAPE OPTIMIZATION BASED ON MICROCLIMATE RESEARCH
zhengzhou
07 SUMMARY OF RESULTS
Correlation with air temperature
Summer
Winter
Architectural Factors
Humidity
Vegetation
Wind speed
Impermeable surface
Green Space
High vegetation
Low vegetation
Bare ground
Water
Solar radiation
Strategies
Green space system
Rivers, water cycle
Vegetation
Architectural layout
Wind speed
Reduce air temperature
08 STRATEGY FRAMEWORK
Green space system & water recycling
River system & vegetation
Architecture & Wind Speed
City Air Temp Research
Problems
Green space fragmentation/ low green space coverage
Water & vegetation in poor condition
Low urban wind speed
Strategies
Detailed Solutions
09 WIND CORRIDOR & ARCHITECTURE
Primary wind corridors
Secondary wind corridors
Wind corridor types
Architecture
Railroad wind corridor
Road
River wind corridor
Road wind corridor
Building layout of residential areas
Focus on the heat comfort of residential outdoor spaces
Rooftop greening
Open space
Follow the wind direction and create open space
Follow the wind direction
Stepped building height
Building layout of Commercial areas
Mixed layout
Continuous wind corridor
Increase Greenery
Follow the main wind direction of the city
Avoid building to block the wind
Building ventilation design
Increase vertical greening
Light-colored low-temperature material
Rainwater collection
Dominant wind direction
10 RIVER SYSTEM & VEGETATION
Ecological Strategy
11 GREEN SPACE SYSTEM & WATER RECYCLING
Building layout of Industrial areas
Encourage energy conservation, reduce heat emissions, and recycle industrial waste heat.
Follow the city wind corridor
Built roof garden
Fountain combined with rainwater recycling.
Building maintains ventilation function
Building creates shade
Preserve open space
Preserve wind corridor
Increase green space ratio
STUDENT : ZHANG YUHAO
NEPTUN CODE : Y7IW10
SUPERVISOR : SÁNDOR JOMBACH
DATE: MAY,2023