Conference Proceedings of 5th International Conference on Countermeasures to Urban Heat Islands (IC2UHI) 2019
December 2-4, 2019, Hyderabad, India

https://doi.org/10.37285/bsp.ic2uhi.47

A study on Park Cooling Island Effect on Surrounding Urban Area, in Urban Design Perspective

Tong Wu, Department of Urban Planning and Design, Nanjing University, No. 22, Hankou Road, Nanjing 210093, (China)
Shuowen Chi, Department of Urban Planning and Design, Nanjing University, No. 22, Hankou Road, Nanjing 210093, (China)
Youpei Hu[1], Department of Urban Planning and Design, Nanjing University, No. 22, Hankou Road, Nanjing 210093, (China)

ABSTRACT

Previous studies have shown that urban green space has a cooling island effect, which is beneficial to mitigate urban heat island, especially in the hot-summer region. However, Researchers' interest is mostly concentrated on the green space itself, and there are a few researches on the phenomenon of the spread of cooling island to surrounding urban areas under the influence of urban wind, which could have a more positive and broad meaning for mitigating UHI. This study focuses on the latter, and aim to identify the key factors which are manipulatable in urban design perspective among various factors influencing the diffusion of green cooling island.

The city of Nanjing is selected as the background city, because of its long-time and high-temperature summer. Two green spaces with different characters are chosen to conduct field measurement, from which the first-hand meteorological data are obtained, and then used to adjust the micro-climate simulation platform, ENVI-met, to ensure the reliability of simulation. Various factors, including green space own factors, meteorological factors, and surrounding urban fabric are parametric analyzed own to simulation method, from which, qualitative conclusions are drawn on the co-relation between factors and the diffusion distance of cooling islands. In the third part, we applied the knowledge obtained in this research to optimize the downwind urban fabrics of a test case. The result shows that with the knowledge, feasible urban design strategies could be applied to maintain and enlarge cooling island effect on surrounding urban area.

Keywords: Park cooling island, urban fabric, urban green space, urban design strategy

1. Introduction

As is well-known, the process of the urbanization has made a large number of artificial structures represented by concrete materials in the city replace the natural underlying surface, which makes the city form a local high temperature zone relative to the surrounding suburban environment, namely “urban heat island” (J.A. Voogta et al. 2003). The heat island effect brings great harm to urban life and development. It directly affects temperature and precipitation, and greatly harms human health (Tan, J et al. 2007).

1 Corresponding Author: [youpei.hu@nju,edu.cn].

Trees and green space could help in improving urban microclimates and mitigating urban heat islands. Trees not only reduce the high temperature caused by solar radiation through shading, but also affect air movement and heat exchange, absorb solar radiation and cool the air by evapotranspiration to achieve local cooling, forming a so-called green space cold island (Barradas, V. L. 1991). Many studies have proved that green space brings valuable practical effects to alleviate heat islands (Fanhua K et al. 2016) (H. Taha et al. 1991) (H Akbari et al. 1997).

The earlier researchers in the world about the phenomenon of green space cold islands are represented by T.R.Oke and R.A. Spronken-Smith. Through a large amount of data measurement and mathematical model establishment, it is confirmed that the urban public green space represented by the green-covered park has local low-temperature airflow phenomenon in both daytime and nighttime (Oke, 1989). Later, Jauregui, E, Barradas VL, Taha, H., Tsuyoshi Honjo and others conducted study on the cold island strength and influencing factors of park green space of different scales, shapes and configurations in cities (Spronken-Smith 1998.1999) (Ca et al. 1998) through the measurement of meteorological data of specific park green space and the application of satellite photo remote sensing technology. The research on the influencing factors of the green space cold island intensity is also deeper. It is believed that the size, shape and internal planting types of urban parks are several important internal factors affecting the cold island effect of urban parks (Wardoyo et al. 2012) (Chen Yu et al. 2006) (X Cao. 2010) (Chang et al. 2007) (Du. 2018). After decades of development, a large number of researchers have already produced meticulous and fruitful research results on the green space cold island itself. However, for the green space cold island under the movement of the urban wind field, there is relatively little research, especially the green space of urban area that is down the wind. The diffusion effect of the cold island is obviously more positive for mitigating the heat island phenomenon in the larger urban environment.

Since the 1990s, scholars have made early speculations and assumptions about the spread of urban green space cold islands. Representatives such as Victor L. Barradas, Tsuyoshi Honjo, RASpronken-Smith, etc., through the establishment of mathematical model simulation, data measurement and satellite remote sensing photo analysis and other technical methods, verified that under the action of the urban wind field, the green space cold island will spread to the outer wind. (Upmanis et al. 1998) (Spronken-Smith. 1994). More scholars believe that this diffusion can affect the range of a few hundred meters downwind. (Feng et al. 2012) (Su et al. 2010) (Hamada et al. 2010) (Gudina et al. 2014).

Most of the existing research on the spread of green space cold islands is based on measured cases. Limited by the sample size of the cases, the uniqueness of the individual cases, and the factors affecting the diffusion, it is difficult to analyze the performance of a single factor and draw universal conclusions (Bowler et al.2010). This study adopts the methodology of parametric modeling and microclimate simulation, and intends to make up for the weakness of research in the case study, so that the utility of single factor can be clearly manifested.

This study consists of three main parts. Firstly, the reliability of the ENVI-met simulation platform is tested in the first part, and the accuracy of the simulation data is improved by correcting the ENVI-met parameter setting based on the measured data. The second part simulates the single factor change of the ideal green space model. The qualitative conclusions of the influence of each factor on the diffusion distance of the cold island are obtained by means of quantitative analysis. The third part is the case study. Based on the qualitative conclusions drawn from the second part, from the perspective of urban design, under the premise of not changing the floor area ratio and building type, the design of a case of architectural form layout of urban green space that is down the wind. The simulation results shown that the urban shape optimization strategy based on the development of qualitative knowledge of influencing factors can effectively expand the diffusion of park cooling islands, thus generating positive ecological value on a wider scale.

2. Methodology

2.1 Test cases and measurements

The city selected for this data survey is Nanjing, the capital of Jiangsu Province, China (east longitude 118°22'-119°14', north latitude 31°14'-32°37'). Its extreme temperature in summer can reach 39.2 °C. Summer in Nanjing is hot and humid with poor comfort.

This survey selected two urban parks green (Fig.1), namely: Beiji Ge Park and Longjiang Moonlight Plaza, where Beiji Ge Park is a municipal park green space. It is a small mountain with an area of about 10ha, an altitude of 60m and a green rate of 85.8%. The trees in the site are represented by tall cedar, camphor tree, and firmiana simplex, and the vegetation coverage is high. Longjiang Moonlight Plaza is a community-level small park. Its site is flat, with an area of about 1ha, and the arbor coverage of the square is high, represented by cedar and metasequoia.

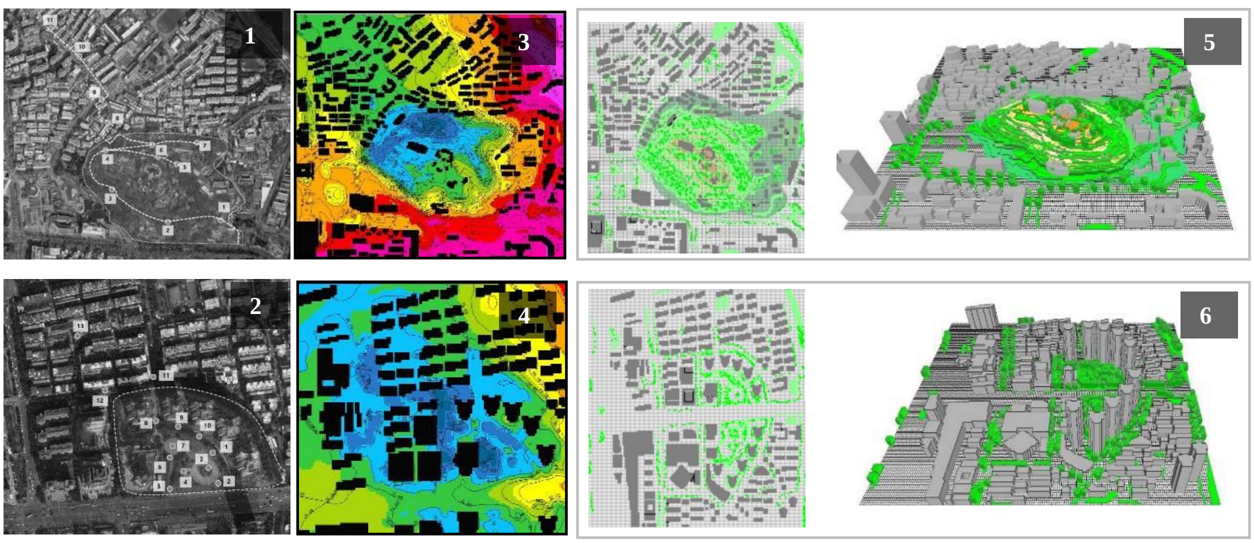


Fig. 1. 1 is Beiji Ge. 2 is Longjiang. 3 is simulation model. 4 is simulation results. 5 and 6 are site plan and 3D view of two cases.

This case measurement was conducted in the summer of 2018. Site 1 (Beiji Ge Park) is measured from 6 am to 8 pm on July 28th. Ten observation points are set in the measured site and another three points are set in the northwest of the site, because the dominant wind directions in Nanjing in summer are east and southeast wind.The measured time of Site 2 (Longjiang Moonlight Plaza) is from 6 am to 8 pm on July 21. Seven observation points are set in the measuredsite, and four points are set in the northwest direction of the site.Set the meteorological data collection point in the measured site and collect the temperature with the XIMA AS847 measuring instrument.And the modes of transportation to record data are cycling and walking respectively, the cycling time through all observation points is within 20 minutes, ensuring the timeliness of data.All the observation points of the two measured sites are set under the architectural projection or vegetation cover, and the data is re-recorded every hour.

2.2 Calibration of ENVI-met

In ENVI-met V_4.4.1, the input parameters required for the model simulation are set in SPACES and ENVI-guide respectively. Model size, model location, nested grid parameters, vegetation parameters, building material parameters, and underlying surface parameters are set in SPACES. The simulation duration, weather parameters, and simulated boundary condition parameters are set in the ENVI-guide (Table. 1).

Table 1. ENVI-met simulation condition setting

Steps of parameter input	Parameter option	Input value
Model grid	X, Y coordinate grid	180×180 (5m resolution) Longjiang 180×180 (5m resolution) Beiji Ge
	Z coordinate grid	25 (2m resolution, B2) Beiji Ge 25 (2m resolution, B2) Longjiang
Simulation location	Latitude and longitude	118.72， 32.05
	Time zone	China Standard Time/GMT+8
Simulation duration	Start time	2018.07.21， 06:00 (Longjiang) 2018.07.28， 06:00 (Beiji Ge)
	Simulation duration (hours)	72 h
Meteorological parameters	Wind speed (10 meters height)	2.2 m/s
	Wind direction (0:N 180:S)	135°
	temperature	26-34℃ (Longjiang) 27-36℃ (Beiji Ge)
	humidity	75% (Longjiang) 79% (Beiji Ge)
Vegetation parameter	3D Plants Trees	K1 Koelreuteria paniculata
	Simple Plants Meadows	XX (25cm high meadows)
Building material parameters	Exterior wall	MI (moderate insulation)
	roof	MI (moderate insulation)
Underlying surface parameters	Main road	ST (Asphalt Road)
	Residential road	PG (gray concrete road)
Nested grid parameters	Quantity	5

Steps of parameter input	Parameter option	Input value
	Material	PG (gray concrete road)
Boundary condition parameter	Temperature and humidity boundary	Open (open type)
	Turbulent boundary	Forced (closed type)

Comparing the measured data with the simulated data, it was found that the highest temperature of the simulated data appears at 4 pm, which was inconsistent with the highest measured temperature at 2 pm. After the careful checking the setting in ENVI-met, we found that the default maximum temperature of ENVI-met was 4 pm. After reset the maximum temperature at 2 pm, the simulation data was in better agreement with the actual measurements (Fig. 2. Fig.3).

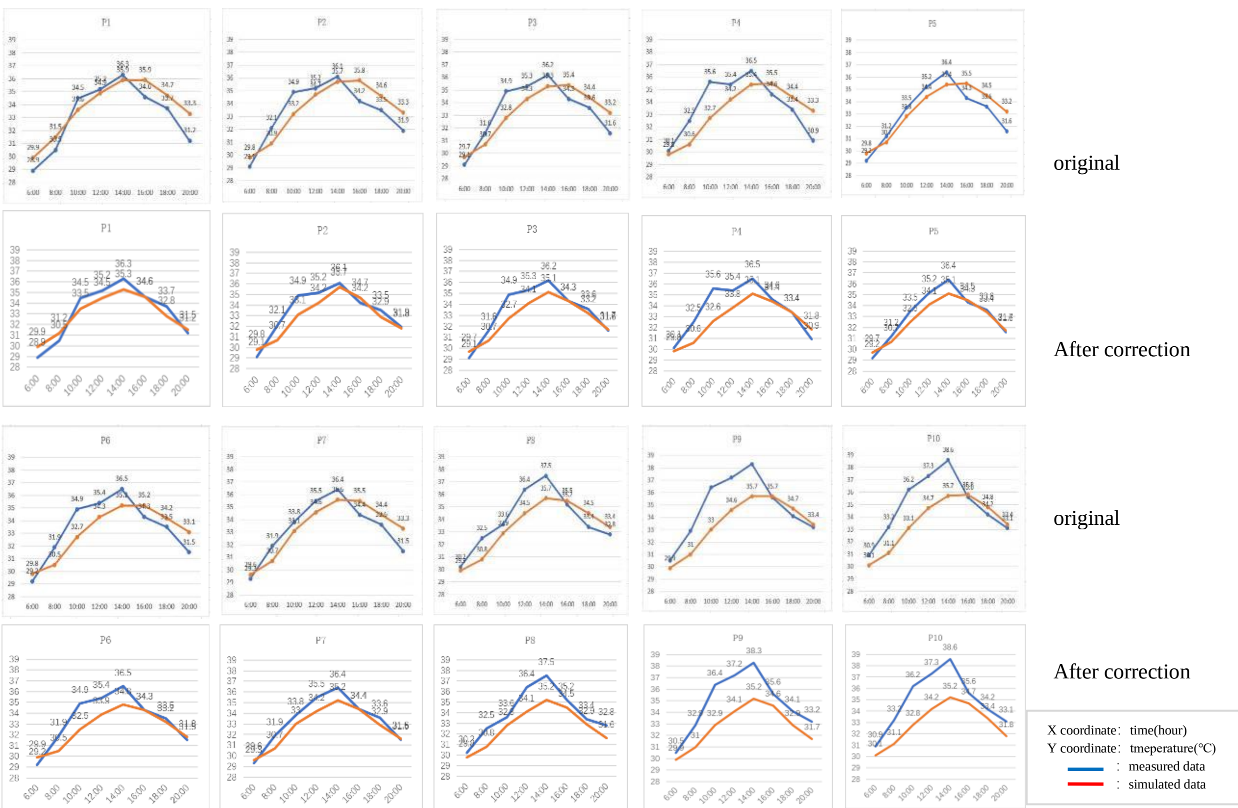


Fig. 2. Comparison of measured and simulation temperature (observation points) of park of Beiji Ge.

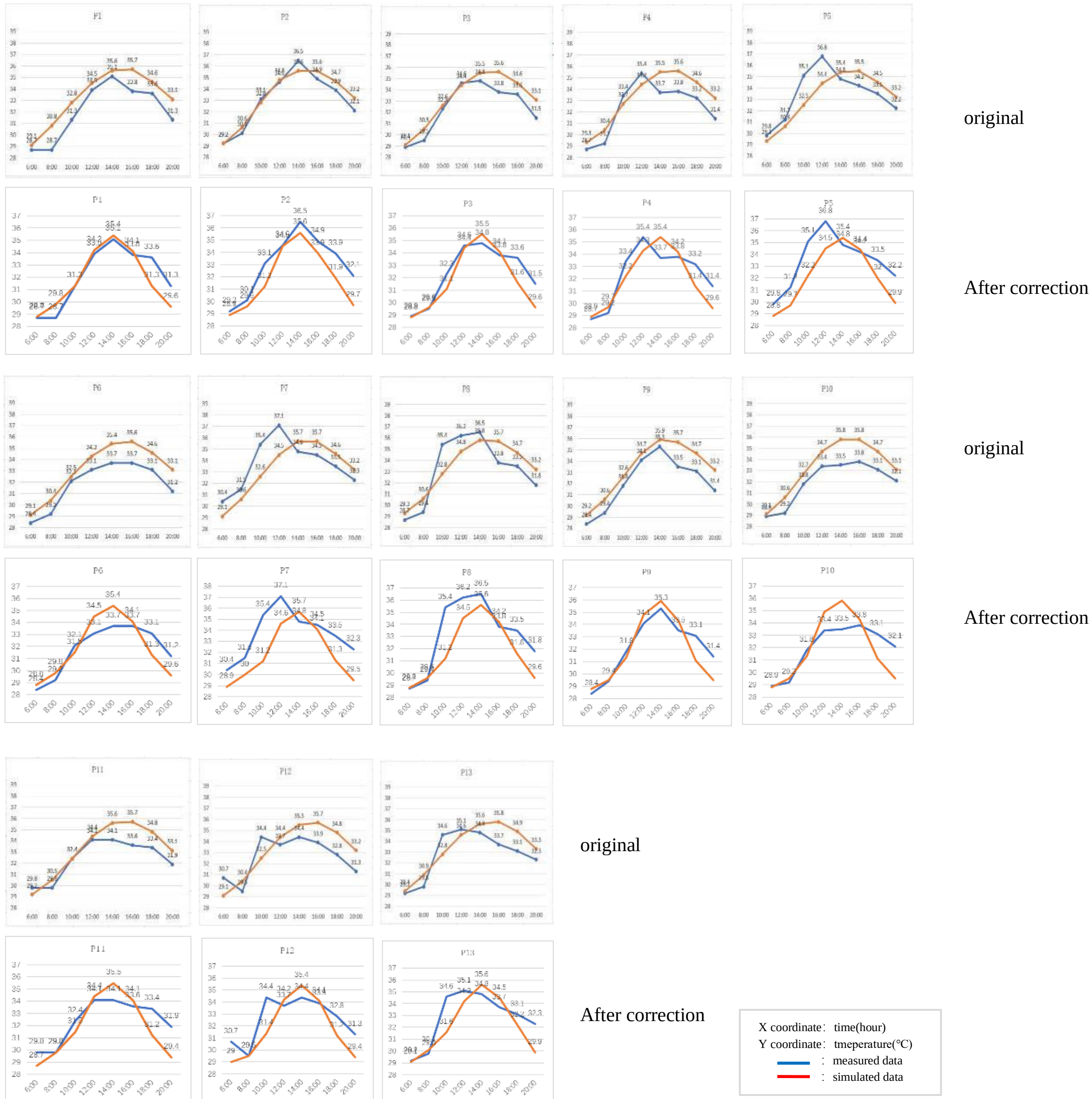


Fig. 3. Comparison of measured and simulation temperature (observation points) of Longjiang plaza.

Although there are detail inconsistent in some points, due to the complicated local context disturbing, like turbulence, anthropogenic heat, but the general trend and magnitude of temperature are the same. This result proved that ENVI-met is reliable as the simulation platform for our study.

2.3 ENVI-met Simulation

The ENVI-met parameter input used in the ideal model simulation is similar with the input value of the case simulation in the previous section. The simulation starts on July 21, 2018, and the duration is 48 hours. The temperature, wind speed and humidity are taken from the typical summer day weather data of Nanjing. See (Table 1) for model input parameters.

Systematic simulation of single factors include the factor of greenland,the factor of meteorological and the factor of urban fabrics. Greenland factors including the size,shape, plants,topography of the greenland. And meteorological factors including wind speed and direction,air humidity,cloudage change,and season.Urban fabric factors mainly focus on the windward area , building interval and orientation.

3. Simulation Results

3.1 Park Own Factors

3.1.1 Size

Set several groups of ideal square green space (1ha green, 2ha green, 5ha green, 10ha green, 20ha green, 40ha green, 80ha green and 160ha green). Under the premise of not changing the software basic simulation parameters and initial meteorological parameters and other factors that may affect the results of the green space cold island experiment, simply increase the green space size by multiples to directly study the relationship between the green space size and the green space cold island diffusion range.

The value of the isotherm temperature at the edge of the cold island diffusion distance is 0.2 °C lower than the average ambient temperature. Through the research results, it is found that the 1ha green space and 2ha green space model have weaker cold islands and the diffusion phenomenon is not obvious. The 5ha green space is the starting threshold for the apparent spread of cold islands. In the 5ha to 10ha interval, the diffusion distance of the cold island increased by nearly 130 meters, and the growth trend was obvious. The diffusion distance of the cold island increased by 30 meters from 10ha to 40ha, and the growth trend slowed down noticeably. In the 40ha to 160ha interval, the green area has expanded by 120ha and the cold island diffusion distance has increased by nearly 50m. The growth trend is more gradual than the previous stage (Fig. 4). Therefore, the cold island diffusion effect and benefit of the 5ha to 10ha green space is the best, which is also the scale of most small and medium green areas in Chinese cities.

3.1.2 Shape

Some researchers have done a qualitative study on the relationship between the spread of green space cold islands and the green space shape index, and draw different conclusions. Some scholars have proved that there is a positive correlation between the green space shape index and the cold island intensity, while some scholars believe that it is a negative correlation (Chen et al. 2012). However, there are few studies on the shape index and the diffusion distance of cold islands.

Setting a 10ha green space model of the same area and associated with different morphological index (land surface index) values. The LSI (morphological index) value ranges from 1.13 square green to 1.81 aspect ratio 1:8 strip green, and there are four sets of models. The simulation is performed without changing other conditions. The following figure extracts the peak temperature of 14 points on the second day of simulation (2018.7.22) as an example to compare the difference between the intensity and diffusion range of cold islands in different green space patterns.

The research found that as the green form index (land surface index) ncreases, the diffusion distance of the green space cold island gradually decreases (Fig.4). We noticed that with the increasing of LSI, the depth of the green space in wind direction decreases. So, we speculate that the depth of the green space in wind direction are the latent factors behind LSI which affecting the diffusion distance of the cold island.

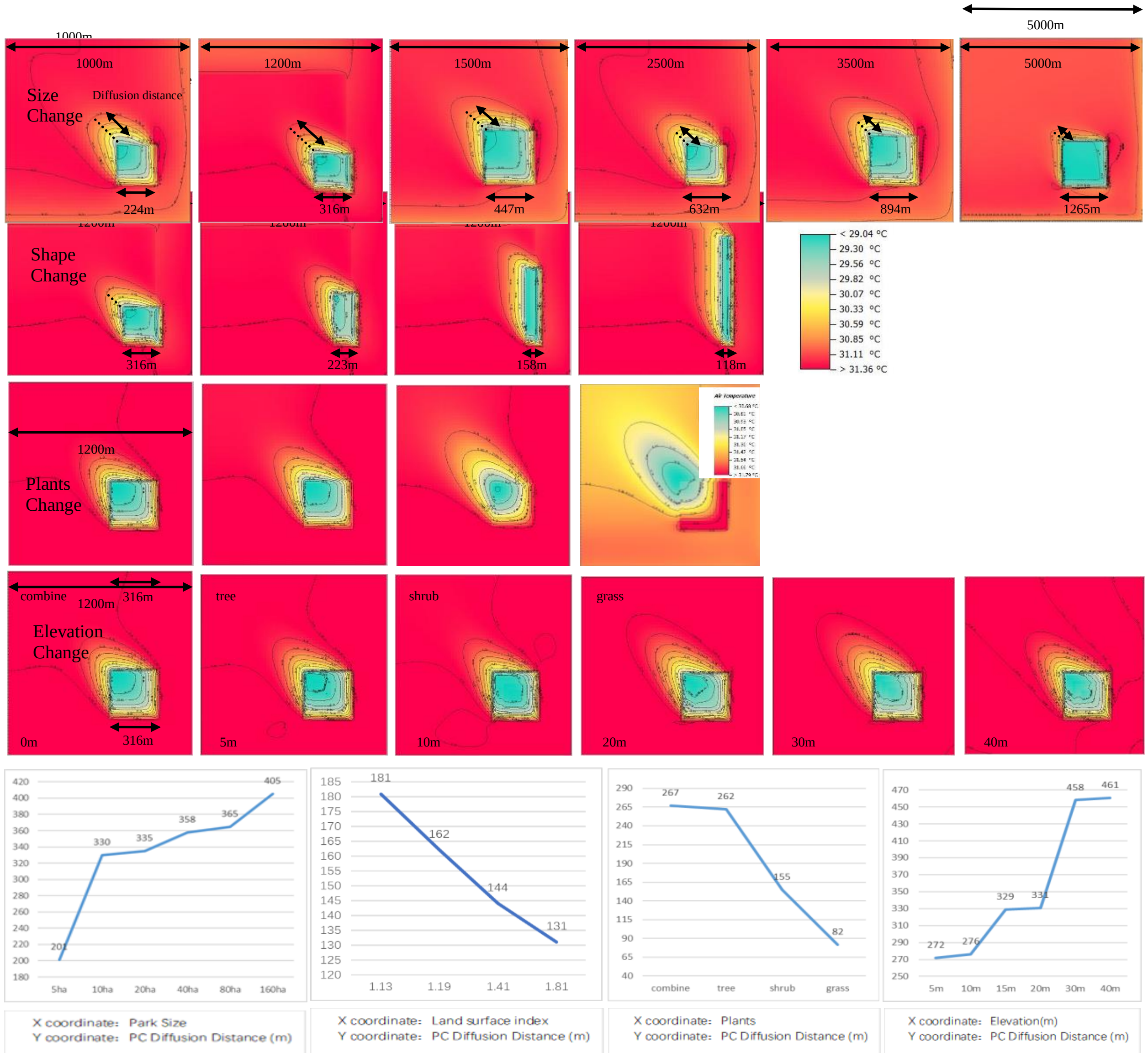


Fig. 4. ENVI-met simulation results about park own factors. First row represents size change. Second row represents shape change. Third row represents plants change. Fourth row represents topography change.

3.1.3 Plants

Setting up four groups of 10ha green space of the same size and shape, and only the green space planting is different. Arbors, shrubs, meadows and integrated planting were planted in four groups of models. The study found that the contribution of arbors to the diffusion distance of cold islands is greater than that of shrubs and meadows. The combination of arbors, shrubs and meadows model has the longest diffusion distance. (Fig. 4).

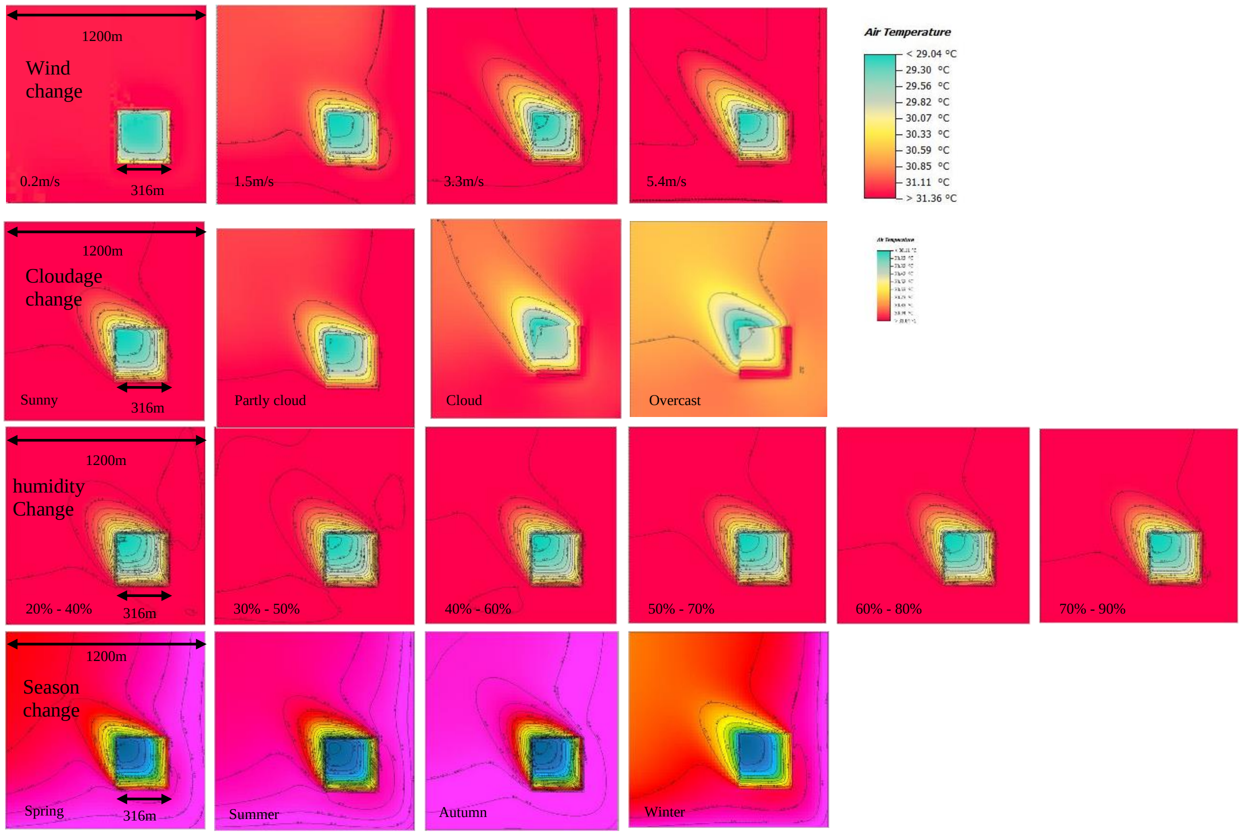
3.1.4 Topography

The height changes of the green space itself is an important factor affecting the spread of green space cold islands, but it has been neglected in previous studies. Setting 7 groups of 10ha green space model, letting the height increased from 0 meters to 40 meters. The simulation found that the 40m elevation green space cold island diffusion range nearly doubled than 0m green space. (Fig.4).

3.2 Meteorological Factors

3.2.1 Wind Speed and Direction

The wind exchanges the local cold airflow of the green space to the downwind to the surrounding environment. Setting four groups of 10ha green space models, letting the wind speed increase from 0.2m/s to 5.4m/s. The simulation results showed that the cold island diffusion distance increases from 18 meters to 355 meters, which indicated that the diffusion of green space cold islands was positively correlated with the wind speed. This shows that the existence of the wind field is a prerequisite for the formation of the diffusion effect of the green space cold island. (Fig. 5)



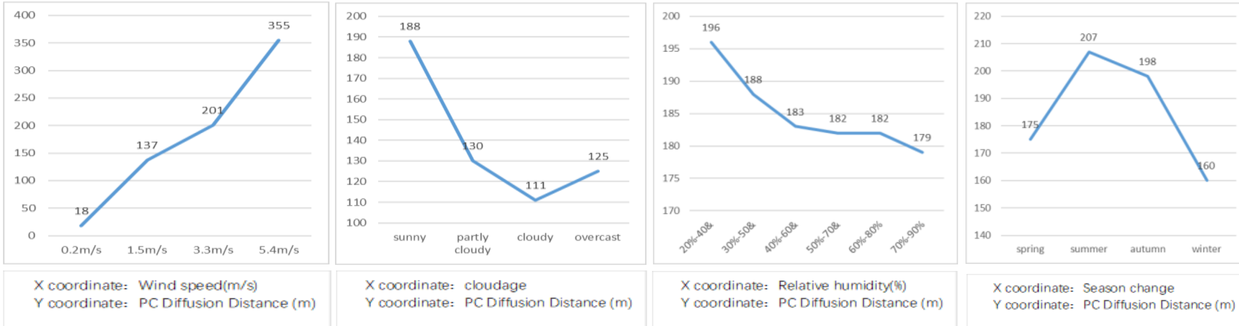


Fig. 5. ENVI-met simulation results about mteorological fctors. First row represents wind change. Second row represent cloudage change. Third row represents humidity change. Fourth row represents season change.

3.2.2 Air Humidity

Setting six sets of 10ha green space models, letting the relative air humidity increase from 30% to 80%. The simulation results showed that as the humidity increases, the diffusion distance of the cold island decreases. Therefore, in the hot and humid regions in summer, considering the dehumidification is a feasible way to improve the strength of the green space cold island. (Fig. 5)

3.2.3 Cloudage Change

Setting four groups of 10ha green space models, letting the cloud parameters be sunny, less cloud, cloudy and overcast. The simulation found that as the traffic volume increases, the cold island diffusion distance gradually decreases. The main reason is that cloud cover is one of the important factors affecting the amount of radiation. When the amount of radiation is affected by the cloud layer, it will reduce the cooling capacity of the plant transpiration endotherm. (Fig. 5)

3.2.4 Season

Setting four groups of 10ha green space, inputting the average temperature of spring, summer, autumn and winter without changing other influencing factors. The simulation found that the cold island has the largest diffusion distance in summer, followed by spring and autumn, and the smallest in winter. The reason for this phenomenon is that vegetation shows differences in transpiration endothermic ability in different seasons. The vegetation types used in this simulation were the ENVI-met model koelreuteria paniculata and the 25 cm high meadows. (Fig. 5)

3.3 Downwind Urban Fabric Factor

Setting the urban fabric around a 10ha green space, which is divided into three types: block, pavilion and slab. With the slab type, changing the orientation of buildings, two more cases are built. The simulation result shows (fig. 6). The sloping slab building has obvious wind guiding properties and the cold island spreads the farthest distance, while the vertical wind direction slab-type building obviously hinders wind diffusion and the cold island diffusion is the smallest. This observation suggests that the frontal area of the fabric in wind direction is a key morphological factor positively affecting the diffusion of the green space cold island. Reducing the frontal area of the building and increasing the building spacing can effectively increase the range of the green underground wind to the cold island.

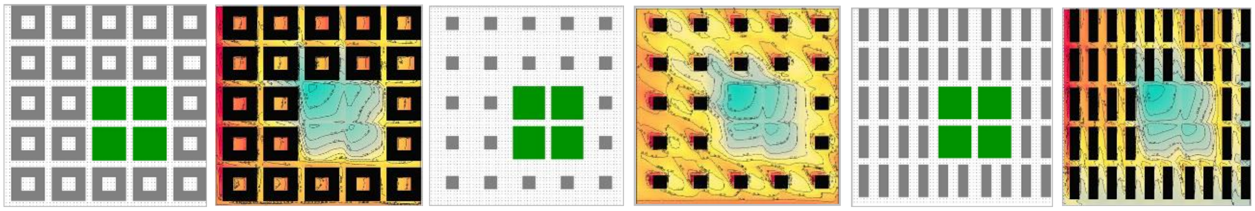


Fig. 6. ENVI-met simulation results about downwide fabric factor. which is divided into three types: block, pavilion and slab.

In summary, the single factor affecting the diffusion of green space cold islands can be divided into controllable factors and uncontrollable factors from urban design perspective. The controllable factors mainly include green space size, shape, planting and downwind urban fabrics. Uncontrollable factors are mainly green space elevation and climate parameters represented by temperature, humidity and wind speed. Therefore, increasing the size of green space, reducing the green form index and enriching the vegetation allocation in green areas are the main internal strategy for increasing the diffusion range of green space cold islands. Reducing the frontal area of the building and increasing the building spacing are the main external design strategy that increase the spread of the cold island.

4. Case study of park cooling island diffusion

The (Beiji Ge Park) area in the previous test case is used as the case study area. This part focuses on the urban fabric factor and explores the urban strategy to expanding the affected area. Based on the original simulation results verified by the measured data, under the premise of not changing the original building volume ratio and building type, we developed two urban design strategies. 1. Reducing the frontal area of fabrics and increasing the building spacing. 2. Setting up a wind corridor. Applying these two strategies, and the premise constraints to the test case, we re-design the downwind fabrics. The simulation is performed again without changing the other parameters of the model. The results are shown in the figure 7. Compared with the control case, it is found that the diffusion range of the cold island is increased by about 200 meters compared with the original site diffusion range, and the diffusion area increased nearly doubled to 10ha. The increased area is the area of light blue and medium green. The cooling zone brought by the cold island spreads to the urban area farther away from the green underground wind, which proves that the optimization strategy is effective (Fig. 7).

The above cases show that the large-scale green space is a valuable source of cold for the city. In reality, the value of this resource is usually limited by the improper urban forms downwind. By applying the optimal urban design strategy in downwind urban area (1, 2), the diffusion zone of the cold island can be expanded to benefit the surrounding urban areas, to a greater extent.

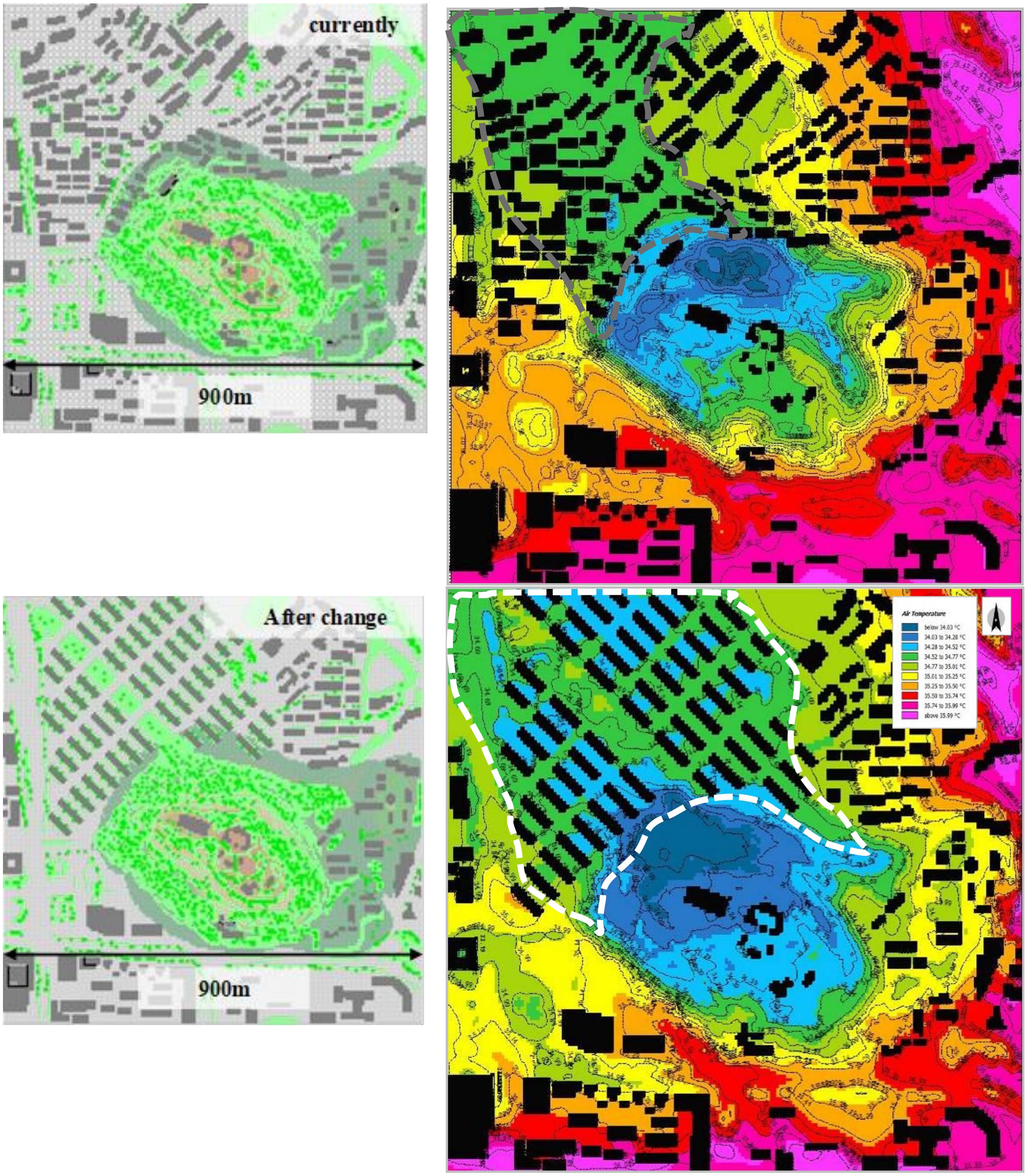


Fig. 7 Redesign of downwind urban fabric of the park Beiji Ge. First two graphics represents the model of Beigi Ge, last two graphics represents simulation results of currently model and redesigned model.

5. Conclusions

This study systematic and comprehensive tests three categories of factors, which might have influences on the diffusion of cooling island to surround urban area. And identify the mainpulatable and sensible factors to urban planning and design. Although the cases we studied was selected in Nanjing, the co-relationship between the factors revealed in this study and the diffusion results is universal. Under different climatic conditions in different locations, the specific diffusion scope will change to some extent, but the influence mode of factors on the diffusion effect is regular.

The first category are the park own factors, including park size, park form, plants in parks, and topography of the park. The green space size and the cold island diffusion distance have a nonlinear positive correlation, and the primitive judgment is an exponential function relationship. As a consequence, 5ha to 10ha green space have the most efficiency to produce cooling island effect. The shape of green space is another factor. More compact shape produce stranger cooling island and thus spread to further urban area. We speculate that the depth of the green space in wind direction are the latent factors behind park shape. Green space planting also plays an important role in the intensity and spread of green space cold islands. The larger the leaf area index, the better the shade of the green space and the stronger the cold island will be. This suggest that increasing the proportion of arbor in green areas is a key to increasing the intensity and diffusion range of cooling islands. The topography of green space is the forth factor, the greater the gradient change, the better the formation of cold island diffusion.

The second category of factors are meteorological factors, including urban wind speed, air humidity, cloudage, and day and night season changes. There is a wind speed and air temperature that are positively correlated with the diffusion of the cold island. The negative correlation is the air humidity and cloudage. The spread of cold islands during the day is greater than at night and the diffusion distance of cold islands in summer is greater than that in spring, autumn and winter.

The third category factors are urban fabrics in downwind area. The study identified frontal area of fabric in wind direction, is the key morphological parameter affecting the diffusion distance of the cold island, there is a negative co-relation between frontal area and diffusion distance.

From urban design perspective, among all these factors, only part of them are manipulatable. They are park own factors and urban fabrics in downwind area. Optimal design strategies could be applied to park design, such as optimizing the shape and size of green space according dominant wind. On the other side, reducing the frontal area of urban fabric, enlarging building spacing, or leave open space as wind corridor would be the feasible ways when concern on the downwind urban area.

Acknowledgments

This research was supported by National Natural Science Foundation of China (51538005) and National Natural Science Foundation of China (51578277).

References

Barradas, V. L, (1991), Air Temperature and Humidity and Human Comfort Index of some City Parks of Mexico City. International Journal of Biometeorology, 35, 24-28.

Bowler, D. E, Buyung-Ali, L. Knight, T. M, & Pullin, A. S, (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and Urban Planning, 97(3), 147–155.

Chen, X. Z., Su, Y. X., Li, D, Huang, G. Q, Chen, W. Q., & Chen, S. S. (2012). Study on thecooling effects of urban parks on surrounding environments using Landsat TMdata: A case study in Guangzhou, southern China. International Journal of RemoteSensing, 33, 5889–5914.

Chen Yu, Wong Nyuk Hien, (2006). Thermal benefits of city parks. Energy and Buildings 38 (2006) 105–120.

Chi-Ru Chang, Ming-Huang Li, Shyh-Dean Chang, (2007). A preliminary study on the local cool-island intensity of Taipei city parks. Landscape and Urban Planning 80 (2007) 386–395.

Du Hongyu, (2018), The Cool Island Effect of Urban Blue-green Spaces and Impact Factors in Mega City: A Case Study of Shanghai. East China Normal University.

Gudina Legese Feyisa, Feyisa, Klaus Dons, Henrik Meilby, (2014). Efficiency of parks in mitigating urban heat island effect: An example from Addis Ababa. Landscape and Urban Planning 123 (2014) 87– 95.

Hashem Akbari, Dan M. Kurn, Sarah E. Bretz, et al, (1997). Peak power and cooling energy saving of shade trees. Energy and Buildings, 1997, 25: 139-148.

H. Taha, H. Akbari, A. Rosenfeld, 1991), Heat Island and Oasis Effects of Vegetative Canopies: Micro-Meteorological Field-Measurements. Theoretical and Applied Climatology Theor. Appl. Climatol. 44, 123-138 (1991).

J.A. Voogta, T.R. Oke, (2003). Thermal Remote Sensing of Urban Climates. Remote Sensing of Environment 86 (2003) 370–384.

Jono Wardoyo, Atiek Suprapti, Hermin Wediningsih, (2012). Vegetation Configuration as Microclimate Control Strategy in Hot Humid Tropic Urban Park. Journal of Applied Sciences Research, 8(11): 5306-5310.

Oke, T. R, (1989), The Micrometeorology of the Urban Forest. Phil. Trans. Roy. Soc. Lond. B324,335–349.

R. A. Spronken-Smith, (1994), Energetics and cooling in urban parks. Vancouver: The University of British Columbia.

R. A. Spronken-Smith, T.R. Oke, (1998). The thermal regime of urban parks in two cities with different summer climates. int. j. Remote Sensing, 1998, vol. 19, no. 11, 2085- 2104.

R. A. Spronken-Smith, T.R. Oke, (1999). Scale Modelling of Nocturnal Cooling in Urban Parks. Boundary-Layer Meteorology 93: 287–312, 1999.

Shuko Hamada, Takeshi Ohta, (2010). Seasonal variations in the cooling effect of urban green area surrounding urban areas. Urban Forestry & UrbanGreening9(2010)15–24.

Tan, J, Zheng, Y, Song, G, Kalkstein, L.S, Kalkstein, A.J, Tang, X, (2007). Heat wave impacts on mortality in Shanghai,1998 and 2003, Int. J. Biometeorol. 51, 193–200.

Upmanis. H, Eliasson. I, Lindqvist. S, (1998). The influence of green areas on nocturnal temperatures in a high latitude city (Goteborg, Sweden). International Journal of Climatology, 18(6), 681–700.

Victor L. Barradas, (1991). Air temperature and humidity and human comfort index of some city parks of Mexico City. Int J Biometeorol (1991) 35:24-28.

Vu Thanh Ca, Takashi Asaeda, Eusuf Mohamad Abu, (1998). Reductions in air conditioning energy caused by a nearby park. Energy and Buildings 29 (1998) 83-92.

Xiaogang Feng, Hui Shi, (2012), A Study on "Cold Island Effect" of Xi'an Urban Park in Summer based on Remote Sensing. Journal of Ecology, 32(23):7355-7363.

Xin Cao, Akio Onishib, Jin Chena, Hidefumi Imura, (2010). Quantifying the cool island intensity of urban parks using ASTER and IKONOS data. Landscape and Urban Planning 96 (2010) 224–231.

Yongxian Su, Guangqing Huang, Xiuzhi Chen, Shuisen Chen, (2010), The Cooling Effect of Guangzhou Urban Park on Surrounding Environment. Journal of Ecology, 30(18):4905-4918.