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# The Effect of Urban Green-Space on Relieving the Urban Heat Island Effect in Beijing, China

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***Abstract:*** *Taking the urban heat island (UHI) effect as the analysis object, studying the changes in temperature data and the frequency of extreme climates in Beijing in the past 30 years, the research shows that since 1980-2019, the ground temperature in Beijing has been increasing and has continued Deteriorating trend; winters have become shorter and summers have increased; after 2000, the total amount of precipitation in Beijing has decreased and the city has become more arid; however, the sandstorms in Beijing have improved significantly. Combining the statistical data of the current sampling survey on the application frequency of garden plants in Beijing and comparing the influence of plant coverage in central and suburban Beijing on urban temperature, the analysis shows that urban green space has a certain mitigation enact on the heat island effect. Studies have shown that a reasonable planting structure can improve the efficiency of plant cooling and increasing humidity. The collocation of trees, shrubs and herbs can weaken the negative impact of the UHI. In the selection of urban landscape plants, try to choose vegetation with large leaves, large canopy, complex structures, low canopy gap, high canopy density and high canopy layer, which can effectively slow down the UHI. It analyzes the lack of quantitative research and a large amount of data in the research on the effect of green space on urban heat island in China at this stage. The study proposes that Beijing should focus on governance and improvement in the urban heart where the UHI is serious, and put forward measures and suggestions for Beijing to alleviate the urban heat island effect in subsequent time.*

***Keywords:*** *Urban Heat Island Effect, urban greening area, urban planning, landscape architecture, global climate, vegetation*

## 1. Introduction

As the process of urbanization continues to accelerate, cities are also rapidly expanding. While urbanization has brought convenience to mankind, it is also adjusting the carrying limit of the natural environment (Chen Sun & Chen 2012; Menzel 2002). The urban heat island effect is one of the factors affecting the urban environment, as well as the quality of life of city dwellers is also affected by it (Gu 2016). The occurrence and impact of the heat island effect have attracted progressively debate from the scientific community (Xu & Yang 2018). As one of the typical "urban diseases" (zhang et al, 2015), urban heat island response not only affects urban weather (Nakayama & Hashimoto 2011; Demanuele 2012), air quality (Zhang 2009), animal and plant growth and development (Lan et al, 2013; Xu Pei & Guo 2011), and energy consumption (Zhou & Shu 1994), but also causes respiratory, cerebrovascular, heart and other related diseases, threatening human life (zhang et al. 2015). With the continuous improvement of people's awareness of the harm of urban heat island effect, how to assuage the UHI has become one of the urban ecological environmental dilemmas that need to be solved urgently (George et al, 2007). As an international metropolis, Beijing must improve the quality of its urban environment. However, as far as the city's thermal environment is concerned, Beijing's heat island effect has also developed to a very serious degree (People's Government of Beijing Municipality 2015). In the summer of 2000, Beijing's high temperature lasted for more than a week, and the highest temperature was as high as 42.6℃, which once became northern China (National Meteorological Science Data Center 2020).

One of the high temperature centers in the region and even in China. At present, most researches in China are only at the stage of numerical simulation and prediction and have not been implemented. The reasons are as follows (Chen Sun & Chen 2012; Li et al. 2011; Tang et al. 2009): First, due to the scarcity of urban land in Beijing, urban green space cannot increase without limit, and the spatial distribution of green space is restricted by urban planning. In urban landscape planning, the function of urban green space to alleviate the heat island effect is generally insufficient. Second, there is still a lack of in-depth research on the relationship between vegetation and urban heat islands. Even if the heat island is taken into account in urban planning, it is difficult to find corresponding guiding theoretical support.

As was mentioned in the previous section, the urban environment of Beijing is affected by the UHI (Chen Sun & Chen 2012). Compared with other countries, Chinese academics have put forward comprehensive measures and suggestions. However, there are few quantitative studies, which are specifically reflected in the lack of quantitative research on cooling and energy-saving benefit analysis of green space and lack of data to support. On the other hand, when studying the moderation effect of urban green space on the heat island effect, the role of plant maintenance and management is ignored. Through the method of literature review (Meineke et al. 2016), it is possible to obtain the positive role of landscape plants in mitigating the heat island effect. For the time being, Beijing's focus on dealing with the heat island effect is not clear. According to the literature, it should focus on the downtown area where the heat island effect is strongest.

Research questions:

What research has China done on the urban heat island effect?

What is the change in temperature recorded in Beijing over the past 30 years?

What impact does the urban landscape pattern have on the heat island effect?

Does different types of plants have different cooling effects in Beijing?

This paper first explained the definition and causes of the UHI, and then explained the current situation of the UHI in Beijing and the extenuation effect of urban landscape on the urban heat island effect through meteorological data analysis. The methodology explains the source of the data and how to analyze valid data. To conclude this section the purpose and significance of the article.

The main objective of the current paper is to discuss the dominant factors of urban green space to alleviate the heat island effect (Jia & Shu 2012; Zhang et al. 2015). Through data analysis, we can find the most urgent areas in Beijing for governance and put forward effective management measures and suggestions. The purpose is to discuss the negative influence of the UHI, the different effects of different greening vegetation configurations on urban heat island effect, study the impact of vegetation coverage on urban heat island effect, and propose the key research directions for urban heat island in the future, looking for sustainable and green Healthy, suitable for Beijing's new development model[1-6].

## 2. About Urban Heat Island (UHI) Effect

### *2.1. Definition and history of urban heat island effect*

The term urban heat island effect is generally understood to mean that, after the rapid development of the city, the temperature of the central area of the city is significantly higher than that of the surrounding area due to the change of the underlying surface (plant reduction, air pollution, industrial exhaust, etc.) (Zhou Liu & Xu 2013). It is the most typical urban climate. It is generally believed that the heat island effect has been observed for about 200 times as an urban climate phenomenon. The term UHI can be traced back to 1811, meteorologist Howard (1833) made detailed observation records of London and its suburbs from 1811 to 1841, and later scholars believed that this was the earliest record of urban heat island phenomenon. However, as a proper noun, urban heat island was formally proposed by Manley (1958) in 1958. The term urban heat island encompasses atmospheric urban heat islands (AUHI), and surface urban heat islands (SUHI) (Chen Sun & Chen 2012). Atmospheric urban heat island refers to the difference in atmospheric temperature between urban and suburban areas (Voogt & Oke 2003). It is the result of direct contact between the heat detector and the air. Atmospheric temperature is generally divided into the urban canopy layer (UCL) and urban boundary layer (UBL) according to different levels (Huang et al. 2016). The study of atmospheric urban heat island (AUHI) uses data from meteorological stations, including fixed and mobile weather stations. The term surface urban heat islands (SUHI) is a relatively new name for a UHI, commonly referred to as the difference in surface temperature between the city center and the suburbs (Dobrovolný 2013).

### *2.2 Causes of UHI*

#### *2.2.1 Changes in the underlying surface of the city*

With the continuous acceleration of urbanization, high-rise buildings have been built in the city, and large-scale paving and structures have changed the underlying surface of the city (Zhang et al., 2015). Compared with the natural underlying surfaces such as plants, water bodies, and soil, these underlying surfaces heat up faster, resulting in a new heat source in the city (George et al., 2007). Moreover, the materials on the exterior of tall buildings and walls also reflect solar radiation. Cause the city temperature to rise.

#### *2.2.2 Decrease of natural underlying surface in cities*

Due to the massive development of urban land, natural underlying surfaces such as water bodies, plants and soil have been replaced by hard paving. These artificial materials absorb solar radiation fast, so it accelerates the overall temperature rise of the city (Peng et al. 2017).

#### *2.2.3 Human factors*

The continuous growth of the population, the emission of automobile exhaust and the energy consumed by industrial production have caused a large amount of heat energy loss, aggravated the heat island effect, and also caused a significant impact on air pollution (Weng 2004; Tang Wang & Zheng 2006). At the same time, the use of some chemical substances also destroys the ozone layer in the atmosphere, forming a greenhouse effect, and finally aggravating the heat island effect (Peng et al. 2017)[7-11].

## 3. Literature review

Due to topography, latitude and climate, the heat island effect in China is very different from all over the world (Zhang et al., 2015). For China at this stage, the heat island effect has been widespread and has produced some negative effects on the normal lives of citizens. With the rapid development of urbanization, China's urban environmental problems have become increasingly prominent. Since 2012, the Chinese government has made many decisions (China National Congress of the Communist Party of China 2012), hoping that urban ecology can become the main goal of urban development. Urban heat islands are considered to be one of the hot spots of environmental problems (George et al. 2007), which will seriously affect the well-being of human society in the future. Therefore, solving the urban heat island problem is an urgent problem that China needs to solve. Solved at this stage. Urban green space not only has the function of purifying the environment and improving the local microclimate, but also can repair the damaged natural environment to a certain extent. Ni et al. (2007) observed that this is the most effective way to reduce the urban heat island effect. Reasonable downtown greenery design can effectively alleviate the heat island effect in the city. As the capital of China, Beijing's economy, culture and industry are developing rapidly. With the acceleration of Beijing's urbanization process, a series of environmental-related problems have begun to appear, and the pressure on urban resources and the environment has also increased. Therefore, the requirements for urban greening have become higher and higher. Compared with internationally recognized international cities such as New York, London and Tokyo, Beijing still has a certain gap in urban landscaping construction with its development goal of world cities (Zheng & Zhang, 2011; Ballinas & Barradas, 2016). It needs to work from multiple aspects, including urban green coverage and per capita public green area, green structure, quality, distribution balance, and fineness of landscaping.

Xu et al. (2002) found that meteorological observation data and numerical simulation methods to study the intensity of the heat island in the Beijing area, and pointed out its degree, and pointed out that the daily average temperature in central Beijing from 1983 to 1985 was 2.4℃ higher than that in Beijing. In the suburbs, the maximum temperature in August is 0.4 to 1.6℃. Research by Ji et al. (2006) found that the intensity of Beijing’s urban heat island increased at a rate of 0.22℃ every 10 years. In 1999, the intensity of Beijing’s heat island attained 1.13℃ (at 02:00 at night), and the intensity of the heat island at night was significantly greater than during the day. The night heat island intensity in the 1980s and 1990s both exceeded 0.5℃, and the seasonal variation trend of the heat island intensity at four times a day was basically the same, showing strong in winter and weak in summer. In addition, the heat island is the strongest at 02:00 at night and the weakest at 14:00 at noon.

### *3.1 The current impact of Beijing's urban heat island effect on the urban area*

Beijing has been the capital of China for more than 860 years. After hundreds of years of historical changes (Zhu, Qi & Wang 2010). The People's Government of Beijing Municipality (2015) stipulates that Beijing now has 16 municipal districts, including Dongcheng District and Xicheng District. Located within the Second Ring Road of Beijing, it has been the city center of Beijing since ancient times. Since 2015, Beijing's Chaoyang District, Fengtai District, Shijingshan District, and Haidian District have been divided into suburbs, while the remaining 10 areas have been divided into outer suburbs. Most of the outer suburbs are close to mountainous areas and reservoirs, and there are many types and numbers of woodland. Currently, there are 20 weather stations in Beijing. These weather stations are located in every district of Beijing. The height of the observation field of these weather stations is between 28.6 meters and 487.9 meters[12-17]. It can effectively collect weather data in Beijing. The statistics show that the temperature of Beijing has changed a lot during the 20 years from 1981 to 2010 (National Meteorological Science Data Center 2020). The cumulative annual average temperature from 1981 to 1997 was 12.7 degrees Celsius, and the cumulative annual average temperature from 1997 to 2010 rose to 13.2 degrees Celsius. The average temperature rises by 0.5 degrees Celsius every ten years. At the same time, the cumulative annual average maximum temperature from 1981 to 1997 was 18.1 degrees Celsius, the cumulative annual average maximum temperature from 1997 to 2010 was 18.5 degrees Celsius, and the average annual maximum temperature increased by 0.4 degrees Celsius per decade. According to the National Meteorological Science Data Center (2020) of Beijing from 1981 to 2010, consequently, it can be concluded that the ground temperature in Beijing is continuously increasing and may have a tendency to deteriorate, as shown in Table 1.

*Table 1: The number of days with the highest daily temperature in Beijing from 1981 to 2010 (days).*

| | ≥ 30℃ | ≥ 35℃ | ≥ 37℃ | ≥ 40℃ |
|---|---|---|---|---|
| 1981- 1997 | 28 | 8 | 3 | 0 |
| 1997- 2010 | 26 | 9 | 3 | 1 |

According to the data provided by the Beijing Gardening and Greening Bureau (2018), of the Green Ratio of 16 districts in Beijing, the lowest green ratio in Xicheng District is only 30.89%, while the highest in Yanqing District is 67.99%. Xicheng District is located in the center of Beijing, with many buildings and population, large-scale commercial districts, ancient buildings, historical sites, and government buildings. Yanqing District is different from Xicheng District. Yanqing District (Yanqing County People's Government 2015) is located in the northwest of Beijing, far from the heart of the city center, and has a significantly fewer population and buildings than the urban area. In terms of geomorphic features, the north, east, and south sides of Yanqing District are all mountainous areas with an average elevation of 500 meters. Yanqing District now has two national nature reserves and is rich in water resources. Yanqing District now has 780 million cubic meters of water resources. Because of this, a large amount of water resources, a small amount of radiation and human activities may contribute to the growth of plants and the survival of wild animals. According to the daily temperature data from 1981 to 2019 (National Meteorological Science Data Center 2020), the average annual maximum temperature in Beijing mainly occurs in August. Therefore, choose any day in Beijing in August 2020, and compare the 24-hour high temperature and body temperature of the two districts with the highest and lowest green coverage in Beijing based on data from the weather website to study how urban green spaces affect the urban climate, as shown in Figure 1.

Under the same other climatic conditions, the evidence of the temperature in Xicheng District is higher than that in Yanqing District can be clearly seen in the case of temperature and apparent temperature (National Meteorological Science Data Center 2020). The highest temperature throughout the day in both districts is 31.80 °C, but the highest apparent temperature in Xicheng District is 34.23°C and the highest apparent temperature in Yanqing District is 30.88°C. The highest apparent temperature in Xicheng District is 3.35°C higher than that in Yanqing District. It can be seen that the temperature that people feel in the city center is significantly higher than that in the outer suburbs, citizen's feeling when they are in the city center will affect people's physical and mental state (Apparent temperature 2009). On the other hand, through statistical data, it can be found that the lowest temperature in Yanqing District is 19.5 degrees Celsius, the lowest temperature in Xicheng District is 24.0 degrees Celsius, and the minimum temperature difference between the two districts is 4.5 degrees Celsius. The dependence on topography and natural environment may be linked to lower overall temperature in Yanqing District. According to the above statistics, the natural environment may have played a vital role in bringing about reducing urban temperature[18-23].

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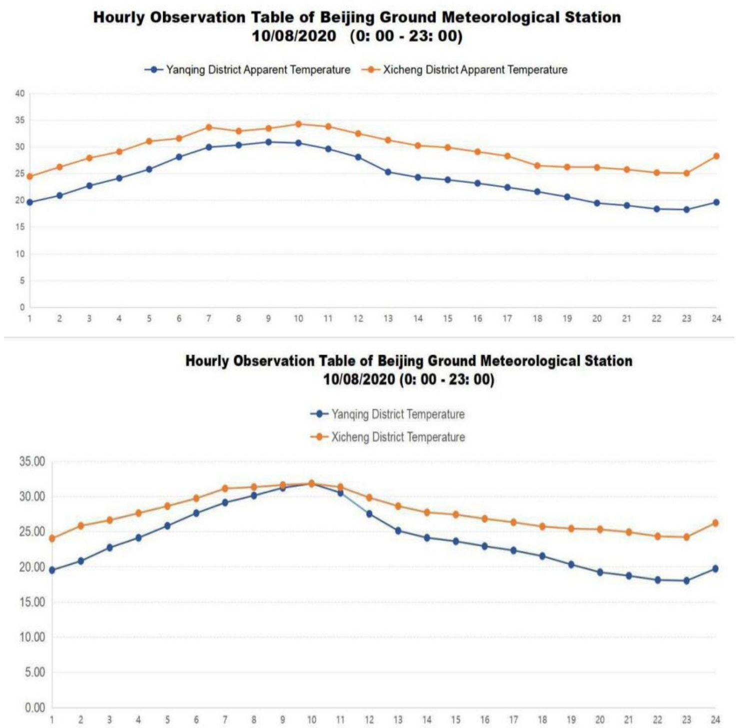


*Figure 1: Hourly Observation Table of Beijing Ground Meteorological Station 10/08/2020 (0: 00 - 23: 00). Compare the temperature (°C) and apparent temperature (°C) changes in Xicheng District and Yanqing District within 24 hours.*

Moving on now to consider the influence of the urban heat island effect on Beijing's winter. In the context of global warming (Yu 2014), Beijing's UHI is also obvious in winter.

#### *3.1.1 The temperature in Beijing in winter has risen significantly*

You (2014) demonstrate in the article that since the 1980s, the winter in China has entered a period of gradual warming. The obvious warming phenomenon first occurred in 1986. During the 28 years from 1986 to 2013, The minimum temperature in Beijing in winter was less than -15 °C for only 8 days, but according to meteorological data, in the 21 years from 1965 to 1985, the number of days when the minimum temperature in Beijing was below -15 °C was 64 days, which is clear from the data. The number of days with the lowest temperature in Beijing has been significantly reduced. Obviously, Beijing's winter temperature has risen a lot compared to before. Ding et al. (2010) calculated the length and start date of Beijing's spring, summer, autumn and winter seasons based on the daily average temperature data of Beijing from 1951 to 2008. The study found that the winter in Beijing was the longest in 57 years and the autumn was the shortest. In addition, summer is gradually extending and winter is gradually shortening. At the same time, spring and summer are gradually advanced, while autumn and winter are gradually delayed. Therefore, the urban heat island effect has made Beijing's winter temperature higher and higher.

#### *3.1.2 After 2000 the total amount of precipitation in Beijing decreased and the city became more arid*

After the heat island effect continues to increase, it affects the precipitation in Beijing. It can be seen from Table 2 that during the ten years from 2001 to 2010 (National Meteorological Science Data Center 2020), the precipitation decreased. Among them, the precipitation in 8 years was less than 450 mm. It will cause drought in the Beijing area, and will also affect the growth of plants (Ding et al. 2010). Some plants that love humidity and shade will be affected, and the diversity of plants will be destroyed.

*Table 2: Statistics of Beijing's total precipitation (mm) over ten years.*

| | Floating dust | Duststorm | Ssandstorm | Total |
|---|---|---|---|---|
| 2001 | 13 | 11 | 0 | 24 |
| 2002 | 8 | 21 | 0 | 29 |
| 2003 | 0 | 1 | 0 | 1 |
| 2004 | 1 | 6 | 0 | 7 |
| 2005 | 1 | 3 | 0 | 4 |
| 2006 | 14 | 8 | 0 | 22 |
| 2007 | 2 | 3 | 0 | 5 |
| 2008 | 6 | 0 | 0 | 6 |
| 2009 | 2 | 1 | 0 | 3 |
| 2010 | 4 | 4 | 0 | 8 |
| 2011 | 2 | 2 | 0 | 4 |
| 2012 | 0 | 2 | 0 | 2 |
| 2013 | 2 | 2 | 0 | 4 |
| Total | 55 | 64 | 0 | 119 |

#### *3.1.3 The intensity of the sandstorm in Beijing in spring has weakened, and the sandstorm has decreased*

In the 1980s, Beijing was often plagued by sandstorms (Sun Zhang & Wang 2011). The phenomenon of sandstorms in spring was very serious, which affected the normal life and daily travel of citizens, and also caused respiratory diseases. After the 21st century, the phenomenon of sandstorms in Beijing has been greatly improved. Now the floating dust weather in Beijing will not exceed ten days in spring, and extreme weather such as sandstorms and strong sandstorms has disappeared (You 2014). After the appearance of the urban heat island effect, the sandstorm in Beijing has been effectively controlled , as shown in Table 3.

*Table 3: Statistics of sand and dust weather in Beijing since the 21st century (Observatory) (Times)*

| Every 10 years | Total annual precipitation |
|---|---|
| 1951-1960 | 781 mm |
| 1961-1970 | 584 mm |
| 1971-1980 | 567 mm |
| 1981-1990 | 580 mm |
| 1991-2000 | 568 mm |
| 2001-2010 | 367 mm |
| 2011-2013 | 677 mm |
| Average annual | 572 mm |

Based on the above research, it seems that the urban heat island effect has a great influence on the climate of Beijing. The temperature in Beijing is increasing year by year and there is a trend of continuous increase. Extreme weather such as high temperature and drought is also increasing. The wintertime is shortened, and the summertime is increased (Ding et al. 2010). However, due to the emergence of the heat island effect, the sandstorm in Beijing has been alleviated. By comparing the two districts with the highest and lowest green ratio, we can know that the more plants the area, the lower the temperature and the more comfortable people are. This phenomenon may occur because the plant's transpiration can absorb heat from the surrounding air and increase the humidity in the surrounding air (Santamouris 2014). On the other hand, plants absorb carbon dioxide in the air during photosynthesis, which can effectively reduce the greenhouse effect. Green plants can absorb, reflect, and block solar radiation, which can also reduce the ambient temperature (Willis & Petrokofsky 2017). In summary, it has been shown from this review that urban green space can assuage the urban heat island effect.

### *3.2 The effect of Urban Landscape Plants' Application in Beijing on relieving the UHI in Beijing*

Beijing is located in northern China and has a temperate continental climate, with cold and dry winters and hot and rainy summers (Zhang et al. 2015). The conditions of high temperature and abundant rain in summer are very beneficial to the growth of plants. The annual average precipitation is 600mm, and the zonal vegetation type formed is baked temperate deciduous broad-leaved forest. Due to the complex and diverse topography of the Beijing area, there are also abundant plant species (Zheng & Zhang 2011; George et al. 2007). According to the statistics of the landscaping survey conducted by the Beijing Municipal Bureau of Landscaping (2010), there are 111 families, 356 genera, and 615 species of plants being managed and maintained in the Beijing urban green space system. There are 130 species of trees, 102 species of shrubs, 363 species of herbs, and 21 species of vines. The species of wild plants are mainly in the Compositae, Gramineae, and Leguminosae (Beijing Gardening and Greening Bureau 2018). According to the analysis of the composition of landscaping plants used in Beijing, there are 438 species of native plants in Beijing, 306 species of wild native plants, and 132 species of cultivated native plants. Among them, the native species of arbor plants accounted for the lowest proportion at 46.9%; shrubs followed by 56.9%; the native species of herbaceous plants accounted for the highest proportion, at 84.3%. This shows that when cultivating and planting plants in Beijing, it mainly focuses on the native plants of Beijing. This can maximize the protection of the diversity of native plants, while also protecting the soil and wild animals(Zheng & Zhang 2011). There are currently two problems with plant cultivation in Beijing. First: Although Beijing’s urban landscape is mainly greened with local plants, the ratio of trees to shrubs is too small, especially some wild trees and flowering shrubs, which are very ornamental. And it can absorb carbon dioxide and control the greenhouse effect. Second: Among the native plants currently in use in Beijing, the proportion of herbaceous plants is the highest. However, in real life, some unsightly herbaceous plants are often removed as useless weeds, which leads to herbaceous plants. The utilization rate is also very low. Therefore, in future landscape design, more consideration should be given to the selection and reasonable distribution of native tree species.

The 2010 Beijing garden plant application frequency sampling survey statistics prove that urban plant planting is dominated by native tree species, such as Pinus tabuliformis, Sophora japonica, Populus tomentosa, Sabina chinensis, Ailanthus altissima, etc., while most of the shrubs planted are foreign species, such as Euonymus japonicus, Buxus sinica, etc (Beijing Gardening And Greening Bureau 2010). The herbs are mainly wild native herbs with strong adaptability. From the above data, the following conclusions can be drawn (Zheng & Zhang 2011): Beijing's urban landscape plants are very single, and they do not highlight the diversity of Beijing's native plants. Some plants with high management costs are still being used, which leads to the need to spend a lot of manpower and material resources to maintain the plants. It would be more reasonable to use more plants that are convenient for management, as shown in Table 4.

*Table 4: The 2010 Beijing garden plant application frequency sampling survey statistics. Plant application frequency ranking.*

| Serial number | Tree | Shurb | Herbaceous |
|---|---|---|---|
| 1 | *Pinus tabuliformis* | *Euonymus japonicus* | *Poa pretensis* |
| 2 | *Sophora japonica* | *Forsythia suspensa* | *Viola philippica* |
| 3 | *Populus tomentosa* | *Buxus sinica* | *Ixeris chinensis* |
| 4 | *Sabina chinensis* | *Lonicera maackii* | *Setaria viridis* |
| 5 | *Ailanthus altissima* | *Rosa chinensis* | *Liriope spicata* |
| 6 | *Platycladus orientalis* | *Prunus triloba* | *Orychophragmus violaceus* |
| 7 | *Cedrus deodara* | *P. ceraifera ‘Pissardii’* | *Taraxacum mongolicum* |
| 8 | *Koelreuteria paniculata* | *Lagerstroemia indica* | *Chenopodium album* |
| 9 | *Ginkgo biloba* | *Hibiscus syriacus* | *Eleusine indica* |
| 10 | *P. bungeana* | *Berberis thunbergii ‘Atropurpurea’* | *Amaranthus retroflexus* |

Wang et al.(2019) selected 16 common superior landscaping plants as test materials in Beijing City, and conducted research and analysis including the plant's carbon sequestration capacity, cooling and humidification effects, and shading effects.

Under the conditions of photosynthesis, garden plants fix carbon dioxide and release oxygen, which not only maintains the carbon balance in the atmosphere, but also plays a positive role in reducing the greenhouse effect (Ballinas & Barradas, 2016). By studying the ecological benefits of 16 common trees in Beijing under sunny, windless and stable natural light conditions. The data shows that the order of fixed carbon dioxide and oxygen released by these 16 tree species in a day is: Fraxinus pennsylvanica> Sophora japonica Linn> Ailanthus altissima> Koelreuteria paniculata> Liriodendron chinense (Hemsl.)> Ulmus pumila L.> Pinus bungeana> Chionanthus> Populus tomentosa> Pinus bungeana Zucc. > Magnolia denudata> Acer truncatum Bunge> Salix babylonica > Sabina chinensis> Ginkgo biloba> Pinus tabuliformis Carr. (Wang et al., 2019). In terms of overall ecological benefits, the ecological benefits of broad-leaved plants are higher than coniferous plants.

Turning now to the experimental evidence on the ability of 16 garden plants to lower the temperature and increase the humidity of the surrounding environment. Through transpiration, green plants absorb heat in the air and release water vapor at the same time, so that they can cool the surrounding environment (Li Zhang & Gu, 2004; Meineke et al., 2016). The transpiration effect of plants can be a good cooling effect in the hot summer of Beijing, especially in the city center with many surrounding buildings. At the same time, the human body temperature will also be reduced (George et al., 2007), and the comfort of residents will be improved, which can better improve the

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living environment of residents. Statistics show that the order of heat absorption and water vapor release of 16 species of trees in a single day is: Fraxinus pennsylvanica> Sophora japonica Linn> Ailanthus altissima> Pinus bungeana> Koelreuteria paniculata> Ulmus pumila L.> Pinus bungeana Zucc. > Chionanthus > Populus tomentosa> Liriodendron chinense (Hemsl.)> Salix babylonica > Acer truncatum Bunge> Magnolia denudata> Pinus tabuliformis Carr.> Sabina chinensis> Ginkgo biloba (Wang et al., 2019). According to the data, the effect of cooling and humidification of plants may have a certain relationship with the difference of plants themselves[24-28].

Moving on now to consider that, in the selection of urban landscape plants, the shading effect of plants is a key consideration. For example, an international metropolis like Beijing has dense buildings and roads, a lot of construction land, and little urban green space. The case reported here illustrates that large exposure areas appear in the city. Citizens often feel very uncomfortable when in the hot summer (Kyriakodis & Santamouris 2018). According to the tree species' comprehensive shading ability from strong to weak, the order is as follows: Koelreuteria paniculata> Chionanthus > Salix babylonica> Fraxinus pennsylvanica> Liriodendron chinense (Hemsl.)> Sophora japonica Linn> Pinus bungeana> Populus tomentosa> Ailanthus altissima> Acer truncatum Bunge> Pinus bungeana Zucc.> Ulmus pumila L.> Ginkgo biloba> Pinus tabuliformis Carr.> abina chinensis> Magnolia denudata (Wang et al., 2019).It is not difficult to discover from the data that the shading effect of plants is related to the crown width, tree height, canopy gap and canopy cover of the tree itself (Meineke et al., 2016; Zheng & Zhang, 2011). In general, the larger the crown, the higher the tree height, the denser and longer branches (except for man-made pruning factors), the better the shading effect of trees.

To conclude this section, the literature identifies the current status of Beijing's urban landscape plants. Due to the scarcity of urban land in Beijing, it is impossible for urban green space to increase indefinitely (Zhang Gao & Yang 2014; Zheng & Zhang, 2011). The spatial distribution of green space is guided by urban planning. In urban planning, the function of green space to alleviate the heat island effect is generally insufficient. Based on current data and existing research. The types of green spaces in Beijing are roughly divided into four types: arbor forests, arbor-shrub forests, shrubs and grasslands (Zhu, Qi & Wang, 2010; Zhou, Liu & Xian, 2013). Different types of green spaces have obvious differences in mitigating the urban thermal environment. Field observations are made to obtain temperature and humidity data, and temperature change index is used. The calculation formula of humidity change index and other methods can reach the final conclusion: both the cooling effect and the humidification effect are arbor forest> arbor shrub forest> shrub> grassland (Zhou, Liu & Xian, 2013). However, in actual cities, urban land is scarce and green space is limited. The study by Wang et al. (2019) argued the role of existing plants in Beijing on the urban heat island effect. In actual urban planning, trees that can alleviate the urban heat island effect and improve the urban microclimate should be selected purposefully (Zhang et al., 2015) , as shown in Table 5.

*Table 5: 16 kinds of garden plant test materials. Height (m). Canopy (m* m). Diameter at Breast Height (cm).*

| Scientifi C Name | Average Height (M) | Average Diameter at Breast Height (CM) | Average Canopy (M × M) |
|---|---|---|---|
| *Pinus tabulif Carrière ormis* | 4.73 | 18.70 | 5.6×6.0 |
| *Pinus bungeana* | 6.62 | 21.63 | 4.9×5.2 |
| *Pinus bungeana Zucc.* | 4.89 | 19.50 | 4.9×4.8 |
| *Sabina chinensis* | 4.63 | 20.53 | 3.7×4.2 |
| *Populus tomentosa* | 23.90 | 40.17 | 7.7×7.5 |
| *Sophora japonica Linn* | 10.50 | 28.20 | 8.6×10.0 |
| *Liriodendron chinense (Hemsl.)* | 11.31 | 24.80 | 7.6×7.4 |
| *Ailanthus altissima* | 10.46 | 23.37 | 7.5×6.8 |
| *Fraxinus pennsylvanica* | 12.60 | 23.17 | 10.5×9.6 |
| *Salix babylonica* | 16.49 | 28.87 | 8.5×8.6 |
| *Koelreuteria paniculata* | 14.28 | 27.80 | 8.0×7.5 |
| *Ginkgo biloba* | 9.51 | 24.87 | 7.5×7.8 |
| *Magnolia denudata* | 5.88 | 13.33 | 4.3×4.1 |
| *Acer truncatum Bunge* | 8.22 | 11.44 | 4.1×5.2 |
| *Ulmus pumila L.* | 17.50 | 31.18 | 7.9×8.2 |
| *Chionanthus* | 9.10 | 31.68 | 7.8×7.9 |

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## 4. Methodology

### *4.1 Data preparation*

The Meteorological data mainly obtained from weather station monitoring(Liu et al., 2014). China Meteorological Data Service Center (CMDC), National Earth System Science Data Center and Resource and Environment Data Cloud Platform are websites that fundamentally acquire figures. Usually the main sources of temperature data are weather station monitoring and remote sensing monitoring, and these two methods have their own advantages and disadvantages (Liu et al., 2014; Luan et al., 2014; Gan 2011). This study mainly selected the data of meteorological stations, because the data of meteorological stations has high time resolution and rich monitoring parameters. Beijing currently has 20 national-level weather stations and 438 automatic weather stations(National Meteorological Science Data Center 2020), which can observe Beijing's weather in all directions. In addition, it is important about meteorological data, currently the data obtained by the weather station monitoring is the most comprehensive and accurate. Meteorological observation data can also be divided into fixed sites and small-scale mobile sites. Fixed sites are often used to make isotherm maps and perform statistical analysis. Small-scale mobile observations are often used for model simulation and parameter verification (Luan et al., 2014; Gan 2011). According to the statistics obtained by these two methods, clear and accurate meteorological data can be obtained.

### *4.2 Compare the ground surface temperature and apparent temperature of Xicheng District and Yanqing District under the same weather conditions*

According to the 24-hour surface temperature of the Meteorological Bureau on August 10, 2020, the daily average surface temperature in Yanqing District is 23.03°C, and the all-day average surface temperature in Xicheng District is 26.45°C (National Meteorological Science Data Center 2020). The green coverage rate of Yanqing District is 2.2 times that of Xicheng District (Beijing Gardening and Greening Bureau 2018), and the plant types and water resources ratio are much higher than that of Xicheng District. According to the temperature change and the green coverage rate of the two districts, it can be clearly concluded that in the city, plants can obviously play a role in cooling and humidifying. Plants increase the relative humidity of the surrounding air through transpiration; the progress of transpiration absorbs tons of heat from the surrounding environment, thereby reducing the ambient temperature. Plant photosynthesis can absorb a large amount of CO2 in the air, thereby inhibiting the greenhouse effect. Greening can reduce the temperature in some areas by 3 to 5°C, with a maximum drop of over 15°C (Weng 2004; Tang Wang & Zheng 2006). On the other hand, green plants can absorb, reflect and block solar radiation, and use their own photosynthesis to convert solar radiation energy into chemical energy, so that the solar radiation reaching the ground and under the canopy is significantly reduced. By reducing direct solar radiation, the temperature of the city can be reduced, and the negative impact of the heat island effect on the city can be mitigated (Wen & Lian 2003). In addition, solar radiation can be absorbed by particulate matter in the air, thereby increasing the temperature of the surrounding environment. The leaves of plants can well absorb and fix the dust in the air, and the annual dust retention per hectare of green space is about 1.6 to 2.2 tons per year, reducing the dust content of the environment by about 50%, and further playing the role of reducing the heat island effect. Recent research has suggested that when the green ratio of an area is more than 30%, the heat island effect can be effectively reduced. If the green ratio in this area is greater than 50%, the weakening effect of green space on the urban heat island effect is more obvious (Wang et al., 2019; Li et al., 2002). There is some evidence to suggest that the concentrated green space with a scale of more than 3 hectares and a green ratio of more than 60% has a significant decrease in the internal thermal radiation intensity, which is basically equivalent to the thermal radiation intensity of the natural underlying surface in the suburbs( Luan et al., 2014; Gan 2011; Wen & Lian 2003) .Urban green space will become the best environment for outdoor recreational activities for people living in the city( Zhou, Liu & Xian, 2013). Urban green space has obvious adjustments to the local microclimate and plays a positive role in mitigating the urban heat island effect (George et al., 2007). The northern part of China is cold in winter and hot in summer. Therefore, buildings in cities need heating in winter and air-conditioning in summer, but the use of machines will consume energy. Vegetation can provide shelter for houses in summer and reduce wind speed in winter, greatly reducing energy consumption for heating and air conditioning in urban areas. It can be concluded that urban green space can alleviate part of the impact of urban heat island benefits , as shown in Figure 2.

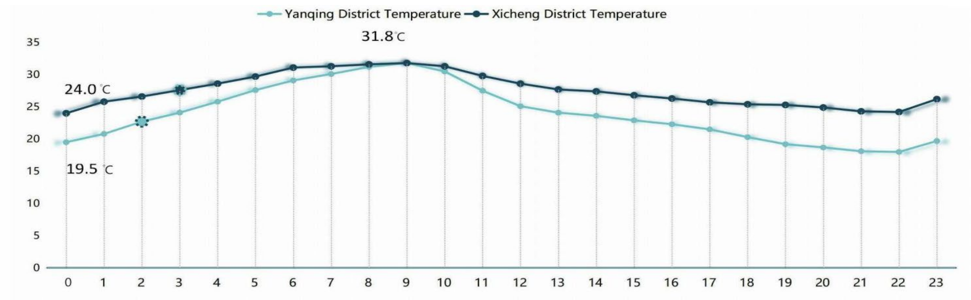


*Figure 2: The maximum and minimum ground surface temperatures (°C) in Yanqing District and Xicheng District, Beijing on August 10, 2020.*

### *4.3 Data analysis*

Under natural conditions, the influence of plants on the improvement of the surrounding environment and the surrounding ecological environment is very complicated. Only through a large number of quantitative experimental studies can the relationship between impact factors and photosynthetic characteristics be explained. Due to the limitation of equipment and measurement time, this study only studied the photosynthetic characteristics of 16 common arbor garden tree species under the same environmental conditions in summer (Wang et al., 2019). The operation is difficult, and there must be certain errors in the results of the ecological benefit evaluation data. Therefore, in the future, a large number of samples and seasonal research should be selected to better provide better selection and configuration of urban landscaping tree species (George et al., 2007; Wen & Lian 2003). For sufficient experimental data and theoretical guidance. However, based on the current experimental data, it can be known that landscaping can alleviate the urban heat island effect in the city (Meineke et al., 2016). The cooling effect is usually proportional to the green coverage rate in the city, and when the green coverage rate is equivalent, the cooling effect of large-area concentrated green land is significantly higher than that of small green land. Research in Beijing also found that the monthly average temperature in urban green areas is about 1.0°C lower than that of high-rise buildings and asphalt pavement areas (Li et al., 2002). Comparative studies on different grounds in cities believe that reducing man-made heat emissions, increasing albedo and urban greening can all reduce the heat island effect to varying degrees. In urban areas, vegetation, especially trees, can reduce the solar radiation reaching the surface through the canopy, thereby curbing the rise of surface temperature; at the same time, the transpiration of forest trees can absorb heat and increase latent heat exchange, thereby helping to alleviate the heat island effect. Studies by McPherson et al. (1997) have shown that a 10% increase in Chicago's Green Ratio, or planting 3 trees per building site, can reduce the total heating and cooling energy of $50 to 90 per household per year. Based on the analysis of the 50a albedo in New York, Susca et al. (2011) pointed out that for urban areas where vegetation and buildings coexist, the maximum cooling range for vegetation area is 2°C. A study of four cities with different climates in the United States shows that in cold regions, trees with dense shade can increase heating costs by 21% just like conifers, but the impact of deciduous trees is not significant; while in cities with temperate and hot climates (McPherson et al., 1997). The findings indicate that urban green space can alleviate the urban heat island effect , as shown in Table 6.

*Table 6: The rate of heating and cooling rate of different underlying surfaces in the city (°C/ h).*

| Urban underlying surface | Concrete | Soil | Grassland | Soil under the shade | Grasslang under the shade | Water |
|---|---|---|---|---|---|---|
| Heating rate | 4.0 | 3.3 | 1.9 | 0.9 | 0.7 | 0.8 |
| Cooling rate | 2.6 | 2.4 | 2.2 | 1.0 | 1.0 | 0.4 |

## 5. Results

### *5.1 The relationship between urban green space and urban heat island effect*

From 2005 to 2011, the temperature in the inner-city areas of Beijing has been higher than the surrounding suburbs (Beijing municipal ecological and environmental monitoring center 2014). In winter (December- January of the following year), the average temperature difference between central urban areas and satellite urban areas and suburbs at 8:00, 14:00, and 20:00 in winter (December-January) found that similar to the annual average temperature difference, the winter average

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temperature difference is also 8： 00 is the highest, with averages of 5.6°C and 2.3°C, followed by 20:00, with 4.0°C and 1.8°C, and 14: 00, with the lowest averages of 2.8°C and 1.6°C. In the winter of 2005-2011, the average temperature difference between the central and satellite cities and the suburbs also increased in a fluctuating manner, indicating that with the urban expansion of Beijing, the winter urban heat island effect of the central and satellite cities in Beijing continued to increase (Zhang et al., 2015; Tang Wang & Zheng 2006). The analysis of the average temperature difference between summer (June- August) and the suburbs found that although the order of the average temperature difference between satellite cities in summer is the same as that in winter, the daily average temperature difference between the central city and the suburbs in summer is the highest at 20:00, and the average is 3.9°C, followed by 8:00, with an average of 3.6°C, and the smallest at 14:00, with an average of 2.5°C (Beijing municipal ecological and environmental monitoring center 2014). In addition, although the average temperature difference between the central city and the satellite city at 8:00 and 20:00 in the summer and the suburbs has fluctuated and increased, the average temperature difference between them and the suburbs at 14:00 has a fluctuating and decreasing trend. This may be the same as that in Beijing in recent years (Sun Zhang & Wang 2011). The continuous strengthening of ecological construction may also be related to the high temperature at noon in summer and the reduction of people going out, resulting in lower energy consumption of motor vehicles , as shown in Figure 3 and Figure 4.

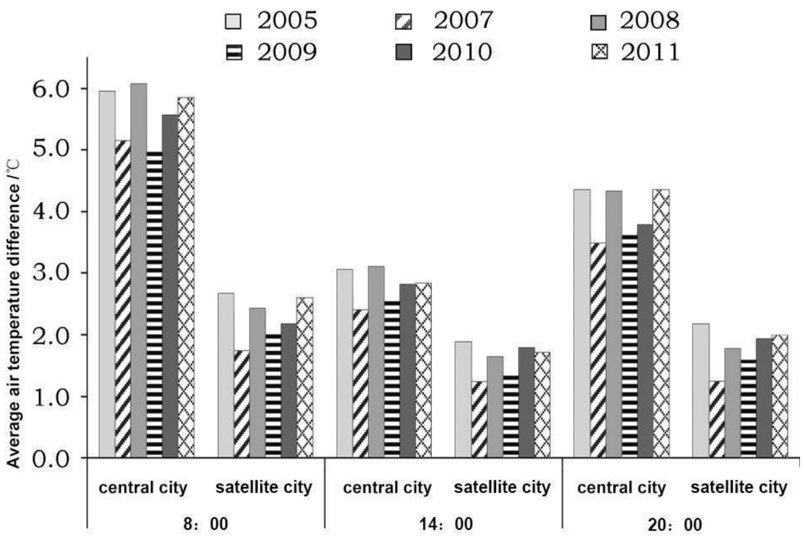


*Figure 3: The differences of temperature between central city, satellite city and suburb in winter from 2005 to 2011.*

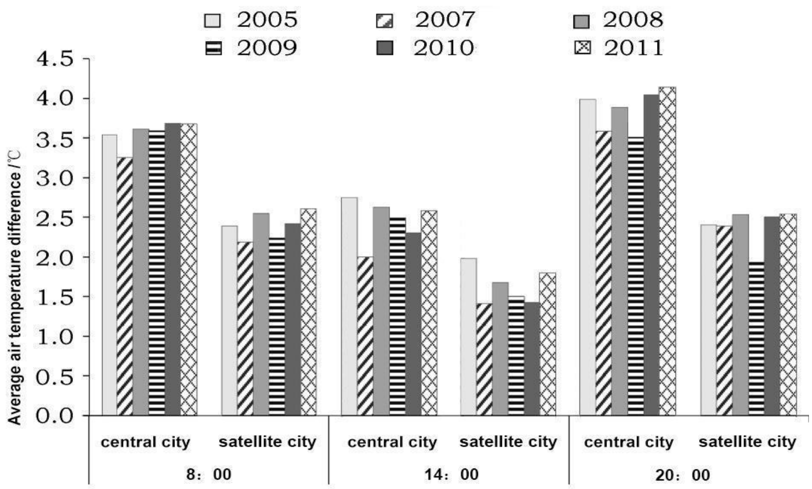


*Figure 4: The differences of temperature between central city, satellite city and suburb in summer from 2005 to 2011.*

Using the long-term temperature data of 19 monitoring stations of the Beijing municipal ecological and environmental monitoring center (2014) from 2005 to 2011 at 3 daily times (8:00, 14:00, and

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20:00), the annual average temperature pattern of each station is analyzed (Zhang et al., 2015). The difference is compared and analyzed, and the intensity and change characteristics of urban heat island effect in the central city and satellite cities of Beijing. The study selected four parks in Beijing as the experimental site (Beijing municipal ecological and environmental monitoring center 2014). Although the monitoring location of the experiment is different from the surrounding environment, it is based on the final result of the experiment. The findings indicate that the vegetation has a strong cooling capacity (Kyriakodis & Santamouris 2018). An useful example of, compared with hardened ground, Huairou Park's green space from 9:27- 16:00 has a cooling range of □1.3 to 6.2℃, with an average cooling of 1.9℃; the park green space in Ma Dian Park reduces the surface temperature by 0.5 to 4.0℃ on average; Pinggu The cooling range of the park green space is □4.2 to 4.1℃, an average decrease of 0.5℃; the 7:45- 16:50 green space cooling range of Mentougou Riverfront Park is □0.6 to 5.2℃, an average reduction of 2.2℃ (Beijing municipal ecological and environmental monitoring center 2014). At the same time, it is also found that the cooling function of urban green space is closely related to the observation time, the amount of sky clouds, rainfall and other weather conditions (Zhang et al., 2015). The impact of weather on the cooling function of urban green space is particularly obvious in Pinggu Park. The sky became cloudy at 11:30 that day, and then it rained lightly, and then it became clear again. The cycle continued until the sky became clear after 3:00 pm, resulting in 12:44, the average temperature of green land within 15:10 is higher than that of hardened ground , as shown in Figure 5.

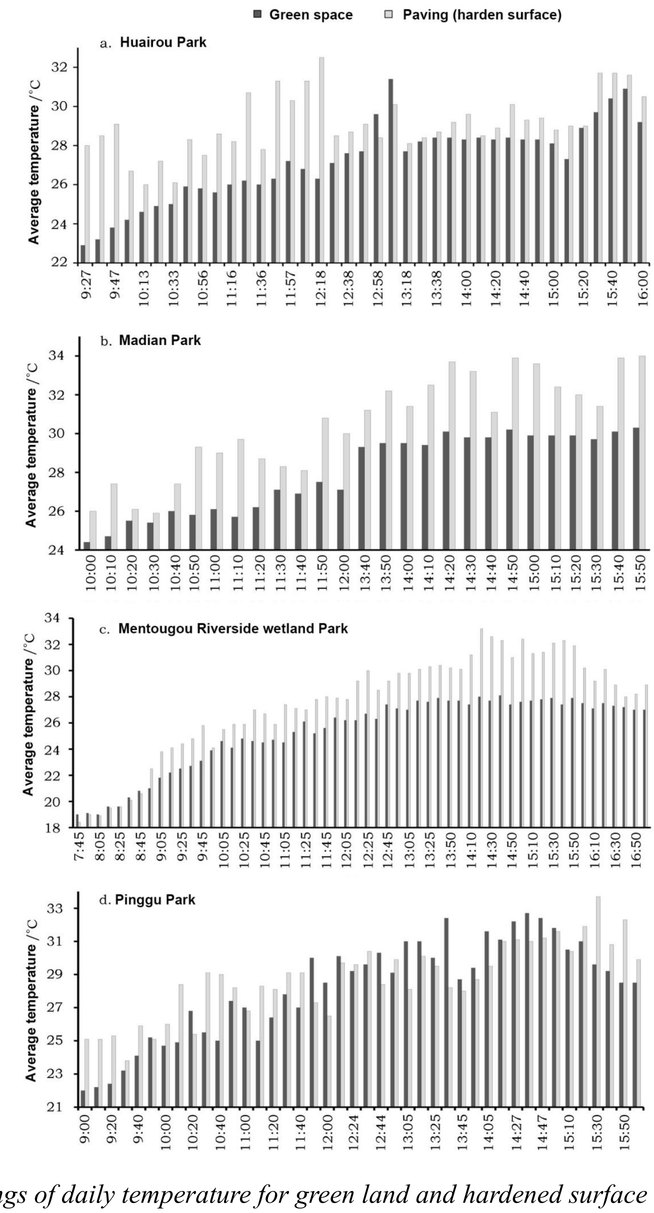


*Figure 5: The changs of daily temperature for green land and hardened surface with times in summer 2013.*

### *5.2 The Influence of Different Green Space Plant Configuration on Urban Heat Island Effect*

Urban green space not only affects the climatic conditions at the regional scale of the city, but also directly affects the surrounding thermal environmental conditions. By improving the thermal properties of the underlying surface of the city, the effect of alleviating the heat island effect can be achieved. Studies have shown that there is an obvious negative correlation between vegetation coverage and temperature, that is, the lower the vegetation coverage, the higher the temperature, and vice versa. There are many types of urban green space, roughly divided into four types: arbor forest, arbor shrub forest, shrub and grassland. Different types of green space have obvious differences in the mitigation effect of urban thermal environments, and their cooling effects on urban heat island effects are different. Generally, the cooling effect of trees is higher than that of shrubs and herbs. According to the measurement of the surface temperature of 52 species of conifers, broad-leaved trees, shrubs and flowers in Beijing, the surface of various plants has a significant cooling effect when the temperature is higher, and when the temperature is low, it has a heating effect (He et al. 2005). To the small are broad-leaved trees, floral plants and shrubs, and conifers.This sequence is consistent with the water transpiration intensity of vegetation. Based on an extensive survey of plant communities in Shanghai (Zhang Qin & Hu 2008), where selected 14 typical communities to determine the effects of cooling and humidification. The results showed that the cooling and humidification effects of the community with complex structure, high canopy closure, large leaf area index, and plant height are obvious. As far as analysis of the correlation between the three-dimensional amount of plant greening in different structures in the city and the temperature is concerned that the shading effect of trees is the main factor affecting the cooling effect of plants (Li et al. 2011). Tang et al. (2009) research on the mitigation effect of different types of green spaces in Nanjing on the urban heat island effect showed that the forest has the strongest cooling effect, the street trees on the street are medium, and the lawn plants are the worst. Li et al. The measurement of relevant data in Rotterdam, the Netherlands shows that the daily transpiration water during the growth period of the broad-leaved forest is about 4.5 mm·d-1, which is the main reason why the canopy can keep the temperature low (Slingerland 2012). In terms of the experiments in Montreal, Canada proved that communities with larger canopy diameters are more effective in reducing urban temperature in summer than communities with tall trees (Wang & Akbari 2016).

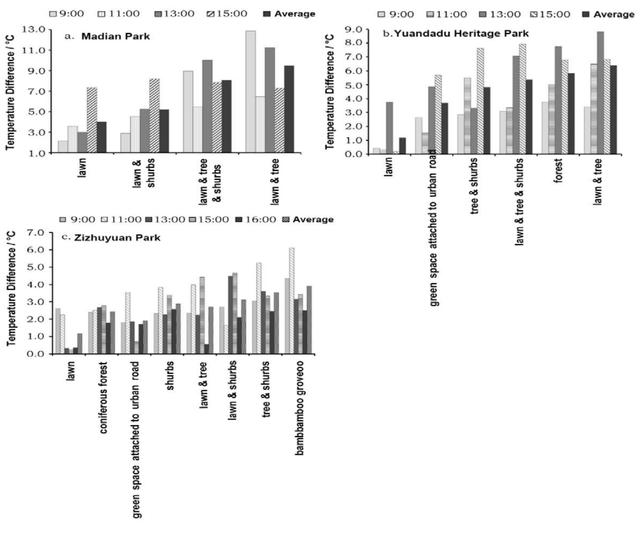


*Figure 6: The changes of temperature difference between green land and hardened surface with times in Beijing.*

An analysis of the cooling test of green space with different structures in Ma Dian Park, Yuandadu Heritage Park and Zizhuyuan Park found that the cooling rate of urban green space varies with the type of green space, the observation time and the structure of the green space community (Zhang et al., 2015). Based on field test data on a typical summer day on August 16-17, 2010, it is shown that compared with hardened ground (Beijing municipal ecological and environmental monitoring center 2014), the cooling range of ordinary green land from 9 am to 4 pm is about 0.2 to 12.9℃, and the average cooling range of various green land is 1.2 to 9.5°C, the average temperature of the green spaces in the three test parks dropped by 4.2°C. Among them, the cooling range of Ma Dian Park green space is 2.2 to 12.9℃, with an average of 4.0 to 9.5℃. The combination of arbor and herb has the largest cooling range, which is 2.4 times that of lawn. The cooling range of the green space in Yuandadu

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Heritage Park is 0.2 to 8.8℃, with an average reduction of 1.2 to 6.4℃. The cooling range of trees and herbs is also the largest, which is about 5.4 times that of grassland; the cooling range of the green space in Zizhuyuan Park is 0.3 to 0.3 to 6.4°C. 6.1°C, with an average of 1.2 to 3.9°C, bamboo forests have the largest cooling range, which is about 3.4 times that of grassland (Zhang et al., 2015). The study also found that broadleaf plants have the strongest cooling ability, and conifers have lower cooling ability than shrubs and herbs , as shown in Figure 6.

### *5.3 Significance of plant conservation and management to urban heat island effect*

In the urban landscape, the maintenance and management of plants often consumes a lot of manpower and material resources. In the selection of urban landscape plants, ornamental and artistic is often the first choice (Liu et al., 2014; Luan et al., 2014; Gan 2011). However, some plants with strong shading ability have been excessively trimmed due to people's special requirements for modeling, and cannot maximize their shading ability. Or because some plants often trim their leaves, photosynthesis cannot be maximized, which weakens the ability of plants to cool down and increase humidity (Susca et al. 2011). On the other hand, the government has reduced the cost of maintenance. The herbs in the city of Beijing are mainly wild native herbs with strong adaptability, which are not beautiful, and the plant species are very simple, leading to some herbs that can reduce the urban heat island effect. Plants cannot be grown in large areas. The regulation function of urban green space is not only related to the area of green space, but also related to the type of green space and the structure of green space community. The arrangement of urban green space plants mainly includes planting techniques such as trees & shrubs & herbs, trees & shrubs, trees & herbs, and herbs. Among them, the arrangement of trees, shrubs and grasses has the greatest impact on urban heat islands, while shrubs and herbs are due to their leaf area. Smaller, less effective in balancing heat and mitigating the urban heat island effect, and improving the urban microclimate. Zhao et al.(2007) in the study of different green spaces in Changsha to alleviate the heat island effect found that the cooling effect of green space is: arbor forest> arbor shrub forest> shrub> grassland, and the cooling effect of arbor forest is arbor shrub forest, shrub and shrub is 1.43, 2.17 and 5.56 times of grass. Therefore, in the construction of urban greening, the method of arranging trees, shrubs and grass should be used to increase the types of plants in the vertical space and maximize the plant space, and to minimize unnecessary pruning, so that the plants can fully demonstrate the ability to alleviate the heat island effect (George et al. 2007).

## 6. Discussion

### *6.1 Current research on the heat island effect of Chinese cities*

Compared with other countries, the green space mitigation measures proposed by Chinese scholars are mostly summary measures and suggestions, and there are fewer quantitative studies. This is specifically reflected in the lack of quantitative research on the cooling and energy-saving benefit analysis of green spaces, and the lack of data as support (Chen Sun & Chen 2012). Literature surveys show that since the 1990s, with the development of information technology, scholars in the field of remote sensing and geography in China have begun to use remote sensing data to quantitatively analyze the heat island effect of major cities. At this time, the focus of research is on UHI. The research on the relationship between green space and heat island is mainly based on qualitative analysis. However, scholars have generally begun to pay attention to the mitigation effect of green space on heat island. After entering the 21st century, more and more scholars in the fields of landscape, plants, agriculture and forestry the research on urban heat islands has begun, and the relationship between green-land and heat islands has also entered the stage of quantitative analysis, and a series of research results have been obtained. Some scholars have conducted a quantitative analysis of the urban heat island effect by doing experiments in a real environment and by using computer simulations. Tong et al. (2005) used remote sensing images and computer simulation technology to study the mitigation effect of Beijing's green space on the heat island effect and simulated predictions. The results showed that the simulated green space cooling effect after completion will reach 1～5°C. The research results of Li et al. (2011) showed that both urban green space coverage and green space area are negatively correlated with heat island intensity. When the green space coverage exceeds 30%, the heat island has a significant mitigation effect. The above research results mainly focus on the quantitative description of the impact of green space on the heat island, and the lack of quantitative analysis in previous studies has led to current research results that cannot directly guide the planning and construction of urban green spaces. Therefore, at present, China needs to do a lot of research and experiments, and conduct regular and systematic research to arrive at effective measures for the urban heat island effect in China. (Jia & Shu 2012)

### *6.2 China's measures to deal with the urban heat island effect*

At present, most of the research on solutions is only at the forecast stage and has not been implemented. There are two reasons (Chen Sun & Chen 2012; Li et al. 2011). First, urban land is very scarce. Because most cities have completed their planning, green space cannot be increased without limit. Plants are restricted by urban planning. Most cities in China cannot improve and alleviate the impact of the urban heat island effect by increasing the green area. Therefore, the heat island effect in most areas of China has not been improved. Second, so far in China, there is no in-depth study on the relationship between green space and the urban heat island effect, and lack of real data and completed cases as a basis. All these have affected China's implementation of measures (Jia & Shu 2012; Zhang et al., 2015; Meineke et al., 2016). Only with a large amount of data and theory as the basis, can we formulate the most scientific and most suitable method for China.

### *6.3 The influence of urban landscape pattern on urban heat island effect*

It is generally believed that the ecological process determines the landscape pattern, and the landscape pattern, in turn, affects the ecological process (Chen Sun & Chen 2012). For a city, the landscape elements of different scales and attributes within the city are repeatedly inlaid together with the three landscape structural components of patches, corridors and substrates to form a certain urban landscape pattern (Buyantuyev & Wu 2010). These landscape patterns affect the hydrology, climate, flora and fauna, including human activities within the city. Many studies have used qualitative or quantitative methods to analyze the relationship between land-use types, land cover types, and their changes and urban heat island effects, and put forward generalized suggestions, such as increasing vegetation, water bodies, and other landscapes, and using appropriate building materials, etc. Ways to alleviate the heat island effect. It can be seen that the mitigation of urban heat islands by changing the landscape matrix has been widely recognized, while the research on mitigating heat islands by changing the landscape configuration and structure is relatively rare (Chen Sun & Chen 2012). There is a lack of quantitative research on how to optimize the area, type (even tree species), and spatial configuration of green space, and how to design the height of residential buildings, so it is difficult to directly serve landscape pattern evaluation and landscape design.

### *6.4 Different types of plants have different cooling effects*

Different types of green space have obvious differences in the mitigation effect of urban thermal environments, and their cooling effects on urban heat island effects are different. Generally, the cooling effect of trees is higher than that of shrubs and herbs. While communities with larger canopy diameters are more effective in reducing the urban temperature in summer than communities with tall trees.

## 7. Conclusions

The urban heat island effect has changed from a general meteorological problem to one of the eight major environmental problems affecting the urban ecological environment and sustainable development (Rizwan Dennis & Chunho 2008). As the capital of China, the speed of urbanization is gradually accelerating, and a series of problems such as spatial conflicts of land use, resource shortage and environmental pollution within the city has become increasingly prominent, becoming the epitome and testing ground of the evolution of China's urban environmental system (Luan et al., 2014; Gan 2011). In summary, it has been shown from this review that through the analysis and comparison of literature data (National Meteorological Science Data Center 2020), it can be known that in the last thirty years in Beijing, the annual average temperature and annual average temperature have been rising, and the daily maximum temperature has also been rising (more than 35 °C). According to the analysis of statistical data, the natural environment may have played a vital role in reducing urban temperatures. The literature compares the temperature in the central and suburban areas of Beijing (Beijing Gardening and Greening Bureau 2018), and it is known that the temperature in areas with a high rate of urban greening is lower than that in the city center, so it is the most important thing to alleviate the heat island effect in the old city of Beijing. However, due to the basic planning of the Beijing city center, it is very difficult to expand the planting area, so optimizing the existing green area, planting types and plant types may be easier to reduce the urban heat island effect in the current city center of Beijing.

Therefore, when proposing measures to alleviate the heat island effect, the main method should be to transform the existing environment (Buyantuyev & Wu 2010; Chen Sun & Chen 2012). Reasonable measures and approaches to tackle the urban heat island effect in Beijing could be to: 1) Vertical greening. Due to the limited area of the city, the green area cannot be increased unlimitedly. Three-dimensional greening and vertical greening (green roofs, green walls, etc.) have become important means to increase the amount of greenery and improve the urban ecological environment. 2) The urban ecological corridor system built by learning. According to the prevailing wind direction in Beijing, a reasonable ecological corridor system will be gradually established in the urban area to draw the cool and clean air from the forest around the city into the city, effectively alleviating the heat island effect inside the city. 3) Reasonably increase the area of urban water bodies. Water surface can not only effectively alleviate the heat island effect in the city, but also an important part of the urban ecosystem. According to the natural conditions and urban characteristics of Beijing, in areas where conditions permit, gradually increase the area of water bodies, which is important for the construction of ecologically sound and beautiful environments. Urban space has a positive meaning. 4) Adopt a reasonable greening structure to improve the efficiency of reducing heat islands per unit area of green space. Plant planting structures that use different plants, such as a combination of trees, shrubs, and herbaceous plants, maximize the use of the cooling and humidification effects of plants to alleviate the negative impact of the urban heat island effect. 5) Maintain the original form of the plant. In cities, plant leaves are often trimmed for urban beauty and artistry. 6) Tree species selection. Choose tree species with large canopy and large leaves, while cooling and humidifying plants. Function is related to canopy density, canopy gap, and canopy layer. The sufficient photosynthesis of plant leaves can help alleviate the impact of urban heat island effect. These findings from these studies suggest that urban green space can have an effect on relieving the urban heat island effect in Beijing.

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